SURFACES, INTERFACES AND COATINGS TECHNOLOGIES

PLASMA PROCESSING AND TECHNOLOGY

SICT 2023

PLASMA TECH 2023

TRIBOLOGY INTERNATIONAL CONFERENCE

Tribology 2023

SICT 2023 / PLASMA TECH 2023 / TRIBOLOGY 2023

JOINT CONFERENCES

26-28 Avril, 2023 - Lisbon, Portugal

Book of Abstracts

Organizer

SETCOR

Conferences & Exhibitions

SICT 2023 / PlasmaTech 2023 / Tribology 2023 Joint Conferences Program

26 - 28 April 2023 | Lisbon, Portugal

26 April 2023		
08:30 - 12:00	**Participants registration**	
08:30 - 10:30	**Welcoming Coffee - Mezzanine Area**	
SICT 2023 / Plasma Tech 2023 / Tribology 2023 Joint Plenary Session		
Conference Room Roma I		
Session's Chairs: **Prof. Luis L. Alves,** Instituto Superior Técnico- Lisbon**, Portugal** **Prof. Igor Adamovich**, Ohio State University, **USA** **Prof. Michael R. Wertheimer**, Polytechnique Montréal, **Canada**		
10:30 - 11:00	Functional Plasma Polymer Films – Optimization, Implementation and Application **D. Hegemann**	**Dr. Dirk Hegemann,** Empa - Swiss Federal Lab for Materials Science and Technology, **Switzerland**
11:00 - 11:30	Thermodynamic quasi-equilibria in high power magnetron discharges: A generalized Poisson-Boltzmann relation K. Köhn, D. Krüger, D. Eremin, L. Xu, **R.P. Brinkmann**	**Prof. Ralf Peter Brinkmann**, Ruhr-University Bochum, **Germany**
11:30 - 12:00	Development of a Portable Surface Modification Technology to Control the Tribological Properties of Al7075-T6 Alloy for Aerospace Applications **A. Amanov** and J-H. Kim	**Prof. Auezhan Amanov**, Sun Moon University, **Rep. of Korea**
12:00 - 14:00	**Lunch Break - Restaurante Rio de Janeiro**	
SICT 2023 Session I. A: **Surface treatments and coatings deposition and functionalization / Characterization / Properties** **Multifunctional composite and hybrid coatings**		
Conference Room Roma I		
Session's Chairs: **Prof. Vasily Efremenko**, Pryazovskyi State Technical University, **Ukraine** **Dr. Mohamed Belhaj**, ONERA-DPHY- Toulouse, **France** **Dr. Madhan K. Arumugam**, King Fahd University of Petroleum and Minerals, **Saudi Arabia**		
14:00 - 14:30	Development of Nanolayered Thin Films for Joining Applications **S. Simões**, M.Silva, F.Viana, A.S. Ramos and M.T. Vieira	**Dr. Sónia Simões,** University of Porto, **Portugal**
14:30 - 14:45	Clay mineral nanosheets suspended in water give bright and noniri-descent structural colors P.H. Michels-Brito, V. Dudko, J. Breu and **J. Otto Fossum**	**Prof. Jon Otto Fossum**, Norwegian University of Science and Technology, **Norway**
14:45 - 15:00	Molecular Layer Deposition – Versatile Tool for High Performance CNT-Polymer Composites **R. Yerushalmi**	**Prof. Roie Yerushalmi**, The Hebrew University of Jerusalem, **Israel**
15:00 - 15:15	Controling porosity of adsorbed polymeric overlayers: Monte Carlo simulations of the Ullmann coupling of halogenated PAHs **P. Szabelski** and J. Lisiecki	**Prof. Paweł Szabelski**, Maria Curie-Skłodowska University, **Poland**
15:15 - 15:30	Revealing atomic-scale phase transition in epitaxial VO2 thin films **M. Ahmadi**, Atul, M. Ahamdi, S. de Graaf and B. Kooi	**Mr. Masoud Ahmadi**, University of Groningen, **the Netherlands**
15:30 - 15:45	Eco-efficient flame retardant bio-based self-stratifying coatings **M. Jimenez**, C. Lemesle, S. Bellayer, S. Duquesne, M. Casetta, A-S. Schuller and J. Molina	**Prof. Maude Jimenez**, University of Lille, **France**
15:45- 16:00	Aerosol Deposition of CuFeO2 photo-cathode coatings **A. Bruera**, A. Elsenberg, G. Bolelli, F. Gärtner, M. Schieda, T. Klassen and L. Lusvarghi	**Ms. Alessia Bruera**, University of Modena and Reggio Emilia, Modena, **Italy**
16:00 - 16:30	**Coffee Break / Posters Session - Mezzanine Area**	

16:30 - 16:45	Superhydrophobic candle soot-coated PDMS surfaces replicated from leek leaves **S.M. Mirmohammadi**, H. Daghigh Shirazi, S. Franssila, J. Vapaavuori and V. Jokinen	**Mr. Seyed M. Mirmohammadi**, Aalto University, **Finland**
16:45 - 17:00	The influence of low temperature plasma oxidizing process on the bioactivity of NiTi shape memory alloy in terms of medical applications **J. Witkowska**, T.Borowski, A. Sowińska, E. Choińska, D. Moszczyńska, J. Morgiel, J. Sobiecki and T.Wierzchoń	**Mrs. Justyna Witkowska**, Warsaw University of Technology, **Poland**

26 April 2023		
Plasma Tech Session I. B: Plasma fundamentals / Modelling / Atomic and Molecular Processes		
Conference Room Roma II		
Session's Chairs: **Prof. Ralf Peter Brinkmann**, Ruhr-University Bochum, **Germany** **Dr. Dirk Hegemann,** Empa - Swiss Federal Laboratories for Materials Science and Technology, **Switzerland** **Prof. Holger Kersten**, University Kiel, **Germany**		
14:00 - 14:30	Isolating and Quantifying the Reactions of Vibrationally Excited Molecules in Nonequilibrium Plasmas **I. Adamovich**	**Prof. Igor Adamovich,** Ohio State University, **USA**
14:30 - 15:00	How relevant is charged-particle transport in global models? **L.L. Alves** and A. Tejero-del-Caz	**Prof. Luis L. Alves**, Instituto Superior Técnico, Lisbon**, Portugal**
15:00 - 15:30	Calculation of Equilibrium Plasma Thermodynamics **G. Colonna**, A. D'Angola and A. Laricchiuta	**Dr. Gianpiero Colonna**, CNR-ISTP-Bari, **Italy**
15:30 - 16:00	A Database of Transport Cross Sections for Planetary Atmospheres **A. Laricchiuta**, A. D'Angola, F. Pirani , M. Capitelli and G. Colonna	**Dr. Annarita Laricchiuta**, National Research Council Bari, **Italy**
16:00 - 16:30	**Coffee Break / Posters Session - Mezzanine Area**	
Session's Chairs: **Prof. Holger Kersten**, University Kiel, **Germany** **Dr. Annarita Laricchiuta**, National Research Council Bari, **Italy** **Dr. Gianpiero Colonna**, CNR-ISTP-Bari, **Italy**		
16:30 - 17:00	Development Process, Structure and Performance Parameters of a Shielded 433 MHz Plasma Jet with 600W **H. Heuermann** and St. Terbrack	**Prof. Holger Heuermann,** FH Aachen University of Applied Sciences, **Germany**
17:00 - 17:15	Energetics of Reactions in a Dielectric Barrier Discharge with Argon Carrier Gas with Admixed Hydrofluoromethanes S. Watson, B. Nisol and **M.R. Wertheimer**	**Prof. Michael R. Wertheimer**, Polytechnique Montréal, **Canada**
17:15 - 17:30	Electron emission yield of metals: in-situ cleaned and exposed to ambient atmosphere surfaces **M. Belhaj** and S. Dadouch	**Dr. Mohamed Belhaj**, ONERA-DPHY, Toulouse, **France**
17:30 - 17:45	Modelling of electrostatic discharge inception conditions in presence of multipactor effect in HF spatial components **Q. Peysson**, P. Sarrailh, M. Belhaj, N. Fil and D. Payan	**Mr. Quentin Peysson**, ONERA-DPHY- Toulouse, **France**
17:45 - 18:00	Thermal & Dielectric Breakdown Criterium for Low Voltage Switching Devices **T. Merciris**, M. Masquere, Y. Cressault and P. Petit	**Mr. Thomas Merciris**, Schneider Electric, **France**

26 April 2023		
SICT 2023 / Tribology 2023 Joint Session I. C: Surface Engineering, Coatings and Tribology		
Conference Room Milão I + II		
Session's Chairs: **Prof. Auezhan Amanov**, Sun Moon University, **Rep. of Korea** **Prof. Ardian Morina**, University of Leeds, **UK**		
14:00 - 14:30	Importance of contact temperatures for tribology of polymer contacts **M. Kalin**	**Prof. Mitjan Kalin**, University of Ljubljana, **Slovenia**
14:30 - 14:45	Metallurgical features and functional properties of NiW coatings deposited onto low alloyed steel D. Figuet, A. Billard, C. Savall, J. Creus and **J-L. Grosseau-Poussard**	**Prof Jean-Luc Grosseau-Poussard,** La Rochelle University, **France**
14:45 - 15:00	Experimental investigations on wear performance of PVD hard coatings using Micro scratch testing method **Maryam A. Zolbin** and R. Aghababaei	**Ms. Maryam A. Zolbin**, University, Aarhus, **Denmark**
15:00 - 15:15	Hard anodizing of diecast AlSi10MnMg alloys **G. Scampone**, A. Russo, R. Muzzani, A. Carminati and G. Timelli	**Ms. Giulia Scampone**, University of Padova, **Italy**
15:15 - 15:30	Tribological Characteristics of Hybrid Thermally Sprayed Coatings using Graphene Family Nanomaterials **D. Skaltsas**, G.N. Rossopoulos, D. Giasafaki, P. Ioannou, D. Andreouli, C.I. Papadopoulos, C.I. Sarafoglou and I. Georgiopoulos	**Mr. Dimitrios Skaltsas**, National Technical University of Athens, **Greece**
15:30 - 15:45	Tribological Behaviour of TiAlN and AlCrN coatings deposited over martensitic stainless steel **E. L. Dalibon**, A. J. Maskavizan and S.P. Brühl	**Dr. Eugenia L. Dalibon**, UTN- FRCU, **Argentina**
15:45 - 16:00	Atomic-scale understanding of the amorphous/crystalline interface evolution in DLC/WC coatings via different quenching rates **L. Ma**, N. Nemati and R. Aghababaei	**Mr. Li Ma**, Aarhus University, **Denmark**
16:00 - 16:30	**Coffee Break / Posters Session - Mezzanine Area**	
Session's Chairs: **Prof. Mitjan Kalin**, University of Ljubljana, **Slovenia** **Prof Jean-Luc Grosseau-Poussard**, La Rochelle University, **France** **Prof. Ardian Morina**, University of Leeds, **UK**		
16:30 - 16:45	Fatigue behaviour of diamond-like carbon coatings with various adhesion layers **J. Vetter**, M. Günther, P. Hofmann, S. Grosse and S. Schmauder	**Mr. Joshua Vetter**, Robert Bosch GmbH/ University of Stuttgart, **Germany**
16:45 - 17:00	Study of the application of DLC coating on cold stamping tools **E. Barba**	**Mr. Eneko Barba**, Public University of Navarre, Pamplona, **Spain**
17:00 - 17:15	Wear reduction by application of silver coatings at 1850 m/s high speed electric sliding contacts C. Biethan, F. Alouahabi, F. Moitrier and **M. Schneider**	**Dr. Markus Schneider**, French-German Research Institute of Saint-Louis, **France**
17:15 - 17:30	Investigate the microstructure and wear resistance of Fe3Al coating on GCI prepared by direct energy deposition **H. Rajaei**, S. Amirabdollahian, C. Menapace, G. Straffelini and S. Gialanella	**Mr. Hossein Rajaei**, University of Trento, **Italy**
17:30 - 17:45	A Hybrid Graphene-Reinforced Copper-Matrix/Multilayer Composite Coating for High-Load and Environment-Resistant Solid Lubrication on Steel **N. Savjani**, S. Zhao, L. Fabbri, G. Paterakis, E. X. Johansson, G. Bartolini, V.O. Mercadillo, E. Piciollo, G. Anagnostopoulos, F. Bertocchi, A.M. Andersson, M.A. Bissett and I.A. Kinloch	**Dr. Nicky Savjani**, the University of Manchester, **UK**
17:45 - 18:00	Characterization of mechanical and lubrication properties of Double network ion gels synthesized by a one-pot process **H. Arafune**, Y. Watarai, T. Kamijo, S. Honma and T. Sato	**Dr. Hiroyuki Arafune**, National institute of technology, Tsuruoka College, **Japan**

18:00 - 18:15	Micro-arc oxidation of hydrostatically extruded titanium in phosphate-based electrolytes **L. Maj**, F. Muhaffel, A. Jarzebska, A. Trelka, K. Trembecka, M. Kulczyk, A. Sulyok, H. Cimenoglu and M. Bieda	**Dr. Lukasz Maj**, Institute of Metallurgy and Materials Science , **Poland**
18:15 - 18:30	Emission behavior and brake performance at mild and severe sliding conditions of a conventional cast iron disc and a cermet-coated disc **S. Candeo**, F. Varriale, A.P. Nogueira, S. Gialanella and G. Straffelini	**Mr. Stefano Candeo**, University of Trento, **Italy**
18:30 - 18:45	Tribological performance of doped-DLC coatings in the presence of functionalized copolymer **T. Omiya**, T Vuchkov, 3, A. Cavaleiro, J.F.J. Coelho and F. Ferreira	**Mr. Takeru Omiya**, University of Coimbra, **Portugal**

27 April 2023		
SICT 2023 Session II. A: **Surface and coatings Characterization / Properties** **Multifunctional composite and hybrid coatings**		
Conference Room Roma I		
Session's Chairs: **Prof. Maude Jimenez**, University of Lille, **France** **Prof. Jon Otto Fossum**, Norwegian University of Science and Technology, **Norway**		
09:00 - 09:30	Nucleation and growth of intragranular acicular ferrite from the interface between NaCl-type particles and steels **W. Mu**	**Dr. Wangzhong Mu**, KTH Royal Institute of Technology, **Sweden**
09:30 - 09:45	In situ study of the interlayer intercalation of 2-mercaptobenzothiazole in layered double hydroxides directly grown on AA2024 alloy **C. Neves**, I. Sousa, A. Salak and J. Tedim	**Dr. Cristina Neves**, University of Aveiro, **Portugal**
09:45 - 10:00	Evaluation of surface functionalization for improved adhesion between nitinol and thermoplastic polyurethane **T. Schneiders** and T. Gries	**Mr. Thomas Schneiders**, RWTH Aachen University, **Germany**
10:00 - 10:15	Wetting and phase electrowetting as a probe for surface chemistry of hydrophobic materials. M.A. F. Figueroa, B. Manchon and **M. Maillard**	**Dr. Mathieu Maillard**, Univ Lyon, **France.**
10:15 - 10:30	Study of the wettability texturing hydrophobic surfaces prepared with cross-linked hybrid solutions under UV **I. Caldeira**, B. Toury, C. Brylinski, V. Gâté, D. Turover and M. Maillard	**Mrs. Izabel Caldeira**, Univ Lyon, **France**
10:30 - 11:00	**Coffee Break / Posters Session - Mezzanine Area**	
Session's Chairs: **Prof. Maude Jimenez**, University of Lille, **France** **Dr. Wangzhong Mu**, KTH Royal Institute of Technology, **Sweden** **Prof. Jon Otto Fossum**, Norwegian University of Science and Technology, **Norway**		
11:00 - 11:15	Substrate controlled hydrophobicity of Y2O3 thin films **J. Borowiec**	**Dr. Joanna Borowiec**, University College London, **UK**
11:15 - 11:30	Spreading Dynamics of Metal on Metal-on-Glass **H. Taitelbaum**	**Prof. Haim Taitelbaum,** Bar-Ilan University, Ramat-Gan, **Israel**
11:30 – 11:45	Elemental and chemical depth profiling of organic-coated steel strips **D. Leidlmair**, J. Duchoslav, G. Mayr, B. Strauß and D. Stifter	**Mr. Daniel Leidlmair**, Johannes Kepler University-Linz, **Austria**
11:45 - 12:00	Analysis of Coatings by Glow Discharge Emission Spectroscopy: Light Elements **Z. Weiss**	**Dr. Zdenek Weiss,** Institute of Physics of the Czech Academy of Sciences, **Czech Republic**
12:00 - 12:15	Ex situ Raman spectroelectrochemistry of IrO2 and Ir metal nanoparticles in as-deposited and electrochemically activated states **A.K. Surca**, L. Moriau, M. Bele, M.A. Nazrulla, A. Lončar, N. Hodnik	**Dr. Angelja K. Surca**, National Institute of Chemistry, Ljubljana, **Slovenia**
12:00 - 14:00	**Lunch Break - Restaurante Rio de Janeiro**	
Group Photo at 13:45		

SICT 2023 / PlasmaTech 2023 Joint session II. B: Bio-interfaces, Biomedical / Bioactive surfaces and coatings Plasma applications for biology, medicine, and agriculture		
Session's Chairs: **Prof. Liutauras Marcinauskas**, Lithuanian Energy Institute/ Kaunas University of Tech, **Lithuania** **Dr. Ana Megía-Macías**, Comillas Pontifical University, **Spain**		
14:00 - 14:30	Design of new antimicrobial osseointegrated dental implants **S. Carvalho**	**Prof. Sandra Carvalho**, University of Coimbra, **Portugal**
14:30 - 15:00	Drug Eluting Coatings to Enhance the Functionality of Implants **M. Zilberman**	**Prof. Meital Zilberman**, Tel-Aviv University, **Israel**
15:00 - 15:30	Fluid interfaces as platforms for understanding the interaction of pollutants with lipid barriers **E. Guzmán**	**Prof. Eduardo Guzman Solis**, Complutense University of Madrid, **Spain**
15:30 - 15:45	Room vs. body temperature to evaluate electrical interface parameters of state-of-the-art PEDOT-PSS electrode for neural stimulation **K. Cysewska**	**Dr. Karolina Cysewska**, Gdansk University of Technology, **Poland**
15:45 - 16:00	Plasma-deposited hydrophobic organosilicon coatings for sustainable leather in footwear applications **C. Ruzafa-Silvestre**, V.M. Serrano-Martínez and E. Orgilés-Calpena.	**Mr. Carlos Ruzafa Silvestre**, Footwear Technology Centre (INESCOP), **Spain**
16:00 - 16:30	**Coffee Break / Posters Session - Mezzanine Area**	
Session's Chairs: **Prof. Eduardo Guzman Solis**, Complutense University of Madrid, **Spain** **Prof. Meital Zilberman**, Tel-Aviv University, **Israel**		
16:30 - 17:00	Plasma applications for smart and sustainable agriculture (PlAgri) with the emphasis on biotechnologies **N. Puač**, O. Jovanović, S. Živković, M. Milutinović, S. Jevremović, G. Malović and N. Škoro	**Dr. Nevena Puac**, University of Belgrade, **Serbia**
17:00 - 17:15	Multifuncional transparent oxide thin films for photocatalytic and antimicrobial applications **J.G. Cuadra**, S. Molina-Prados, G. Mínguez-Vega, A.C. Estrada, T. Trindade, C. Oliveira, M.P. Seabra, J. Labrincha, S. Porcar, R. Cadena, D. Fraga and J.B. Carda	**Mr. Jaime González Cuadra**, University Jaume I, **Spain**
17:15 - 17:30	In vitro Analysis of Plasma Activated Water: A Step Toward Effective Plasma Medicine **A. Megía-Macías**, O.D. Cortázar, , S. Moreno, A. Brun, Y. Ballesteros and E. Gómez-Casado	**Dr. Ana Megía-Macías**, Comillas Pontifical University, **Spain**
17:30 - 17:45	A Step Forward in Ulcer Management: The Clinical Findings of Cold Plasma Therapy for Torpid Ulcers in Legs A. Megía-Macías, **O.D. Cortázar** and B. Hontanilla	**Dr. Daniel Cortázar**, MEDICAL PLASMAS S.L, **Spain**
17:45 - 18:00	Treatment of microalgae by gliding arc plasma and pulsed electric field **L. Marcinauskas**, K. Jonynaitė, R. Uscila, A. Stirkė, Ž. Kavaliauskas, M. Aikas, S. Keršulis and V. Stankevič	**Prof. Liutauras Marcinauskas**, Lithuanian Energy Institute/ Kaunas University of Tech, **Lithuania**
18:00 - 18:15	Cold Atmospheric Plasma treatment of in-vivo B16/F10 Melanoma cancer cells and the immunological responce **A.S. Mashayekh** ,S. Yin, Z. Liu and K. Yan	**Mr. Amir Shahriar Mashayekh**, Zhejiang University, **China**
18:15 - 18:30	Plasma Polymerized Nano particles: Synthesis, Diagnostics, and Bio-functionalization **L. L. Haidar**, M. M. M. Bilek and B. Akhavan	**Mrs. Laura Haidar**, The University of Sydney, **Australia**

27 April 2023		
SICT 2023 / Plasma Tech 2023 Joint Session II. C: Plasma fundamentals / Modelling / Atomic and Molecular Processes Plasma Processing / Materials Interactions / Coatings		
Conference Room Roma II		
Session's Chairs: Prof. Ralf Peter Brinkmann, Ruhr-University Bochum, **Germany Dr. Dirk Hegemann**, Empa - Swiss Federal Lab for Materials Science and Technology, **Switzerland Dr. Tiago Silva**, Instituto Superior Técnico- Lisbon, **Portugal**		
09:00 - 09:30	Particle fluxes towards surfaces in plasma processing: Are probe diagnostcs still in vogue? **H. Kersten**, T. Trottenberg, L. Hansen, M. Klette, F. Schlichting, V. Schneider, A. Spethmann	**Prof. Holger Kersten**, University Kiel, **Germany**
09:30 - 09:45	Studies in the sheath of an asymmetric CCP with an optically trapped microparticle **V. Schneider**, J. Schleitzer and H. Kersten	**Dr. Viktor Schneider**, Christian-Albrechts Univ Kiel, **Germany**
09:45 - 10:00	Langmuir probe measurements in a dual-frequency capacitively coupled rf discharge **J. Schleitzer**, V. Schneider and H. Kersten	**Ms. Jessica Schleitzer**, Christian-Albrechts University Kiel, **Germany**
10:00 - 10:15	Simulation of facility effects on magnetic nozzle expansions **D. García-Lahuerta**, M. Merino and E. Ahedo	**Mr. Diego García-Lahuerta**, University Carlos III de Madrid, **Spain**
10:15 - 10:30	First Characterisation of a Dual ECR Thruster **C. Boyé**, J. Navarro and M. Merino	**Mr. Célian Boyé,** University Carlos III de Madrid, **Spain**
10:30 - 11:00	**Coffee Break / Posters Session - Mezzanine Area**	
Session's Chairs: Prof. Ralf Peter Brinkmann, Ruhr-University Bochum, **Germany Prof. Holger Kersten**, University Kiel, **Germany Dr. Tiago Silva**, Instituto Superior Técnico- Lisbon, **Portugal**		
11:00 - 11:15	Complex plasma with active Janus particles **V. Nosenko**	**Dr. Volodymyr Nosenko**, German Aerospace Center DLR, **Germany**
11:15 - 11:30	Characterization and Modelling of Surface Plasma Devices **S. Marín-Meana**, G. Regodon-Harkness, A. Palmero, J. Cotrino, A. R. González-Elipe, A. Gómez-Ramírez and M. Oliva-Ramírez	**Mr. Servando Marin-Meana**, Seville University, **Spain**.
11:30 - 11:45	Modeling and experimental characterization of the extraction of a focused broad ion beam from an inductively coupled plasma source. **K.M. Rettig**, T. Dunger, E. Loos, M. Nestler and J. Schuster	**Mr. Kevin M. Rettig**, scia Systems GmbH, **Germany**
11:45 - 12:00	Modelling of an electric arc during contact separation. **O. Ojeda Mena**, Y. Cressault, P. Teulet and J. P. Gonnet	**Mr. Oswaldo El. Ojeda Mena**, Paul Sabatier University-Toulouse, **France.**
12:00 - 12:15	Synthesis of High-entropy Alloy Nanoparticles by an Induction Thermal Plasma Jet **K.S. Kim**, M; Couillard, Z; Tang, H. Shin, D. Poitras, C. Cheng, O. Naboka, D. Ruth, M. Plunkett, L. Chen, M. Nganbe and Y. Zou	**Dr. Keun Su Kim**, National Research Council Canada, **Canada**
12:15 - 12:30	Atmospheric-Pressure Nanosecond-Pulsed Plasma-Induced Free-Radical Polymerization of HEMA Liquid Layers **I. A. Goncalves**, N. D. Boscher, D. Abessolo Ondo and R. Quintana	**Ms. Ingrid A. Gonçalves**, Luxembourg Institute of Science and Technology, **Luxembourg**
12:00 - 14:00	**Lunch Break - Restaurante Rio de Janeiro**	
Group Photo at 13:45		

Session's Chairs: **Prof. Luís L. Alves**, Instituto Superior Técnico- Lisbon, **Portugal** **Dr. Gianpiero Colonna**, CNR-ISTP-Bari, **Italy** **Prof. Holger Heuermann**, FH Aachen University of Applied Sciences, **Germany**		
14:00 - 14:15	Large RF plasma data set for training plasma processing machine learning models **A. Fierro**, T. Hardin, A. Lietz, M. Hopkins, A. Belianinov and B. Bentz	**Prof. Andrew Fierro**, University of New Mexico, **USA**
14:15 - 14:30	Preparation of ceramic composite coatings by combining cold-spray deposition and plasma electrolytic oxidation **J. Martin**, A. Maizeray, C. Da Silva Tousch, G. Marcos, M.P. Planche, H. Liao, T. Czerwiec and G. Henrion	**Dr. Julien Martin**, University of Lorraine- Nancy, **France**
14:30 - 14:45	New insights into the plasma electrolytic oxidation of aluminium with incorporation of carbon nanoparticles. **C. Da Silva Tousch**, L. Magniez, C. Czerwiec, J. Martin, G. Marcos, S. Fontana, C. Herold and G. Henrion	**Mr. Corentin Da Silva Tousch,** University of Lorraine- Nancy, **France**
14:45 - 15:00	Development of a water repellent/anti-icing transparent plasma polymerized HMDSO coating **R. Jafari**, E. Eslami and G. Momen	**Mr. Reza Jafari**, University of Quebec in Chicoutimi, **Canada**
15:00 - 15:15	Superhydrophobic bio-inspired stainless steel surfaces by coupling additive manufacturing and atmospheric pressure plasma coatings **K. Dourgaparsad**, D. Balloy, I-C. Gruescu and M. Jimenez	**Mr. Kevin Dourgaparsad**, University of Lille, **France**
15:15 - 15:30	Multi-physics multi-scale modelling of SiO2 deposition by HC-PECVD with O2/TMDSO mixture used as gaseous precursors **J. Müller**, P. Moskovkin, D. Cornil, K. Tomanková, A. Obrusník and S. Lucas	**Dr. Jérôme Müller**, University of Namur, **Belgium**
15:30 - 15:45	Low pressure cold plasma treatment and coating of expanded polypropylene beads. **M. Dilger**, S. Bellayer, S. Duquesne and M. Jimenez	**Mr. Melvin Dilger**, University of Lille, **France**
15:45 - 16:00	Reactive DCMS vs. Reactive HiTUS of TiNbVTaZrHf-Nx Coatings **F. Lofaj**, L. Kvetková, P. Hviščová, M. Kabátová, T. Roch and V. Girman	**Dr. Frantisek Lofaj,** Institute of Materials Research of SAS**, Slovakia**
16:00 - 16:30	**Coffee Break / Posters Session - Mezzanine Area**	
16:30 - 16:45	Hard transparent oxides by High Power Impulse Magnetron Sputtering **A.W. Oniszczuk** ,W. Gajewski and P. Różański	**Dr. Anna Wiktoria Oniszczuk**, TRUMPF Huettinger Sp. z o.o., **Poland**
16:45 - 17:00	Hot active plasma treatment of ZnMgAl corrosion protection coatings **J. Duchoslav**, D. Leidlmair, G. Säckl, M.Kehrer, T.Stehrer, C.K.Riener, M.Arndt and D. Stifter	**Dr. Jiri Duchoslav**, Johannes Kepler University Linz, **Austria**
17:00 - 17:15	Plasma Etching of SiO2 Using Fluorinated Ethers with Low Global Warming Potential S. You and **C. -K. Kim**	**Prof. Chang-Koo Kim**, Ajou University, **Rep. of Korea**
17:15 - 17:30	Role of low pressure plasma composition in ZnxMnyOz stoichiometry and electrochemical performances as Zinc-Ion Batteries cathode **L. Bekkar**, A. Lemarchand, C. Bazin, H. Perrot and M. Nikravech	**Mr. Lounis Hakim Bekkar**, University Sorbonne Paris Nord, **France**
17:30 - 17:45	The effect of electrolytic-plasma hardening on the microstructure, mechanical and tribological properties of medium carbon steel B.K. Rakhadilov, D.R. Baizhan, L.G. Zhurerova, **N.M. Magazov** and N.E. Berdimuratov	**Mr. Nurtoleu Magazov**, Sarsen Amanzholov East Kazakhstan University, **Kazakhstan**

27 April 2023		
Tribology 2023 Session II. D: Coatings and Surfaces Corrosion / Tribological Properties / Physics or Chemistry of Tribo-Surfaces/ Nanotribology		
Conference Room Milão I + II		
Session's Chairs: Prof. Auezhan Amanov, Sun Moon University, **Rep. of Korea Dr. Madhan K. Arumugam**, King Fahd University of Petroleum and Minerals, **Saudi Arabia**		
09:00 - 09:30	The application of a new Raman-based optical profilometry for understanding the governing factors of the tribofilm growth on a a-C:H coating N. Xu and **A. Morina**	**Prof. Ardian Morina,** University of Leeds, **UK**
09:30 - 10:00	Advancing solid interfaces and lubricants by first principles materials design **M. Clelia Righi**	**Prof. Maria Clelia Righi**, University of Bologna, **Italy**
10:00 - 10:30	Surface Effect : a Key to Understand and Reduce Friction in Lubricated Contacts **J. Cayer-Barrioz**	**Prof. Juliette Cayer-Barrioz** , Ecole centrale de Lyon-CNRS, **France**
10:30 - 11:00	**Coffee Break / Posters Session - Mezzanine Area**	
Session's Chairs: Prof. Auezhan Amanov, Sun Moon University, **Rep. of Korea**		
11:00 - 11:30	Modeling inelastic deformation in contact problems **L. Nicola**	**Prof. Lucia Nicola**, University of Padova, **Italy**
11:30 - 11:45	Enhanced tribological properties of Ti-6Al-4V ELI alloy through combination of slide burnishing and low-temperature gas nitriding **D. Toboła**, J. Morgiel, Ł. Maj, A. Polkowska and A. Łętocha	**Dr. Daniel Tobola**, Łukasiewicz Research Network/ Krakow Institute of Technology, **Poland**
11:45 - 12:00	Improving wear and corrosion resistance of a ta-C film by sealing surface with ALD TiO2 for biomedical applications **G. Wu**, J. Wu, A. Morina, N. Xu and L. Yang	**Dr. Guizhi Wu**, University of Leeds, **UK**
12:00 - 12:15	Development of Corrosion and UV Resistant Fusion Bonded Epoxy Coatings on Steel components for offshore applications **M. K. Arumugam**	**Dr. Madhan K. Arumugam**, King Fahd University of Petroleum and Minerals, **Saudi Arabia**
12!15 - 12:30	Use of the parallel and normal SVET vibration modes and data recollection for the direct investigation of corrosion processes **J. Izquierdo**, A. Abreu-García and R.M. Souto	**Dr. Javier Izquierdo Pérez**, University of Laguna, **Spain**
12:00 - 14:00	**Lunch Break - Restaurante Rio de Janeiro**	
Group Photo at 13:45		
Session's Chairs: Prof. Maria Clelia Righi, University of Bologna, **Italy Prof. Juliette Cayer-Barrioz**, Ecole centrale de Lyon-CNRS, **France**		
14:00 - 14:30	Graphene derivatives as solid lubricant in polymer-tribology, Challenges and opportunities **N. Emami** and J. Somberg	**Prof. Nazanin Emami**, Luleå University of Technology, **Sweden**
14:30 - 14:45	Investigation of Modification with GLYMO and Carbodiimide on Thermomechanical Properties of Two-Component Castor Oil Based Polyurethane Adhesives **A. Yıldırım**, N.K. Mermer and M.A. Özkan	**Ms. Arzu Yildirim**, Kalekim Construction Chemicals Co, **Turkey**
14:45 - 15:00	Why Teflon is so slippery while other polymers are not **H. Terwisscha-Dekker**, B. Weber and D. Bonn	**Mr. Hans Terwisscha-Dekker**, Uni. of Amsterdam, **The Netherlands**
15:00 - 15:15	Influence of different deterministic surface texturing processes on friction and tool life for load collectives in sheet metal forming **P. Schumann**, R. Lindner and P. Groche	**Mr. Philipp Schumann**, TU Darmstadt, **Germany**

15:15 - 15:30	Dedicated Hybrid Turbo GDI Engine with Low Friction Loss **Q. Zhou**	**Dr. Quanbao Zhou**, Changan UK R&D Centre, **UK**
15:30 - 15:45	Nanoscale study of the growth of ZDDP tribofilm based on compression/shear stress **K. Sato** and S. Sasaki	**Mr. Kaisei Sato**, Tokyo University of Science, **Japan**
15:45 - 16:00	Research on Pitting Fatigue Properties of Diamond-like Carbon Films under Pure Rolling Contacts **K. Nakayama**, S. Watanabe, A. Harada, K. Sato and S. Sasaki	**Mr. Kenya Nakayama**, Tokyo University of Science, **Japan**
16:00 - 16:30	**Coffee Break / Posters Session - Mezzanine Area**	
Session's Chairs: **Prof. Lucia Nicola**, University of Padova, **Italy** **Prof. Maria Clelia Righi**, University of Bologna, **Italy**		
16:30 - 17:00	LUBGEAR – Increased Lifetime of Gears under Loss of Lubrication **L. Braumann**	**Mr. Lorenz Braumann**, Research, Advanced Drivetrain Technologies, **Austria**
17:00 - 17:15	Experimental approach to evaluate the fatigue life of DLC coating based on friction and continuous wear data **M. Zellhofer**, M. Jech, E. Badisch, F. Ditrói, A. Kübler and P. H. Mayrhofer	**Mr. Manuel Zellhofer**, AC2T research GmbH, **Austria**
17:15 - 17:30	Measuring Rolling Friction of Microparticles using Lateral Force Microscopy **S. Scherrer**, S. N. Ramakrishna and L. Isa	**Mr. Simon Scherrer**, ETH Zürich, **Switzerland**
17:30 - 17:45	Smart Lubrication Management of Rolling Bearings using a State-Estimation-Based Control Strategy **B. Mrak**, B. Peremans, Y. Perremans, D. Fauconnier, Z. Tao and S. Schlimpert	**Dr Branimir Mrak**, Flanders Make, **Belgium**
17:45 - 18:00	A mapping approach for the influence of the operating conditions on wheel-rail damage **N. Zani**, C. Petrogalli and A. Mazzù	**Dr. Nicola Zani**, University of Brescia, **Italy**
18:00 - 18:15	Capabilities of multiphysics simulations for thrust bearings **S. Cupillard**	**Dr. Samuel Cupillard**, Hydro-Québec research Institute, **Canada**
18:15 - 18:30	A Generalized Oval Equation for the Film Thickness Calculation of Journal Bearings Operating under Heavy EHL Regime **G. N. Rossopoulos**, I. Pervelis and C. I. Papadopoulos	**Mr. Georgios-Nikitas Rossopoulos**, National Technical University of Athens, **Greece**

28 April 2023		
Tribology 2023 Session III. A: Lubricants and hydrodynamic lubrication / Biotribology		
Conference Room Roma I		
Session's Chairs: Prof. Moises Garcia-Morales, University of Huelva, **Spain Dr. Shouhei Kawada**, Kansai University, **Japan Mr. Lorenz Braumann**, Advanced Drivetrain Technologies, **Austria**		
09:00 - 09:30	Predicting total hip replacement wear: recent in-silico developmenst combining synovial lubrication and multibody dynamics. **A. Ruggiero**	**Prof. Alessandro Ruggiero**, University of Salerno, **Italy**
09:30 - 09:45	In Situ Formation of Lubricious Phases in HIPIMS Deposited Mo-W Doped Carbon Coatings in Boundary Lubrication Conditions **P.E. Hovsepian** and A.P. Ehiasarian	**Prof. Papken Hovsepian**, Sheffield Hallam University, **UK**
09:45 - 10:00	Influence of Ionic Liquids Admixture on Electrorheological and Tribological Properties of PAO6 and GP1 Lubricating Oils **T.J. Kaldonski**, J. Juda, P. Wychowański and T. Kaldonski	**Dr.Tomasz J. Kaldonski**, Military Univ. of Technology, Warsaw, **Poland**
10: 00 - 10:30	**Coffee Break / Posters Session - Mezzanine Area**	
10:30 - 10:45	Effects of Lubricant Viscosity on Rolling Contact Fatigue Damage of Bearing Steel **R. Ohashi**, A. Harada, Y. Yuhara, K. Sato and S. Sasaki	**Mr. Ryotaro Ohashi**, Tokyo University of Science, **Japan**
10:45 - 11:00	Active Control of Friction Coefficient under Ionic Liquids Lubrication Using Surface Potential **S. Kawada**, S. Tanji, M. Miyatake and S. Sasaki	**Dr. Shouhei Kawada**, Kansai University, **Japan**
11:00 - 11:15	Sustainable biolubricants based on recycled oils **D. Márquez** and L. Batlle	**Mr. Daniel Marquez**, Leitat Technological Center, **Spain**
11:15 - 11:30	The influence of heuristic and ad-hoc choices on the determination of lubricant viscosities from equilibrium molecular dynamics simulations **G. Toraman**, T. Verstraelen and D. Fauconnier	**Ms. Gözdenur Toraman**, Ghent University, **Belgium**
11:30 - 11:45	High-Fidelity Fluid-Structure Interaction Simulation of Elastohydro-dynamically Lubricated Line Contact **N. Delaissé**, P. Havaej, D. Fauconnier and J . Degroote	**Mr. Nicolas Delaissé**, Ghent University, **Belgium**

28 April 2023		
SICT 2023 Session III. B: Coatings for Energy and Environmental Applications		
Conference Room Roma II		
Session's Chairs: Dr. Mikhail Gromov, Ghent University, **Belgium Dr. Zdenek Weiss**, Institute of Physics of the Czech Academy of Sciences, **Czech Rep.**		
08:30 - 09:00	Plasma Etching of High Aspect Ratio Semiconductor Features: Challenges and Remedies F. Krüger, E. Litch, T. Piskin and **M.J. Kushner**	**Prof. Mark J. Kushner**, University of Michigan, **USA**
09:00 - 09:30	Validation of non-equilibrium kinetics in CO2-N2 plasmas **T. Silva**, C. Fromentin, T. C. Dias, E. Baratte2=, O. Guaitella and V. Guerra	**Dr. Tiago Silva**, Instituto Superior Técnico- Lisbon, **Portugal**
09:30 - 09:45	XPS analysis of ethylene-based encapsulants and damp heat aged fractured glass laminate surfaces **G. Säckl**, G. M. Wallner, J. Duchoslav, M. Tiefenthaler and D. Stifter	**Mr. Gary Säckl,** Johannes Kepler University Linz, **Austria**
09:45 - 10:00	Hybrid polymer-liquid electrolytes for lithium-ion batteries: effect of porosity on the ionic and molecular mobility. **M. Cattaruzza**, Y. Fang, I. Furó, G. Lindbergh, F. Liu and M. Johansson	**Ms. Martina Cattaruzza**, KTH Royal Institute of Technology, **Sweden**
10:00 - 10:15	Synthesis and Characterization of Low VOC Unsaturated Polyester Coatings for Electrical Insulation Applications **K. Aksoy**, S.Gümüş and A. Aytaç	**Dr. Kaan Aksoy**, Betek Boya ve Kimya Sanayi A.Ş, Kocaeli, **Turkey**
10:00 - 10:30	**Coffee Break - Mezzanine Area**	
Plasma Tech 2023 Session III. C: Plasma application in Energy and environment		
Session's Chairs: Dr. Tiago Silva, Instituto Superior Técnico- Lisbon, **Portugal Prof. Mark J. Kushner**, University of Michigan, **USA**		
10:30 - 11:00	Plasma-Assisted Nitrogen Fixation in the Presence of Water **M. Gromov**, I. Sremački, K. Leonova, N. Kamarinopoulou, E. Vervloessem, N. Britun, P. Dimitrakellis, Y. Gorbanev, C. Leys, D. G. Vlachos, N. De Geyter, A. Bogaerts, R. Morent, R. Snyders and A. Nikiforov	**Dr. Mikhail Gromov**, Ghent University, **Belgium**
11:00 - 11:15	CO2 neutral concrete and sustainable fuels and chemicals produced in a novel plasma-based process **P. Roessner**, S. Renninger, M. Lambarth, J. Stein, S. Kaufmann, V. Seithümmer, J. Hemmerling and K. P. Birke	**Mr. Paul Roessner**, University of Stuttgart, **Germany**
11:15 - 11:30	Influence of Enthalpy Inhomogeneity on the CO2 Splitting Performance in a High-Power ICP **H. Burghaus**, C. F. Kaiser, S. Fasoulas and G. Herdrich	**Mr. Hendrik Burghaus**, University of Stuttgart, **Germany**
11:30 - 11:45	Techno economic potential of plasma based CO2 splitting in power to liquid plants **S.J. Kaufmann**, S; Renninger, M; Lambarth, M; Raab, J; Stein, P; Roessner and K.P. Birke	**Mr. Samuel J. Kaufmann**, University of Stuttgart, **Germany**
11:45 - 12:00	Utilizing the Power of Thermal Plasma Technology for the Electrification of the Chemical Industry **S. Mirpour**, D.C.M. van den Bekerom, Y. Creyghton and H. Linden	**Dr. Shahriar Mirpour**, TNO-Geleen, **The Netherlands**
12:00 - 12:15	Plasmas reactors enabling the fossil-to-electric transition of industrial processes **C. Winnewisser**, S. Salem, G. Hintz, E. Mann and V. Ramopoulos	**Dr. Carsten Winnewisser** TRUMPF, **Germany**

SICT 2023 / PlasmaTech 2023 / Tribology 2023 Joint Conferences Posters

N.	Poster Title	Author, Affiliation, Country
1.	Sensor-plasma coupling resistance: model and measurements in the Earth ionosphere **E. Seran**, S. Hess and M. Godefroy	**Dr. Elena Seran**, Sorbonne University, Paris, **France**
2.	Hybrid plasma source with wireless power transmission system **J-H. Kim**, J-Y. Park and C-W. Chung	**Dr. Ju Ho Kim**, Hanyang University, **Rep. of Korea**
3.	Non-transferred plasma torch modeling : methods and studies of the plasma properties with COMSOL **A. Truilhé**, Y. Cressault, F.Valensi and B.Chinè	**Mr. Antoine Truilhé**, Paul Sabatier University, Toulouse, **France**
4.	Determination of Vibrational and Rotational Temperatures of a Non-Equilibrium Nitrogen Atmospheric Pressure Plasma Torch dedicated for Surface Treatment by Optical Emission Spectroscopy and Diatomic Molecular Spectra Simulation. **V.E.Solofondrakotroka**, Y.Cressault, M.Masquère, R.Rakotosaona, V.Ramarozatovo and R.Ramanantsoa	**Mr. Vahatra E. Solofondrakotroka**, Paul Sabatier University, Toulouse, **France**
5.	A 0D kinetic modelling of a DBD reactor in humid air **G. Pierotti**, A. Popoli and A. Cristofolini	**Mr. Giacomo Pierotti**, University of Bologna, **Italy**
6.	Injection's core moulds reusing through the degraded coating's re-moval by laser technology. **R. Santos**, I. Marcelino, T. Ferreira, L. Pereira, F. M. Costa and N. M. Ferreira	**Mr. Rodrigo Santos**, University of Aveiro, **Portugal**
7.	Development of a smart PDMS icephobic coating using encapsulated phase change materials M. Shamhsiri, **G.Momen** and R.Jafari	**Prof. Gelareh Momen**, University of Quebec at Chicoutimi, **Canada**
8.	Anodizing of AlSi10Mg alloy fabricated by LPBF **A. Togni**, M. F. Bonilauri, A. Bruera, G. Bolelli and L. Lusvarghi	**Mr. Alessandro Togni**, University of Modena and Reggio Emilia, **Italy**
9.	Low-temperature gas and plasma nitriding on Inconel 718 produced by Laser-Powder Bed Fusion: effects on wear and corrosion resistance **M.F. Bonilauri**, L. Bortolotti, G. Bolelli, R. Bolzonella, O. Messe and L. Lusvarghi	**Mrs. Maria Francesca Bonilauri**, University of Modena and Reggio Emilia, **Italy**
10.	A Low Friction and High Repetition Durability Sliding System based on Ionic Liquid Type Polymer Brushes Combined with a Molecularly Smooth Surface **T. Kamijo**, H. Arafune, T. Morinaga and T. Sato	**Dr. Toshio Kamijo**, National Institute of Technology, Tsuruoka College, **Japan**
11.	Effects of Chemical Surface Modification on Diffusion Coefficients in Hierarchically Porous Media Through Multiscale Simulations **U. Tallarek**, D. Hlushkou, N. Trebel and A. Höltzel	**Prof Ulrich Tallarek**, Philipps University, Marburg, **Germany**
12.	Effect of Chemial Surface Modification with Long Alkyl Chains on Surface Diffusion Properties: Chain Length vs. Ligand Density **N. Trebel**, J. Rybka, A. Höltzel and U. Tallarek	**Ms. Nicole Trebel**, Philipps University, Marburg, **Germany**
13.	Obtaining of superhydrophobic surfaces by nanosecond laser ablation **I; Urzica**, C; Logofatu, A; Simon and C. Udrea	**Mrs. Iuliana Urzica,** National Institute for Laser, Plasma and Radiation Physics, **Romania**
14.	Improving adhesion of vulcanised rubber by atmospheric plasma sur-face treatment for the footwear industry **V.M. Serrano-Martínez**, C. Ruzafa-Silvestre, M.P. Carbonell-Blasco and E. Orgilés-Calpena.	**Mr. Víctor M. Serrano Martínez**, Footwear Technology Centre (INESCOP), **Spain**
15.	Polymer Surface Characterization Improved by DCSBD Plasma Technique **M. Pajtášová**, S. Ďurišová, D. Ondrušová, P. Skalková, R. Janík and S. Brigantová	**Prof. Mariana Pajtášová**, Faculty of Industrial Technologies- Púchov, **Slovakia**
16.	Plasma activation for the growth of titanium and titanium dioxide thin films. **Y F Barragan**, P A Tsygankov,FF Parada-Becerra, E A Orozco, Y Q Pacheco and C J Páez	**Mr. Yerson Fabian B. Jimenez**, Industrial Universiy Santander, **Colombia**
17.	Computational study and diagnostics of glow discharge plasma **Y F Barraga**, Y Q Pacheco, P A Tsygankov ,FF Parada-Becerra,E A Orozco and C J Páez	**Mr. Yerson Fabian B. Jimenez**, Industrial Universiy Santander, **Colombia**

18.	Tribological Assessment of SLM Fabricated Biomedical Steel After Pulsed Plasma Processing **V. Efremenko**, Yu. Chabak, I. Petryshynets, B. Efremenko, A. Lekatou and V. Zurnadzhy	**Prof. Vasily Efremenko**, Pryazovskyi State Technical University, **Ukraine**
19.	Development of amorphous carbon hard mask with the high etch selectivity by addition of nitrogen for high aspect ratio patterning **S. J. Park**, K.-C. Shin, D. Kim, S. Y. Baek, J. Kim, J. Park, S. Roh, S. Kyung and C. Choi	**Dr. Sejun Park**, Samsung Electronics, **Rep of Korea**
20.	Microwave Cold Atmospheric Pressure Plasma for Surface Preparation in Aerospace Composite Bonding **K. Papangelis**, A. Bennett, A. Prasad, Z. Huang and D. Ayre	**Mr. Konstantinos Papangelis**, ADTEC Europe LTD, **UK**
21.	Low Temperature Atmospheric Pressure Plasma Treatment for Mould Inactivation on Building Materials **M. Domonkos**, J. Jirešová, E. Lokajová and P. Tichá	**Dr. Mária Domonkos**, Czech Technical University in Prague, **Czech Republic**
22.	Cleaning injection moulds through laser technology R. Santos, I. Marcelino, T. Ferreira, L. Pereira, F. M. Costa and **N. M. Ferreira**	**Dr. Nuno Ferreira**, University of Aveiro, **Portugal**
23.	Modeling of the focusing system of an ion beam with the plasma lens **Y.Q. Pacheco**, Y F Barragan,F F Prada and P A Tsygankov	**Mrs. Yhonatan Pacheco**, University industrial of Santander, **Colombia**
24.	Solar furnace synthesis of persistent luminescent strontium aluminate ceramic with improved luminescent properties **V. Vitola** and I. Bite	**Dr. Virginija Vitola**, University of Latvia, **Latvia**
25.	Crystallographic quality and surface morphology of V2O3 thin films deposited on annealed sapphire surfaces **U.B. Arnalds** and K. Ignatova	**Prof. Unnar Arnalds**, University of Iceland, **Iceland**
26.	Bio-degradation of Mechanical and Structural Materials Subjected to Mine Water Affected Environments. **A.M. Sarmiento**, J.M. Dávila, F. Macías, F. Córdoba, J.C. Fortes and J.A. Grande	**Dr. Aguasanta Sarmiento**, University of Huelva, **Spain**
27.	Extrem Reduction of Tensile Concrete Strength Subjected to Mine Water Affected Environments. **J.M. Dávila**, A.M. Sarmiento, M. santisteban, A.T. Luís and J.A. Grande	**Dr. Jose M. Davila Martin**, University of Huelva, **Spain**
28.	Development of Transparent, Scratch Resistant, and Hydrophobic Coatings for Aerospace Transparencies **A. Kuban**, Y. Okumus, N. Erdogan, B. Baytekin and H. Y. Ersan	**Mr. Anil Kuban**, Turkish Aerospace, **Turkey**
29.	Effect of curring methods on the abrasive and corrosion wear resistance of organic coating systems I. Stojanović , I. Juraga , M. Kurtela , **M. Logar** and I. Fatović	**Ms. Mirta Logar**, University of Zagreb, **Croatia**
30.	Effect of Nano Particles on Mechanical and Thermal Properties of Polyurethane Based Transparent Coatings **Y.Okumuş**, A. Kuban, S. Ağar and N. Erdoğan	**Dr. Yigitalp Okumus**, Turkish Aerospace Industries Inc., **Turkey**
31.	Airborne Contamination Contribution to Nanoscale Friction of Graphene Surfaces **F. Ptak**, C. M. Almeida and R. Prioli	**Dr. Felipe Ptak**, Weizmann Institute of Science, **Israel**
32.	Influence of steel and copper fibres in train brake friction materials on airborne wear particle emissions to the environment Y. Tsybrii, I. Zglobicka, **M. Kuciej** and O. Nosko	**Prof. Michal Kuciej**, Bialystok University of Technology, **Poland**
33.	Cellulose Nanofiber Oleogels: A Target-Oriented Approach towards Environmental Preservation through Sustainable Lubrication C. Roman, M.A. Delgado, S.D. Fernández-Silva, M. García-Pérez and **M. García-Morales**	**Prof. Moises Garcia-Morales**, University of Huelva, **Spain**
34.	Tribological Properties of Glycol-Based Deep-Eutectic Solvents C. Del Toro, **M.D. Avilés**, M.D. Bermúdez and F.J. Carrión-Vilches	**Dr. María Dolores Avilés**, Technical University of Cartagena, **Spain**
35.	An approach on the potential application of a smart nanoclay-based biolubricant in electrified ball bearings S.D. Fernández-Silva, M. García-Morales, C. Roman, T. Amann , F. Gatti, A. Kailer and **M.A. Delgado**	**Prof. Miguel A. Delgado**, University of Huelva, **Spain**
36.	Woven fabric abrasion resistance conditioned by weave, weft density and raw material composition **I. Schwarz**, S. Brnada, T. Bardov and A. Kalazic	**Prof. Ivana Schwarz**, University of Zagreb, **Croatia**

37.	Triboelectric Activation of Wood Surfaces by means of Wood Disintegration Processes **LM. Leiter** and R. Wimmer	**Ms. Lena M. Leiter**, University of Natural Resources and Life Sciences Vienna, **Austria**
38.	Multilayer Chitosan/Lignin Nanocoating with Silver Nanoparticles for Antimicrobial Cotton **M. Radetić,** D. Marković, J. Petkovska, N. Mladenovic, M. Radoičić, N. A. Vest, B. Palen, J. C. Grunlan and I. Jordanov	**Prof. Maja Radetic**, University of Belgrade, **Serbia**
39.	Carbon-based coatings on ureteral stents to prevent urinary infections**S. Cruz**, D.Santo, P. Pereira, D. Calheiros, L. Rodrigues, T. Gonçalves, A. Cavaleiro and S. Carvalho	**Dr. Sandra Cruz**, Instituto Pedro Nunes, **Portugal**
40.	Inactivation of Spores and Mycelium of Aspergillus Brasiliensis by Non-Thermal Atmospheric Pressure Plasma **P. Tichá**, M. Domonkos, K. Zdeňková and P. Demo	**Dr. Petra Tichá**, Czech Technical University in Prague, **Czech Republic**
41.	Optical limiting behavior of the DNA-based materials functionalized with natural dyes **P. Gheorghe**, A.M. Anton and A. Petris	**Mrs. Petronela Gheorghe**, National Institute for Laser, Plasma and Radiation Physics, **Romania**
42.	Integration of capacitive sensors and LEDs into HPL boards.- interactive surfaces **F. Wirth** and T. Volkmer	**Mr. Filipp Wirth**, Bern University of Applied Sciences, **Switzerland**

SICT 2023 / Plasma Tech 2023 / Tribology 2023 Joint Plenary Session

Functional Plasma Polymer Films – Optimization, Implementation and Application

D. Hegemann [1,*]
[1] Plasma & Coating, Empa - Swiss Federal Laboratories for Materials Science and Technology, St.Gallen, Switzerland

Abstract:
Plasma polymer films are deposited via reactive intermediate species as formed in a low temperature plasma. This type of plasma provides highly non-equilibrium conditions, meaning that the electrons gain high kinetic energies in elastic collisions with heavy particles that must be sufficient for ionizing reactions to sustain the plasma. For molecular gases, an average energy per heavy gas particle is thus available in the plasma, known as specific energy input (SEI), yielding plasma chemical reactions by inelastic collisions (excitation, dissociation, and ionization). Since the mean free path lengths for such activation reactions follow a distribution law yielding an energy distribution, the probability for the activation mechanism can be described by a simple Arrhenius-like equation, where temperature is replaced by SEI. The potential of this approach to optimize process conditions to deposit functional plasma polymer films is demonstrated on the basis of siloxanes, hydrocarbons and gaseous mixtures.
Hexamethyldisiloxane (HMDSO) has been well studied in the past revealing insights into the plasma chemical reaction pathway, which can thus be used as a model monomer following Arrhenius-like behavior [1]. Since actual plasma polymer film growth also involves the sticking probability of the film-forming species that are converted in the plasma, this parameter becomes accessible by comparing, for example, plasma polymerization with different hydrocarbon molecules. It is demonstrated that C_2H_4 and C_2H_6 approach the same chemical reaction pathway as observed for C_2H_2 for sufficiently high SEI. The sticking probability is also a key parameter when it comes to deposition in complex geometries such as textiles or scaffolds for tissue engineering. Therefore, deposition is investigated on substrates that are shielded from the direct plasma interaction such as in cavities and undercuts involving long-living radicals [2]. This purely plasma-chemical deposition shows further differences compared to direct plasma exposure, where ions are depositing their energy during film growth (Figure 1).
Considering these differences, highly durable hydrophilic or hydrophobic coatings can be deposited on a variety of materials. Examples for process implementation are presented yielding technical applications such as cutlery baskets, filtration, and fiber-reinforced composites as well as biomedical applications.

Keywords: plasma deposition, plasma chemistry, hydrophilization, hydrophobization, nanoporous films, near-surface hydration, technical and biomedical applications.

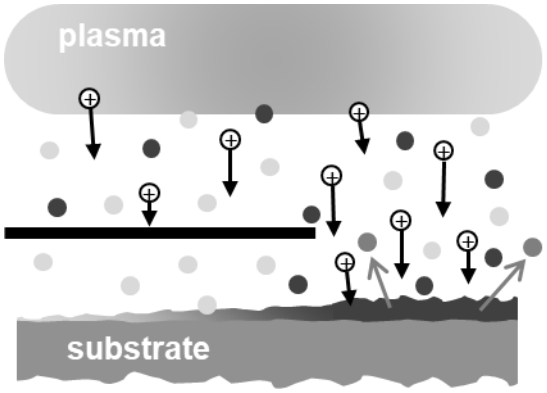


Figure 1: While film growth directly exposed to the plasma is governed by highly reactive intermediates and energetic ions, shielded deposition is based on plasma chemistry involving longer living radicals.

References:

1. Hegemann, D., Gaiser, S. et al. (2021), Plasma polymerization of hexamethyldisiloxane: Revisited, *Plasma Process. Polym.*, 18, e2000176
2. Vandenbossche, M., Hegemann, D. et al. (2018), Formation of lateral chemical gradients in plasma polymer films shielded by an inclined mask, *Plasma Process. Polym.*, 15, e1700185.

Thermodynamic quasi-equilibria in high power magnetron discharges: A generalized Poisson-Boltzmann relation

K. Köhn, D. Krüger, D. Eremin, L. Xu, R.P. Brinkmann
Department of Electrical Engineering and Information Technology,
Ruhr-University Bochum, Bochum, Germany

Abstract:
The Poisson-Boltzmann (PB) relation is a elliptic nonlinear partial differential equation to describe thermodynamic equilibria of conducting fluids. Via a quasi-thermodynamic variational principle using the balances of particle number, entropy, and electromagnetic enthalpy, it can be justified also for a class of unmagnetized technological plasmas far from thermodynamic equilibrium [1]. This study extends the variational principle and the resulting Poisson-Boltzmann relation to magnetized discharges as used in planar high power pulsed magnetron sputtering (HiPIMS).
The example in focus is a planar high power circular magnetron. The discharge chamber and the magnetic field are assumed to be axisymmetric. The dynamics need not share this symmetry. The domain is split into the ionization region close to the cathode where electrons are confined, i.e., can escape from their magnetic field lines only by slow processes such as drift and diffusion, and the outer region where the electrons are free and the plasma is cold. With regard to the dynamics of the electrons and the electric field, a distinction is made between a fast thermo-dnamic and a slow dissipative temporal regime. The variational principle derived for the thermodynamic regime is similar to its parallel for unmagnetized plasmas but accounts for magnetic confinement by treating the magnetic flux tubes as distinct thermodynamic units. The resulting solutions obey a generalized Poisson-Boltzmann relation; they are thermodynamic equilibria of the fast regime but must be interpreted as dissipative structures in the slow regime. The presented theoretical characterization of the dynamics of high power magnetrons is confirmed by experimental results published in the literature.

Keywords: High power magnetron sputtering, technological plasmas, modeling and simulation of magnetized technological plasmas, theory, Poisson-Boltzmann (PB) relation.

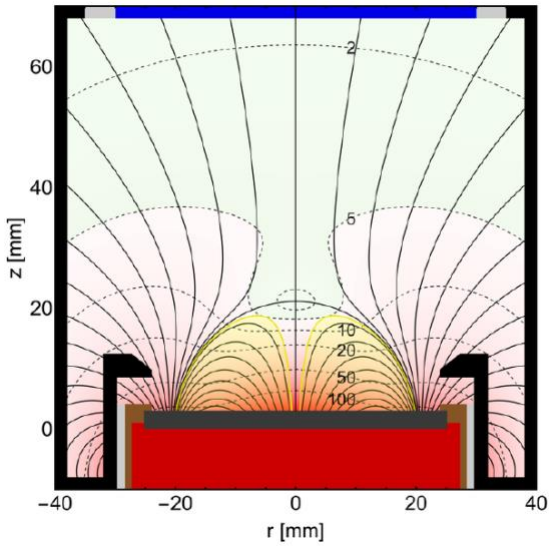


Figure 1: Cross section of a circular planar magnetron and its magnetic field topology (to scale), mounted in a cylindrical chamber (not to scale). The chamber wall and the anode (black) are at zero potential (grounded). The cathode (red), the target (grey), and the target clamp (brown) are at negative potential. A further electrode (blue) is also on fixed potential. Insulators (grey) separate the electrodes. The magnetic field lines are shown in black; the field strength is indicated by the background color and by the dashed lines (in mT). The domain V is split into an ummagnetized region (green) and a magnetized region. The part of the latter which consists of field lines from cathode to cathode forms the ionization region (yellow).

References:

1. Köhn K., Krüger D., Kemaneci E., Xu L., Eremin D., Brinkmann R.P. Plasma Sources Sci. Technol. 30, 105014 (2021)

Development of a Portable Surface Modification Technology to Control the Tribological Properties of Al7075-T6 Alloy for Aerospace Applications

A. Amanov [1*] and Jun-Hyong Kim[2]
[1] Department of Mechanical Engineering, Sun Moon University, Asan, Korea
[2] DesignMecha Co. Ltd., Asan, Korea

Abstract:
Al7075-T6 alloy is one of the most commonly used aluminum alloys for highly stressed structural applications and has been extensively used in aircraft structural parts. Al7075-T6 alloy exhibited desirable mechanical properties such as high specific strength. However, the tribological properties and corrosion resistance have limited the application of Al7075-T6 alloy due to the unreachable parts that cannot be treated by existing surface peening technologies. Thus, a portable ultrasonic nanocrystal surface modification (UNSM) technology was developed to overcome these limitations. In this study, a newly developed high-frequency portable UNSM device was designed and manufactured. This technology is considered one of the surface severe plastic deformation (S^2PD) methods [1]. The effect of this newly developed portable UNSM technology was experimentally assessed on surface properties such as roughness, hardness, residual stress, etc. Characterization of microstructure and the formation of the nanostructured surface layer were analyzed by electron backscattered diffraction (EBSD) and transmission electron microscope (TEM) to understand the hardening and grain refinement mechanisms as the holistic understanding of the microstructural evolution has the potential to allow tailoring of microstructures and properties. The tribological properties of Al7075-T6 alloy before and after portable UNSM treatment were evaluated using a ball-on-disc tribo tester under dry conditions. The results revealed the greater effectiveness of the portable UNSM technology in terms of improvements in surface and tribological properties, where the friction coefficient was reduced and the wear resistance was enhanced compared to the untreated Al7075-T6 alloy. Figure 1 shows the SEM-EDX images of the wear track formed on the surface of the untreated and UNSM-treated specimens. It can be observed that the portable UNSM technology enhanced the wear resistance by forming a nanostructured surface layer with significantly increased hardness. The current research study provides a more comprehensive discussion of the relationship between the microstructural evolution and the tribological properties of Al7075-T6 alloy for aerospace applications. Hence, it is expected that the portable UNSM technology can be used as an alternative promising peening technology in the aviation industry.

Keywords: Al7075-T6 alloy, portable surface modification technology, grain size, tribology, industrial applications.

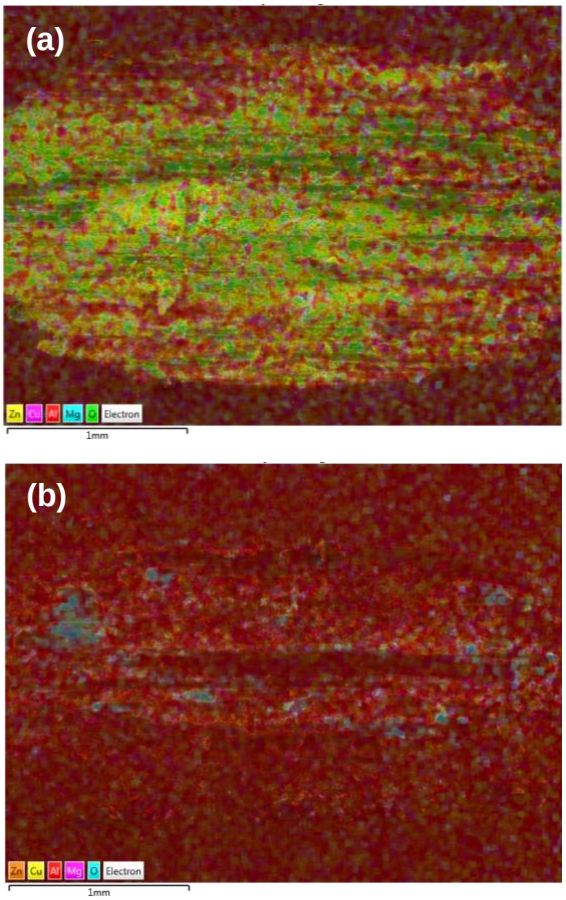


Figure 1: SEM-EDX images of the wear track formed on the surface of the untreated (a) and UNSM-treated (b) Al7075-T6 alloy.

Reference:

1. Amanov, A. (2023) Enhancement of sliding wear and scratch resistance of two thermally sprayed Cr-based coatings by ultrasonic nanocrystal surface modification, *Wear*, 512–513, 204555.

SICT 2023 Session I. A: Surface treatments and coatings deposition and functionalization / Characterization / Properties Multifunctional composite and hybrid coatings

Development of Nanolayered Thin Films for Joining Applications

S. Simões [1,2,*], M.Silva, [3] F.Viana [1,2], A.S. Ramos [4], M.T. Vieira [4]

[1] Department of Metallurgical and Materials Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[2] LAETA/INEGI—Institute of Science and Innovation in Mechanical and Industrial Engineering, Rua. Dr. Roberto Frias, 4200-465 Porto, Portugal
[3]Department of Mechanical Engineering, Federal University of Amazonas, General Rodrigo Octavio Jordão Ramos ST., Manaus 69067-005, Brazil;
[4] University of Coimbra, CEMMPRE, Department of Mechanical Engineering, R. Luís Reis Santos, 3030-788 Coimbra, Portugal; sofia.ramos@dem.uc.pt (A.S.R.); teresa.vieira@dem.uc.pt (M.T.V.)

Abstract:
Developing new approaches for joining processes of advanced materials is crucial as these processes are responsible for the significant increase in the final price of the product and production challenges. The main problem to these processes is the need to use an external heat source to melt the base materials [1]. Even in the case of techniques that do not require the melting of base materials, the temperatures often induce phase transformations, structural modifications, and localized residual stresses. Brazing and solid-state diffusion bonding are the most suitable for promoting the successful bonding of advanced or dissimilar materials [2,3]. Joining processes assisted by multilayer thin films as interlayers may be an approach to conventional techniques to overcome the problems presented by them. This research shows the reliability of Ni/Me multilayer thin films (Me = Al or Ti) with total thickness close to 3 μm and modulation periods (bilayer thickness, Λ) between 12 and 50 nm in diffusion bonding of different metallic materials. Figure 1 shows a brigth field transmission electron microscopy image of Ni/Al multilayer with 30 nm modulation period. The nanolayered thin films are deposited onto the base materials by magnetron sputtering from two targets. The power applied to each target is selected to obtain near equiatomic average chemical composition, while the period is adjusted by varying the substrates' rotation speed. The nanometric character of these interlayers can promote the increase of diffusivity through the interface, leading to decreased processing conditions. In addition, the possibility of using multilayer nanometric reactive multilayers as interlayers has the great advantage that they can be used as an additional heat source because of the ability to react in an exothermic and self-sustaining way after ignition by a power pulse. To date, reactive multilayer-assisted bonding processes have been successful in the similar and dissimilar bonding of metallic materials, especially titanium alloys, steel, and nickel superalloys
Recently, this approach was extended to ceramic/metal joining, and Ti-6Al-4V and Al_2O_3 base materials were bonded using Ni/Al multilayer thin films.

Keywords: TiAl alloys, nanolayers, diffusion bonding, aerospace applications.

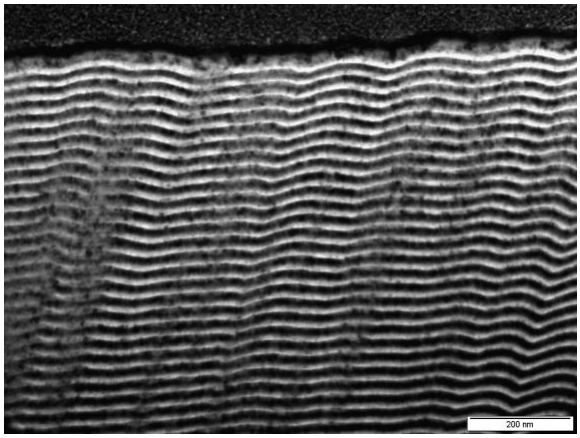


Figure 1: Brigth field transmission electron microscopy image of Ni/Al multilayer with 30 nm modulation period.

References:

1. Threadgill, P.L. (1995), The prospects for joining titanium aluminides. *Mater. Sci. Eng. A*, 192, 640–646.
2. Cam, G., Clemens, H., Gerling, R.. Kocak, M, (1999), Diffusion bonding of gamma-TiAl sheets, *Intermetallics*, 7, 1025–1031.
3. Shiue, R.K., Wu, S.K., Chen, S.Y. (2003), Infrared brazing of TiAl intermetallic using BAg-8 braze alloy. *Acta Mater.* 51, 1991–2004.

Clay mineral nanosheets suspended in water give bright and noniridescent structural colors

Paulo H. Michels-Brito[1], Volodymyr Dudko[2], Josef Breu[2], Jon Otto Fossum[1]*

[1] Norwegian University of Science and Technology (NTNU), Trondheim, Norway.
[2]University of Bayreuth, Bayreuth, Germany.

Abstract:
Structural colors originate by constructive interference following reflection and scattering of light from nano-structures with periodicity comparable to visible light wavelengths. Bright and noniridescent structural colorations are highly desirable. Recently, we demonstrated that bright noniridescence structural coloration can be easily and rapidly achieved from suspended two-dimensional nanosheets of a clay mineral. We showed that brightness is enormously improved by using double clay nanosheets, thus optimizing the clay refractive index that otherwise hampers structural coloration from such systems. Intralayer distances, and thus the structural colors, can be precisely and reproducibly controlled by clay concentration and ionic strength independently, and noniridescence is readily and effortlessly obtained in this system. Embedding such clay-designed nanosheets in recyclable solid matrices could provide tunable vivid coloration and mechanical strength and stability at the same time, thus opening a pre-viously unknown venue for sustainable structural coloration.

Keywords: structural colors, nanosheets, clay minerals

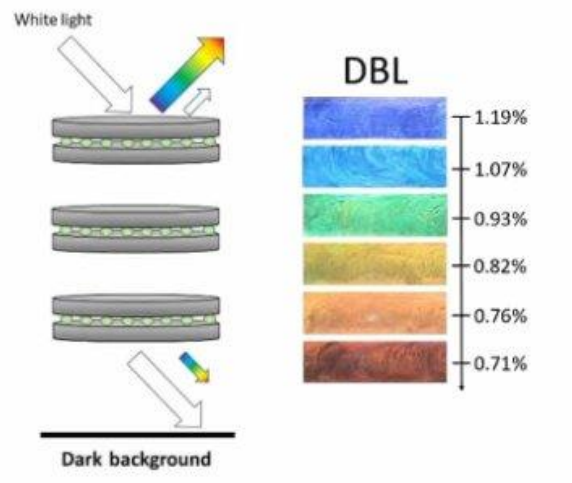


Figure 1: Figure illustrating structural coloration from interference due to clay mineral DBLs, including a dark background in principle similar to forinstance peakcock feathers, that are bright on fron side and dark on back side.

References:

1. Bright, noniridescent structural coloration from clay mineral nanosheet suspensions, Paulo H. Michels-Brito, Volodymyr Dudko, Daniel Wagner, Paul Markus, Georg Papastavrou, Leander Michels, Josef Breu, Jon Otto Fossum, *Science Advances* 8(4), DOI: 10.1126/sciadv.abl8147 (2022)

Molecular Layer Deposition – Versatile Tool for High Performance CNT-Polymer Composites

R. Yerushalmi[1,*]
[1] Institute of Chemistry, The Hebrew University of Jerusalem, Jerusalem, Israel

Abstract:
Composite materials such as carbon nanotube (CNT) reinforced polymer composites are of great interest due to their potentially high strength-to-weight ratio compared with traditional materials. In addition, these materials exhibit exceptional thermal and electrical properties. One of the key challenges preventing full realization of their extensive potential in a wide range of applications is originating from the very same property that makes those materials so attractive – the CNT Csp2-Csp2 network. In order to make CNTs compatible with polymer matrices in the context of reinforced composite materials the surface properties of the CNTs must be adjusted. However, such surface modification typically results in compromising the pristine CNT Csp2-Csp2 network leading to an impasse. To overcome this fundamental limitation, we have developed a novel vapor-phase approach using combined Atomic & Molecular Layer Deposition (M/ALD) allowing molecular-level precision tailoring of CNT interfaces while minimizing the undesired effects.
We address these challenges by combining surface engineering with M/ALD vapor phase chemistry, featuring a balance between non-covalent interactions and covalent interactions with the polymer matrix in one integrated process. Utilizing atomic and molecular layer deposition vapor phase chemistry allows fine-tuning of final physical properties and enables the design of high performance CNT reinforced-polymer composites. The application of a combined M/ALD methodology is widely applicable to engineer the CNT-polymer interphase with high level control over surface interactions. This may pave a way to systematically develop and utilize high CNT loading composites as well as other nano reinforced composite systems showing both high strength and toughness as well as numerous other desirable properties related to nano materials composites in general.

Keywords: CNT, ALD, MLD, composite materials, surface chemistry.

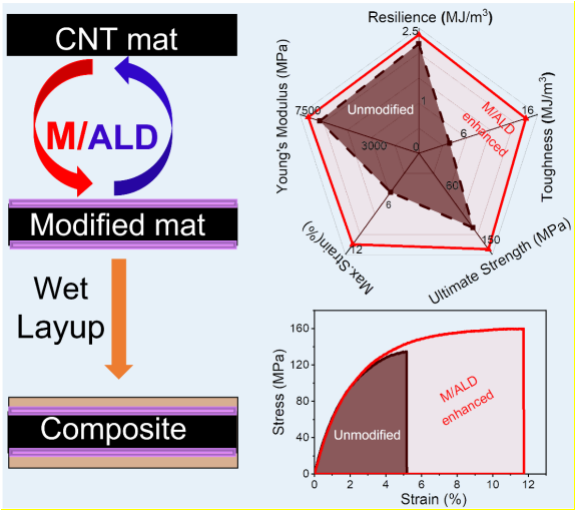


Figure 1: Figure illustrating the fundamental question that we are tempting to solve experimentally: what is the importance of silica surface modification nanoporous silica-based sol-gel glasses prepared from functionalized organosilane precursors on the parameters affecting the conformation, biological activity and functionality of encapsulated biomolecules.

References:

1. Krushnamurty Killi, Yuval Madmon, Ronen Verker, and Roie Yerushalmi. (2022) Combined Atomic and Molecular Layer Deposition Surface Modification of Carbon Nanotubes for CNT–Epoxy Polymer Composites, *ASC Appl. Nano Mater., 5, 15429-15440.*
2. Boaz Kalderon, Debabrata Sarkar, Krushnamurty Killi, Tamuz Danzig, Doron Azulay, Oded Millo, Gili Cohen-Taguri and Roie Yerushalmi. (2021) Layered Si–Ti oxide thin films with tailored electrical and optical properties by catalytic tandem MLD-ALD. *RSC Adv., 11, 35099-35109*

Controling porosity of adsorbed polymeric overlayers: Monte Carlo simulations of the Ullmann coupling of halogenated PAHs

P. Szabelski [1,*], J. Lisiecki [1]
[1] Department of Theoretical Chemistry, Maria Curie-Skłodowska University, Lublin, Poland

Abstract:
Controlled synthesis of low-dimensional structures on surfaces has been important to fabrication of molecular materials with unique physicochemical properties. A promising method in this field has been the surface-assisted self-assembly based on metal-ligand coordination, often followed by further covalent polymerization of adsorbed intermediate structures. In this contribution we demonstrate how theoretical methods such the Monte Carlo simulations can be effectively used to predict structure formation in metal-organic precursor assemblies on crystalline substrates. To that end selected results of calculations performed for halogenated (poly)aromatic building blocks differing in size, shape and intramolecular distribution of active centers are discussed. These findings show the wide possibility of directing the self-assembly towards 2D porous networks with diverse periodicity, connectivity and porosity. Our theoretical investigations provide also useful insight into the formation of metal-organic precursors of the on-surface Ullmann coupling of halogenated polyaromatic monomers. The obtained set of molecular structures can be a practical guide for designing new polymeric networks with tailorable structural features and functions.

Keywords: on-surface polymerization, adsorption, polyaromatic hydrocarbons, Ullmann coupling, metal-organic precursors, Monte Carlo simulations, structure formation, 2D porous networks

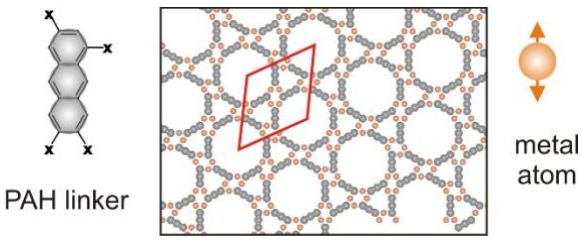


Figure 1: Fragment of the theoretically predicted metal-organic porous network comprising molecules of 1,3,6,7-tetrahalogenated anthracene and bivalent metal atoms adsorbed on a model (111) crystalline surface.

References:

1. Lisiecki, J., Szabelski, P. (2020) Surface-Confined Metal–Organic precursors comprising naphthalene-like derivatives with differently distributed halogen substituents: a Monte Carlo model, *J. Phys. Chem. C, 124, 20280-20293*.
2. Lisiecki, J, Szabelski, P. (2021) Designing 2D covalent networks with the lattice Monte carlo simulations: precursor self-assembly, *Phys. Chem. Chem. Phys., 23, 5780-5796.*
3. Lisiecki, J., Szabelski, P. (2022) Monte Carlo simulation of the surface-assisted self-assembly of metal-organic precursors comprising phenanthrene nuilding blocks, *Coll. Surf. A, 648, 129177.*

Acknowledgement:
This work was supported by the National Science Center, Poland; grant no. 2018/31/B/ST4/01759

Revealing atomic-scale phase transition in epitaxial VO_2 thin films

Masoud Ahmadi [1*], Atul [1] , Majid Ahamdi [1], Sytze de Graaf [1], Bart Kooi [1]
[1] Zernike Institute for Advanced Materials, University of Groningen, Nijenborgh 4, 9747, AG, Groningen, the Netherlands

Abstract:
VO_2 films exhibit promising applications in switching devices, memristors and optoelectronics. This research contributes to understanding of the relationship between atomic structure/interfaces and phase transformation in VO_2 thin films. Unravelling the atomic structures and interfaces of VO_2 thin films can shed light on the evolution of structural and electrical properties in these functional coatings. Due to the coexistence of the heavy and light elements in these films, the atomic resolution imaging of both vanadium and oxygen atoms is not possible using standard transmission electron microscopy. This barrier has been removed by employing a state of art imaging technique in aberration corrected scanning transmission electron microscopy (STEM), namely integrated differential phase contrast (iDPC), while simultaneously also utilizing high-angle annular dark field (HAADF) imaging.

In this study, we developed an electron microscopy-based methodology to identify and quantify the complex phases present during the metal-insulator transition (MIT) in epitaxially-grown VO_2 thin films on TiO_2 substrates.

Keywords: VO_2 thin films, metal-insulator transition (MIT), electron microscopy, STEM

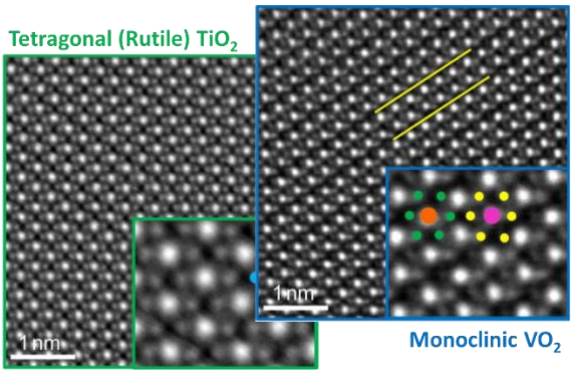


Figure 1: The high resolution atomic scale (iDPC) imaging of tetragonal to monoclinc phase transition in VO_2 thin films on TiO_2 substartes where both V and O atomic columns are imaged simultaneously.

Eco-efficient flame retardant bio-based self-stratifying coatings

Maude Jimenez*[1,2], Charlotte Lemesle[3], Severine Bellayer[1], Sophie Duquesne[1], Mathilde Casetta[1], Anne-Sophie Schuller[4], Julien Molina*[3]

[1] Univ. Lille, CNRS, INRAE, Centrale Lille, UMR 8207 - UMET - Unité Matériaux et Transformations, F-59000 Lille, France
[2] Institut Universitaire de France (IUF), Paris, France
[3] Mäder Group, Parc de la Haute Borne 60 Avenue Halley 59650, Villeneuve d'Ascq, France
[4] Laboratory of Macromolecular Photochemistry and Engineering (LPIM), University of Haute Alsace, Mulhouse, France

Abstract:
This work aims at designing bio-based flame retardant self-stratifying coatings for railway applications. This process provides a multifunctional coating in one application step, offering an alternative to conventional multi-layer coating process as it meets current environmental and industrial constraints, such as reduction of waste production, electricity consumption and cost. In this study, self-stratifying coatings based on different bio-based epoxy and silicone resins were designed. The main parameters influencing the stratification process were investigated and revealed that the nature, surface energy and polarity of the resins, as well as the solvent volatility, curing temperature and nature of the cross-linking agent have an impact on the degree of stratification. Flame retardant agents were incorporated in the formulations without affecting the stratification. Finally, a comparative Life Cycle Assessment was carried out to quantify the environmental impact of the self-stratifying process using bio-based resins compared to the conventional oil-based multilayer process

Keywords: self-stratifying coating, flame retardancy, functional property, eco-efficient, environmental impact, life cycle analysis

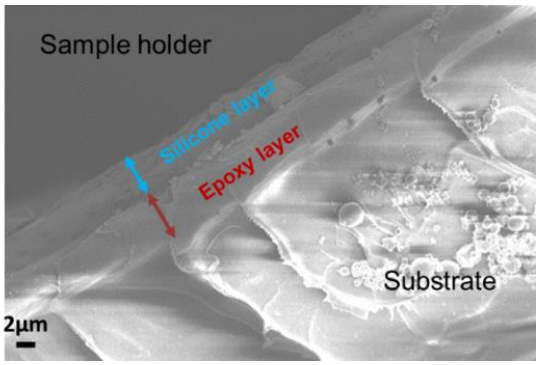


Figure 1: Cross-section cryo-electron SEM picture of a bio-based epoxy/silicone resin coating

References:

1. Lemesle, C. *et al.* (2020) Life cycle assessment of multi-step versus one-step coating processes using oil or bio-based resins. *J. Clean. Prod.* 242.
2. Lemesle, C. *et al.* (2021) Self-stratified bio-based coatings: Formulation and elucidation of critical parameters governing stratification, *Applied Surface Science* 536, 147687 .

Aerosol Deposition of $CuFeO_2$ photo-cathode coatings

Alessia Bruera[1,2,*], Andreas Elsenberg[4], Giovanni Bolelli[1,2,3], Frank Gärtner[4], Mauricio Schieda[5], Thomas Klassen[4,5], Luca Lusvarghi[1,2,3]

[1]Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, Modena, Italy
[2]INSTM Research Unit, University of Modena and Reggio Emilia, Modena, Italy
[3]InterMech - MO.RE., University of Modena and Reggio Emilia, Modena, Italy
[4]Institut für Werkstofftechnik, Helmut-Schmidt-Universität, Hamburg, Germany
[5]Institute of Hydrogen Technology, Helmholtz-Zentrum Hereon GmbH, Geesthacht, Germany
*Corresponding author: alessia.bruera@unimore.it

Abstract:
Hydrogen may play a major role in the current and future challenges of environmental and energy problems. Unfortunately, 95% of H_2 is currently produced from fossil fuels, as "grey" hydrogen, associated with the generation of large amounts of CO_2. [1] Photoelectrochemical (PEC) water splitting represents a viable and sustainable technology for "green" hydrogen generation. PEC cells require photoelectrodes capable of light harvesting and charge carrier generation. Electrodes coated with thin films of a suitable semiconductor material are usually employed for this application. [2] Several earth-abundant, semiconductive metal oxides are being studied for PEC water splitting. Among them, $CuFeO_2$ exhibits good potential as a photo-cathode material due to its suitable band gap energy (1.5 eV) and high conductivity. [3] Cost-efficient manufacturing of high-quality photoactive $CuFeO_2$ cathode layers is one of the requirements to enable the industrialization of the PEC water splitting technology. Recently, the Aerosol Deposition (AD) process has been studied for this purpose, since it offers several advantages compared to traditional processes: high deposition rates, low cost, and no phase transformation in the deposited material. To better understand material adhesion and coating building up mechanisms of Aerosol deposited $CuFeO_2$ films, the first part of this study investigates the effect of several process parameters on the quality of $CuFeO_2$ coatings sprayed on AISI 304 stainless steel plates. In the second part, AD process parameters are optimized to obtain thin $CuFeO_2$ films (≈400 μm) on FTO-glass substrates, suitable for PEC applications. The feedstock powder was synthesized by a solid-state reaction, starting from two powder precursors (hematite and cuprite), milled down to different size distributions, and subsequently sprayed by AD. The chemical and phase composition and the microstructure of powders and coatings were investigated by X-ray diffraction, Raman spectroscopy and SEM+EDX. PEC properties were analysed by UV-Vis spectroscopy, cyclic voltammetry and current-amperometry. A window of deposition was developed for $CuFeO_2$ thick coatings on steel, and tailored parameters allowed to obtain suitably thin and homogeneous films for PEC (Figure 1). Aerosol deposited $CuFeO_2$ thin films showed promising optical properties and the ability to produce photocurrent, if preliminarily annealed in air. However, their performances are still limited by poor charge transport properties and degradation under reductive conditions, thus further optimization will be needed.

Keywords: hydrogen generation, $CuFeO_2$, aerosol deposition, water splitting, photocurrent

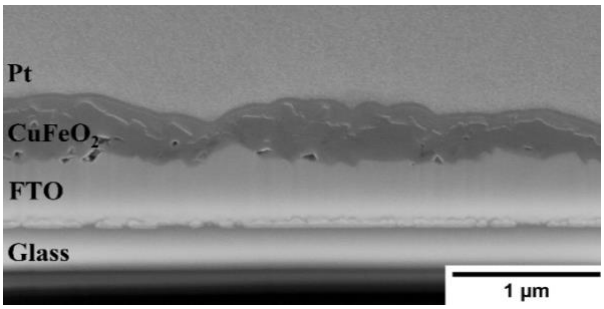


Figure 1: SEM micrograph showing the cross-section (prepared by FIB) of a thin AD $CuFeO_2$ coating on FTO-coated glass substrate

References:

1. P. Nikolaidis and A. Poullikkas, A comparative overview of hydrogen production processes, *Renew. Sustain. Energy Rev.*, vol. 67, pp. 597–611, 2017.
2. Z. Chen, H. N. Dinh, and E. Miller, Photoelectrochemical Water Splitting, New York, NY: Springer New York, 2013.
3. C. G. Read, Y. Park, and K. S. Choi, Electrochemical synthesis of p-type $CuFeO_2$ electrodes for use in a photoelectrochemical cell, *J. Phys. Chem. Lett.*, vol. 3, no. 14, pp. 1872–1876, 2012.

Superhydrophobic candle soot-coated PDMS surfaces replicated from leek leaves

S. M. Mirmohammadi, H. Daghigh Shirazi, S. Franssila, J. Vapaavuori, V. Jokinen
Department of Chemistry and Materials Science, Aalto University, Espoo, Finland

Abstract:
Superhydrophobic (SHB) surfaces are characterized by high water contact angles (CAs > 150°) and low sliding angles (SAs < 10°) for droplets in the microliter range [1,2]. There are numerous examples of superhydrophobicity in nature, such as butterfly wings, lotus leaves, and rose petals.
SHB surfaces have been fabricated by coating a structured surface with low surface energy materials or creating hierarchical micro-to-nanoscale topography. Fabrication of dual micro-nano scale hierarchical structures can be done by several methods, e.g., replication. Polymer replication is a simple method for fabricating topographical surfaces of hydrophobic/superhydrophobic materials [1,2]. Natural surfaces like plant leaves or rough metal surfaces can be used as master molds, and polymers like polydimethylsiloxane (PDMS) and polyurethane (PU) can be used as replica materials. These polymer replica surfaces are usually in Wenzel state with high sliding angles; however, they show high static contact angles [1]. There has been growing interest in carbon nanoparticles (CNPs) obtained from candle soot (CS) due to their facile and low-cost fabrication in multifunctional coatings. As a hydrophobic particle with low surface energy, candle soot can be used to achieve hierarchical structures to fabricate superhydrophobic surfaces [3].
In this work, we introduce a simple and low-cost method to fabricate superhydrophobic PDMS/candle soot surfaces by mimicking the surface morphology of leek leaves. We have developed both the PDMS replication molding and soot coating processes to obtain wetting properties as close as possible to the original leaf. CS depositing on the final structure or negative mold by various methods, e.g., spray coating, has been tested. Our final surface structures comprise multiple size scales from tens of nanometers to tens of micrometers obtained by replication and candle soot deposition (Figure 1a-c). Leek was chosen as a master mold due to its availability, low price, and anisotropy in wettability which means there is a difference in water contact angles and sliding angles between the across and along directions of the leek leaves (Figure 1d). Leek leaf selection, dried vs. non-dried leaf, has also been studied.
Keywords: Superhydrophobicity, PDMS, candle soot, replication, leek leaf, anisotropy.

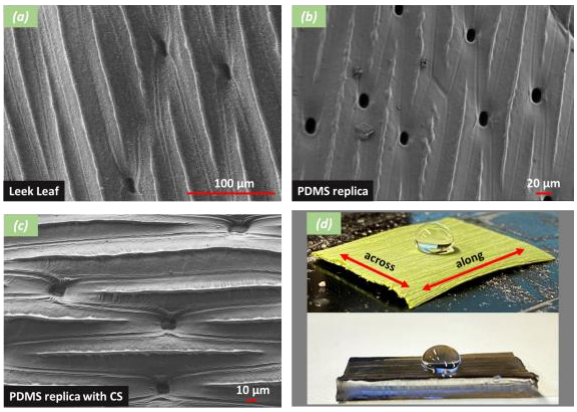


Figure 1: Micrographs show replication of leek surface morphology into PDMS: (a) leek leaf, (b) positive PDMS replica, and (c) PDMS/CS replica. (d) Digital photographs of leek leaf and PDMS replica displaying water contact angle > 150°.

References:

1. Mirmohammadi, S. M., Hoshian, S., Jokinen, V. P., & Franssila, S. (2021). Fabrication of elastic, conductive, wear-resistant superhydrophobic composite material. *Scientific reports*, 11(1), 1-10.
2. Khan, M. Z., Militky, J., Petru, M., Tomková, B., Ali, A., Tören, E., & Perveen, S. (2022). Recent advances in superhydrophobic surfaces for practical applications: A review. *European Polymer Journal*, 111481.
3. Yang, C., Li, Z., Huang, Y., Wang, K., Long, Y., Guo, Z., Li, X., & Wu, H. (2021). Continuous roll-to-roll production of carbon nanoparticles from candle soot. *Nano Letters*, 21(7), 3198-3204.

The influence of low temperature plasma oxidizing process on the bioactivity of NiTi shape memory alloy in terms of medical applications

Justyna Witkowska[1], Tomasz Borowski[1], Agnieszka Sowińska[2], Emilia Choińska[1], Dorota Moszczyńska[1], Jerzy Morgiel[3], Jerzy Sobiecki[1], Tadeusz Wierzchoń[1]

[1]Warsaw University of Technology, Faculty of Materials Science and Engineering, Warsaw, Poland
[2] Pathology Department, Children's Memorial Health Institute, Warsaw, Poland
[3] Institute of Metallurgy and Materials Science of the Polish Academy of Sciences, Krakow, Poland

Abstract:
NiTi alloy with a near-equiatomic chemical composition belongs to the new group of so-called 'smart materials' and is increasingly used in medicine due to its unique properties, like shape memory and superelasticity [1,2].
Our previous studies have shown that the improvement of corrosion resistance, biocompatibility and the reduction of the release of nickel ions into the biological environment can be achieved through the use of glow discharge treatment processes conducted at low-temperature plasma [3,4]. However, the chemical bioactivity of the layers formed in glow discharge processes, understood as the ability to biomimetic deposition of calcium phosphates, in particular hydroxyapatite, is not well understood [5]. This is an extremely important aspect in the potential use of a shape memory alloy for the production of bone implants for long-term use, because better bioactivity translates into faster osseointegration of the implant with the patient's bone.
Therefore, in this work, we describe the effect of the glow discharge oxidation process conducted at low-temperature plasma on the bioactivity of the NiTi shape memory alloy. We also present the properties of produced surface layers, such as structure (with the use of TEM observations), surface morphology (with the use of SEM observations), chemical and phase composition (with the use of EDS and XRD measurments) and wettability (with the use of optical gonimeter), as well as the biological response of osteoblasts and platelets to the surface oxidized in comparison with the NiTi alloy in the initial state. The proposed surface modification of NiTi shape memory alloy by oxidizing conducted at low-temperature plasma resulted in the formation of a continuous nanometer-thick layer of nanocrystalline titanium oxide TiO_2 (rutile). The obtained results indicated that oxidized layer increases the bioactivity of the shape memory alloy, which was verified by the spontaneous biomimetic growth of apatite deposits from simulated body fluid (SBF) solution, which occurred faster on the modified surface compared to the initial state. The appearance of hydroxyapatite among the calcium phosphates present in the biomimetic layer produced in vitro indicates a potential better bioactivity also in vivo, as the SBF solution used resembles both the composition and pH of human body fluids. Better proliferation of osteoblasts on the modified surface was also demonstrated, as well as greater adhesion and activation of platelets derived from platelet-rich plasma (PRP).
The proposed surface modification can be a way to increase the biocompatibility and bioactivity of the NiTi shape memory alloy in the aspect of long-term use bone implants.

Keywords: NiTi shape memory alloys, glow discharge oxidizing, biocompatibility, bioactivity, osseointegration

References:

1. A. Biesiekierski, J. Wang, M. Abdel-Hady Gepreel, C. Wen, A new look at biomedical Ti-based shape memory alloys, *Acta Biomater.* 8, 2012, .
2. N.B. Morgan, Medical shape memory alloy applications - The market and its products, *Mater. Sci. Eng. A.* 378, 2004, .
3. E. Czarnowska, T. Borowski, A. Sowińska, J. Lelątko, J. Oleksiak, J. Kamiński, M. Tarnowski, T. Wierzchoń, Structure and properties of nitrided surface layer produced on NiTi shape memory alloy by low temperature plasma nitriding, *Appl. Surf. Sci*., 334, 2015, 24–31.
4. J. Witkowska, A. Sowińska, E. Czarnowska, T. Płociński, T. Borowski, T. Wierzchoń, NiTi shape-memory alloy oxidized in low-temperature plasma with carbon coating: Characteristic and a potential for cardiovascular applications, *Appl. Surf. Sci*., 421, 2017, 89–96.
5. J. Forsgren, F. Svahn, T. Jarmar, H. Engqvist, Formation and adhesion of biomimetic hydroxyapatite deposited on titanium substrates, *Acta Biomater.*, 3, 2007, 980–984.

Plasma Tech Session I. B: lasma fundamentals / Modelling / Atomic and Molecular Processes

Isolating and Quantifying the Reactions of Vibrationally Excited Molecules in Nonequilibrium Plasmas

Igor V. Adamovich
[1] Department of Mechanical and Aerospace Engineering, Ohio State University, Columbus, OH, USA

Abstract:
Nonequilibrium plasmas generated by a superposition of a ns pulse train and a sub-breakdown RF waveform are used to study the effect of vibrationally excited N_2 and CO_2 molecules on the plasma chemical reactions. The combined ns pulse / sub-breakdown RF waveform generates a diffuse plasma between two parallel plate, dielectric-covered electrodes. The ionization is generated by the ns pulse train, and additional energy is coupled to the plasma by the RF waveform. The plasma parameters are characterized by the measurements of the electric field during the ns pulses and the RF "bursts", by ps Electric Field Induced Second Harmonic (EFISH) generation. The measurements are made in the bulk of the plasma and in the sheaths. The reduced RF electric field in the sheaths is significantly higher compared to that in the plasma, exceeding 100 Td. However, kinetic modeling indicates that the electron impact ionization in the sheaths is largely ineffective, due to the low electron density. Peak reduced RF electric field in the plasma ranges from 10 to 40 Td, indicating the efficient vibrational excitation of N_2 by electron impact. This is confirmed by the measurements of N_2 vibrational populations by measured by Coherent Anti-Stokes Raman Scattering (CARS), which exhibit significant vibrational excitation enhancement by the RF waveform (see Fig. 1). This suggests that the "hybrid" ns pulse / RF plasmas can be used for the selective vibrational excitation of molecular species, such as N_2, CO_2, CO, and H_2. This approach has been used to study the CO_2 dissociation kinetics in CO_2-N_2 mixtures, and the plasma-catalytic ammonia generation in N_2-H_2 mixtures. Time-resolved vibrational populations of CO_2 and CO, translational-rotational temperature, and CO yield are measured by mid-IR, tunable Quantum Cascade Laser (QCL) Absorption Spectroscopy. The NH_3 yield is measured by FTIR absorption spectroscopy. The results are used to isolate the effect of the targeted vibrational excitation of N_2 and CO_2, respectively, on the process yield.

Keywords: Ns pulse discharge, RF discharge, electric field, vibrational excitation, plasma chemical reactions.

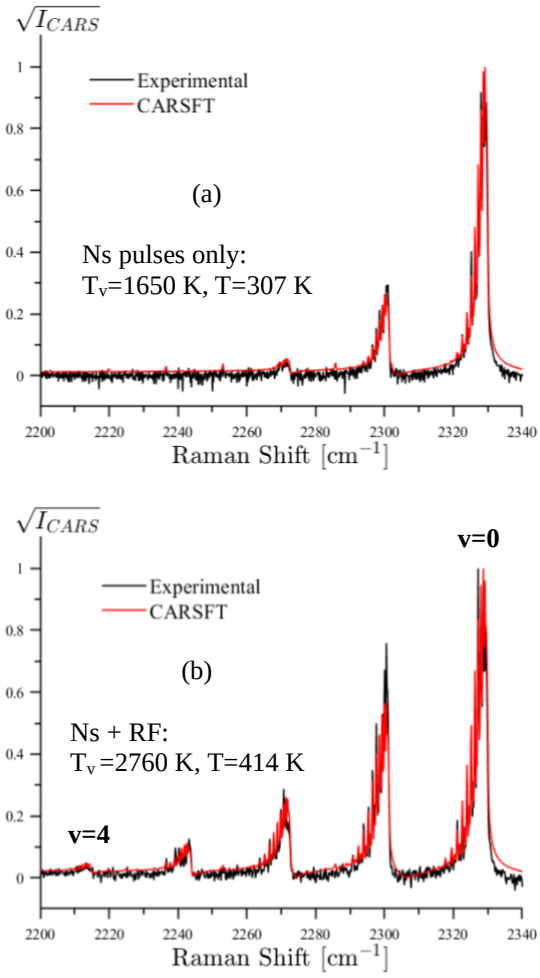


Figure 1: Broadband N_2 CARS spectra measured at the end of a 100-pulse ns discharge burst, without (*a*) and with (*b*) RF voltage applied between the pulses, compared to the best fit CARSFT synthetic spectra. Nitrogen, P=100 torr. Inferred N_2 vibrational temperatures and translational rotational temperatures labeled in the plots.

How relevant is charged-particle transport in global models ?

L.L. Alves[1,*], A. Tejero-del-Caz[1,2]

[1] Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Univ. Lisboa, Lisboa, Portugal
[2] Departamento de Física, Facultad de Ciencias, Univ. Córdoba, Córdoba, Spain

Abstract:
Global (zero-dimensional) models are very popular in the study of low-temperature plasmas (LTPs), especially when the focus is on plasma chemistry [1]. Unfortunately, and despite proposals in the literature to consider space-dependent phenomena in global models [2], the transport of species (in particular charged particles) is still often neglected and/or not discussed in global models.
In this lecture we analyse the influence of different charged-particle transport models on the global modelling of LTPs. The simulations use the LisbOn KInetics (LoKI) simulation tool [3,4], calculating the charged-particle loss frequency due to transport with various formulations, categorized into two large groups: ambipolar-based and h-factor transport models. The models are applied to the description of (i) a DC discharge in oxygen (as example of an electronegative multi-ion plasma), at low to intermediate pressures; (ii) a microwave discharge in helium (as example of an electropositive multi-ion plasma), from low to atmospheric pressures. In both cases, we adopt validated kinetic schemes as reference [5-7].
Results show that using different charged-particle transport models can result in uncertainties of 20-60% and 8-115% in the discharge characteristics of oxygen (see figure 1) and helium, respectively, with larger dispersion at low pressure and low electron density. The spreading in the results is observed also in the densities of the main plasma species. Since transport accounts for more than 50% of total charge losses, this mechanism should always be part of the quantitative sensitivity analysis of a kinetic scheme, considering several models according to the positive/negative ion features and the low/high pressure conditions considered.

Keywords: low-temperature plasmas, charged-particle transport, global model, kinetic scheme, LoKI.

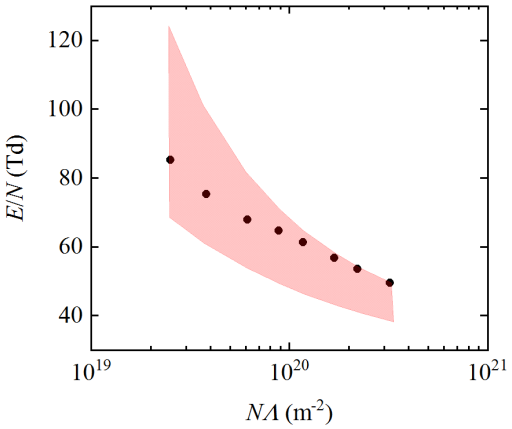


Figure 1: Discharge characteristics in oxygen, for DC discharges with 1 cm radius at 10 mA current. Points: measured values; bands: regions of values calculated adopting various charged-particle transport models.

References:

1. Alves, L.L. *et al.* (2018), *Plasma Sources Sci. Technol.* 27, 023002.
2. Hurlbatt, A. *et al.* (2017), *Plasma Process. Polym.* 14 1600138.
3. https://nprime.tecnico.ulisboa.pt/loki/
4. Tejero-del-Caz, A. *et al.* (2019), *Plasma Sources Sci. Technol.* 28 043001
5. Dias, T.C. *et al.* (2023), *Plasma Sources Sci. Technol.*, submitted.
6. Alves, L.L, Gousset, G., Ferreira, C.M. (1992), *J. Phys. D: Appl. Phys.* 25 1713.
7. Santos, M. *et al.* (2014), *J. Phys. D: Appl. Phys.* 47 265201.

Acknowledgments
Work partially supported by FCT-Fundação para a Ciência e a Tecnologia (UIDB/50010/2020 and UIDP/50010/2020), the European Union (NextGenerationEU) and the Spanish Ministry of Universities (Plan de Recuperacion, Transformación y Resiliencia).

Calculation of Equilibrium Plasma Thermodynamics

G. Colonna [1*], A. D'Angola [1,2], A. Laricchiuta [1]
[1] CNR-ISTP Bari section, Bari, Italy
[2] Scuola di Ingegneria, Università della Basilicata, Potenza Italy

Abstract:
The thermodynamic characterization of thermal plasma is a fundamental aspect in many fields, such as high-pressure plasma torches, LIBS (Laser induced Breakdown Spectroscopy), lightning physics and so on. Different aspects must be considered to determine equilibrium quantities. In this paper, we will describe the approach implemented in the code EquilTheTA [1], a web tool to calculate equilibrium composition and the corresponding thermodynamic and transport properties of a plasma. The tool is based on the statistical physics of gases, accessing to an accurate core database of single species internal levels [2]. The tool includes ortho-para separation, important at low temperature for light molecules such as H_2 (and isotopologues) and O_2. For atomic species, multiply ionized atoms are included and to cope with the divergence of the internal partition function, the number of levels, limited according to the Fermi and Griem cutoff criteria [2], is calculated self-consistently with the composition. The tool has been used also to investigate plasma in high density conditions [3], when also the internal structure of the atoms is influenced by the electron density. In these conditions, quantum effects become important and the Fermi-Dirac distribution must be used for the electron gas [4]. To reduce the size of the core database a general expression, based on the lumped level approach [4], allows to accurately determine the internal thermodynamic properties of species in a wide temperature range. To determine the composition of complex plasmas a novel algorithm has been included, finding one reaction equilibrium, consisting in finding the root of a polynomial, in each step, up to convergence. The possibility of using analytical solution for polynomials up to fourth degree speedup the convergence.

Keywords: Thermal Plasmas, Equilibrium Calculation, Non-Ideal Corrections.

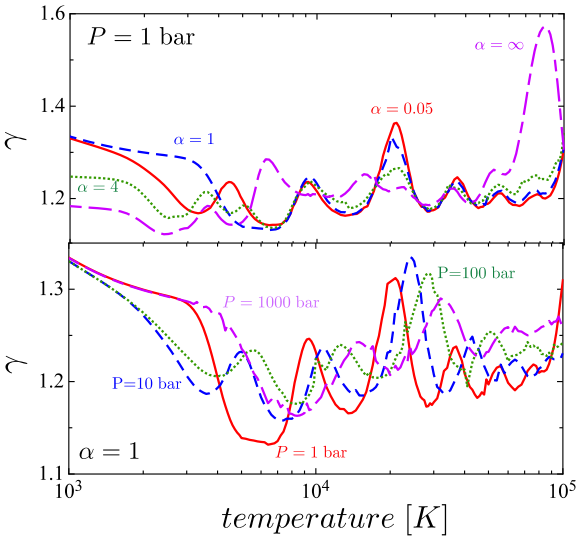


Figure 1: Isentropic coefficient of the SiC/Air mixture for different vlues of $\alpha=\chi_{SiC}/\chi_{O2}$ (χ_s molar fraction of sth species) [5].

References:

1. 2023 EquilTheTA http://phys4etrydb.istp.cnr.it/EquilTHETA/
2. M. Capitelli, G. Colonna, A. D'Angola (2012), Fundamental Aspects of Plasma Chemical Physics: Thermodynamics, Springer Series on Atomic, Optical, and Plasma Physics volume 66
3. G. Colonna, A. Laricchiuta (2020) Thermodynamic and Transport Properties of Equilibrium Debye Plasmas, *Entropy* 22 (2), 237
4. G. Colonna, A. D'Angola, A. Laricchiuta, (2023) Thermodynamic and Transport Properties of Complex Plasmas, Chap 21 in Plasma Modeling: Fundamentals and Applications, Ed. G. Colonna and A. D'Angola, IO Publishing
5. G. Colonna (2019) Thermodynamic properties of air plasma seeded by SiC molecules, *Rendiconti Lincei* 30, 537

A Database of Transport Cross Sections for Planetary Atmospheres

A. Laricchiuta [1,*], A. D'Angola [2,1], F. Pirani [3], M. Capitelli [1], G. Colonna [1]

[1] CNR ISTP Bari Section, Bari Italy
[2] Scuola di Ingegneria, Università della Basilicata, Potenza Italy
[3] University of Perugia, Perugia Italy

Abstract:
The new impulse to the solar system exploration, testified by the planned NASA missions to the Ice Giants [1], i.e. Neptune and Uranus, is triggering the theoretical activity on the modeling of the hypersonic entry in the planets' atmospheres. In this context it is relevant to characterize the thermodynamics and transport properties of the plasma formed in the shock layer, also accounting on the role of chemical species ablated from the carbon phenolic thermal protection systems.
For the accurate estimation of thermodynamic properties and transport coefficients, here the web-access tool EquilTheTA (EQUILibrium for plasma THErmodynamics and Transport Applications) [2] is exploited. The tool, stable and reliable in wide temperature and pressure ranges, derives the quantities from core databases of atomic and molecular energy levels and collision integrals, in the frame of the classical theory of statistical thermodynamics and the Chapman-Enskog theory, respectively.
The creation of a complete database of transport cross sections for binary heavy-particle interactions in complex mixtures including large number of species has been successfully tackled adopting a *hybrid approach* [3] that combines the traditional *multi-potential* with the *phenomenological approach* [4]. In the multi-potential approach, the effective collision integrals for a given interaction results from the averaging procedure of terms corresponding to each allowed interaction between the two colliding partners, while the phenomenological approach is very attractive, allowing the derivation of complete and consistent datasets of collision integrals for any interaction, estimating the interaction potential on a physically sound basis. In fact, the average interaction is modeled by an Improved Lennard Jones (ILJ) potential, whose features (depth and position of the well) are derived by correlation formulas given in terms of fundamental physical properties of interacting partners (dipole polarizability, charge, number of electrons effective in polarization). These approaches, combined with the asymptotic approach for the estimation of the resonant charge-exchange contribution to odd-order collision integrals, represent a powerful strategy to extend the collision integral database.
The transport cross sections for the matrix of binary interactions involving chemical species relevant to the H_2/He/C/H system are derived, including molecules, molecular ions, neutral and ionized atoms, so as to fully describe the low temperature, dissociative and ionization regimes of the plasma.

Keywords:transport properties, hybrid approach, collision integrals, planetary atmospheres.

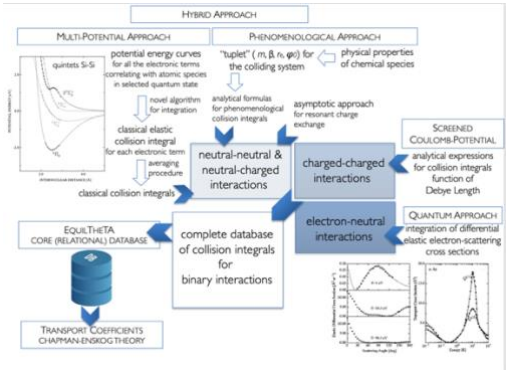


Figure 1: Sketch of the approach in the creation of the core database of EquilTheTA.

References:

1. Cohen, I. J., & Rymer, A. M. (2020). Cross-NASA divisional relevance of an Ice Giant mission. *Philosophical Transactions of the Royal Society A*, 378(2187), 20200222
2. 2023 EquilTheTA http://phys4etrydb.istp.cnr.it/EquilTHETA/
3. Laricchiuta, A., D'Angola, A., Pirani, F., Pietanza, L.D., Capitelli, M., Colonna, G.: Thermodynamic and transport properties of reacting air including ablated species. In: *Hypersonic Meteoroid Entry Physics*. IOP Publishing (2019)
4. Capitelli, M., Cappelletti, D., Colonna, G., Gorse, C., Laricchiuta, A., Liuti, G., Longo, S., Pirani, F.: On the possibility of using model potentials for collision integral calculations of interest for planetary atmospheres. *Chemical Physics* 338(1), 62–68 (2007).

Development Process, Structure and Performance Parameters of a Shielded 433 MHz Plasma Jet with 600W

H. Heuermann [1], St. Terbrack [1]

[1] Institute of Microwave and Plasma Technology (IMP),
University FH Aachen, Aachen, Germany

Abstract:
Plasma jets were mainly operated by AC signal down to the lower MHz range and used for surface activation up to welding processes. In the meantime, plasma jets have been introduced to the market in the GHz range, which in many respects also compete with lasers, [1]. In this paper, a plasma jet is presented which is placed between these two classes. This 433 MHz plasma jet was developed in a similar way as the GHz jets are developed, [2]. Except for the work of the research group [3], the authors are not aware of any other work on 433 MHz plasma jets.
First, it is shown how a high voltage is constructed for automatic ignition using internal coaxial line components. In order to be able to guarantee power matching for operation also via the same unit, this must be accomplished at a slightly different frequency. So that this frequency change can take place a semiconductor amplifier is needed for the operation. In addition, it is necessary to measure the plasma at 433 MHz and full power (600 W), which requires the use of a hot-S-parameter, which was specially built for this plasma jet development. Based on a plasma modeling regarding the spatially distributed electrical conductivity, the matching elements for the operation were developed. However, the ignition network is affected in this process. Therefore, simulation optimizations for both operating points and the optimum operating frequencies are to be carried out in further work. For legal approval reasons, the continuous operation should be at 433 MHz.
Due to the large plasma achieved, it was necessary to shield this plasma, as otherwise this jet would radiate too much energy and endanger the users. The generated plasmas and applications of these 433 MHz plasmas complete this article.

Keywords: Plasma jet, torch, athmosphere plasma, chamber plasma, hot-S-parameter, plasma modelling, high voltage generation, plasma matching, activation, plasma treatment

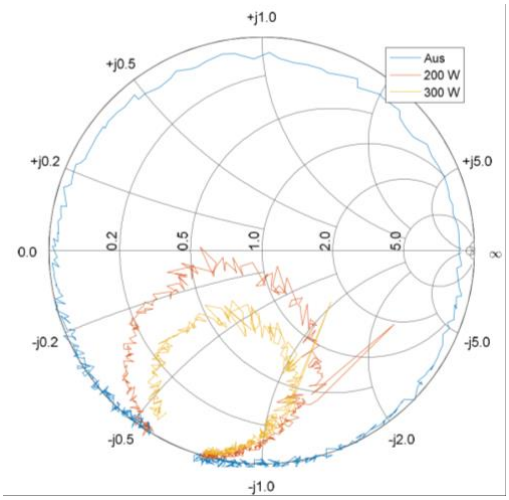


Figure 1: Complex reflexion results of the plasma jet in the frequency band from 415-450 MHz at an input power of 0.1, 200, and 300 W.

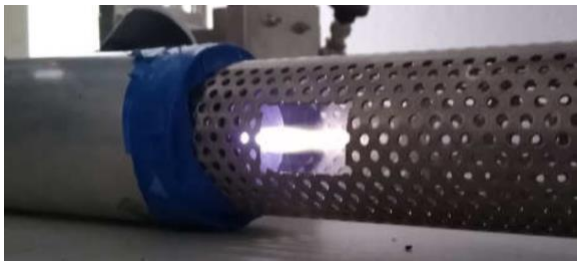


Figure 2: Illustration of the 433 MHz plasma jet at an input power of 600 W (diameter of the shielding is 64mm).

References:

1. Datasheets of 2.45 GHz cannula plasma jets: https://hhft.de/jets-pc-serie
2. Schopp, C., Nachtrodt, F., Heuermann, H., Scherer, U. W., Mostacci, D., Finger, T., Tietsch, W., (2012) A novel 2.45 GHz/200 W Microwave Plasma Jet for High Temperature Applications above 3600 K, *Journal of Physics Conference Series*, (http://iopscience.iop.org/1742-6596/406/1/012029).
3. Wu, L., Zhang, W., Liu, Z., Yu, J., Huang, K., Tao, W., (2020) Experimental Investigation of Microwave Frequency Effects on the Discharge Properties in an Atmospheric-Pressure Coaxial Plasma Jet, *2020 IEEE International Conference on Plasma Science (ICOPS)*

Energetics of Reactions in a Dielectric Barrier Discharge with Argon Carrier Gas with Admixed Hydrofluoromethanes

Sean Watson[1], Bernard Nisol[1,2], Michael R. Wertheimer[1]

[1]Groupe des Couches Minces (GCM) and Department of Engineering Physics,
Polytechnique Montréal, Box 6079, Station Centre-Ville, Montreal QC H3C 3A7, Canada
[2] Molecular Plasma Group (MPG), 20 Rue du Commerce, Technoport – Hall 4B,
L-3895 Foetz, Luxembourg

Abstract:
The method we have developed for understanding energetic exchanges between organic precursor molecules and argon (Ar) carrier gas in a pilot-scale dielectric barrier discharge (DBD) reactor has by now achieved much proven merit. This presentation focuses on a series of hydro-fluoromethane molecules, CH_xF_y ($0 \leq x \leq 4$; $y = 4 - x$), precursors that were mixed in ‰ concentrations with 10 slm of Ar in a 20 kHz, 8 kV (peak-to-peak) DBD; for each compound, E_m, the energy absorbed per molecule, was plotted as a function of precursor flow rate. Beside determination of E_m from precise electrical measurements, we have used optical emission spectroscopy (OES) as a diagnostic of the plasma's physico-chemistry in the gas-phase. The influence of precursors' chemical structures has also been investigated by depositing thin plasma polymer coatings, for which we measured deposition rates and water contact angles; these have been convincingly correlated with E_m values and XPS analyses.

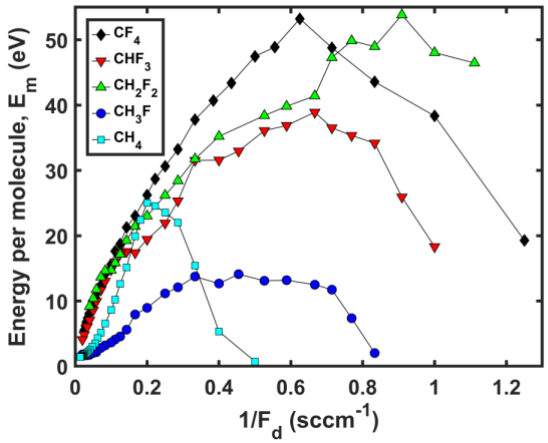


Figure 1: Plots of E_m versus $1/F_d$ for the five CH_xF_y molecules used in this research. Characteristics of particular interest, namely the values of $(E_m)_{max}$ and of the initial slopes, $[d(E_m)/d(F_d)]$, will be discussed in detail.

Keywords: Dielectric Barrier Discharge, Energetics, Fragmentation, Polymerization

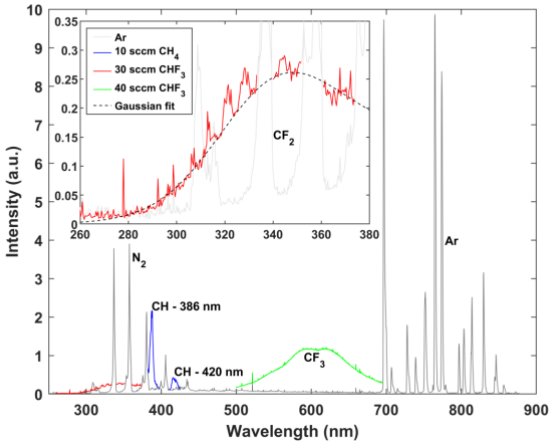


Figure 2: Optical emission spectra of Ar/CH_xF_y mixture DBD plasmas. Different colors, corresponding to specific cases, highlight the main spectral features that served for diagnostics.

References:

1. Watson, S., Nisol, B, Lerouge, S. Wertheimer, M.R. (2015), Energetics of Molecular Excitation, Fragmentation and Polymerization in a Dielectric Barrier Discharge with Argon Carrier Gas, *Langmuir* 31, 10125-10129
2. Watson, S., Nisol, B., Gagnon, H., Archambault-Caron, M., Sirois, F., Wertheimer, M.R. (2019), Energetics of Noble Gas Dielectric Barrier Discharges (DBD): Novel Results related to Electrode Areas and Dielectric Materials, *IEEE Transactions on Plasma Science* 47, 2680-2688

Electron emission yield of metals: in-situ cleaned and exposed to ambient atmosphere surfaces

M. Belhaj*, S. Dadouch
ONERA-DPHY, Toulouse, France

Abstract:
The total electron emission yield (TEEY) measure the number of secondary and backscattered electrons emitted from a surface when it is bombarded by incident electrons. Technical metallic materials, such as those used in electronic components, RF hardware, spacecraft, and particle accelerators, typically have generally a higher TEEY than pure, cleaned surface materials. This is because technical materials often have surface contaminants, such as oxides and hydroxides, that can modify the transport of secondary electrons undergoing emission. In contrast, pure, cleaned surface materials have fewer contaminants and therefore a lower total electron emission yield. For instance, we found that the TEEY yield of aluminum exposed to ambient conditions for more than four years is about 2.5, while that of an in-situ ion cleaned surface is about 1. In this situation, choosing the appropriate dataset for a specific application may induce a high error margin that should be quantified. For this purpose, we have measured the TEEY of four metallic surfaces that were in-situ argon cleaned: aluminum, copper, gold, and silver, as well as their counterparts that were exposed to the ambient atmosphere for an extended period. The results were fitted using a TEEY model, and the possible error amplitude on the TEEY according to the material environment and application will be discussed. A strategy for choosing the appropriate TEEY among those of the in-situ cleaned surface and the surface exposed to the ambient environment, depending on the application and the material environment, will also be discussed.

Keywords: electron impact, secondary electron, surface contamination

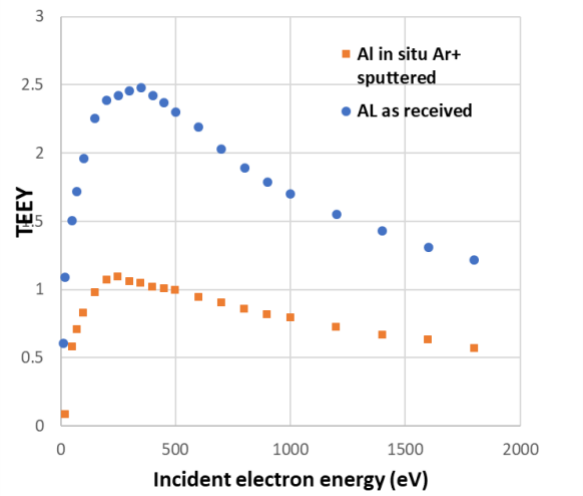


Figure 1: Total electron emission yield of long time exposed 99.99 aluminum foil to ambient atmosphere compared to that in situ cleaned aluminum 99.99 with argon sputtering. The data is extracted from Thomas Gineste Thesis

References:

1. R. Cimino, L. A. Gonzalez, R. Larciprete, A. Di Gaspare, G. Iadarola, and G. Rumolo, Detailed investigation of the low energy secondary electron yield of technical Cu and its relevance for the LHC, Phys. Rev. ST Accel. Beams 18, 051002 (2015), https://doi.org/10.1103/PhysRevSTAB.18.051002
2. T. Gineste, M. Belhaj, G. Teyssedre, J. Puech, Investigation of the electron emission properties of silver: From exposed to ambient atmosphere Ag surface to ion-cleaned Ag surface, Applied Surface Science, Applied Surface Science, 359, 398 (2015), https://doi.org/10.1016/j.apsusc.2015.10.121
3. Thomas Gineste, Émission électronique sous impact d'électrons : applications spatiales. Toulouse, France 2015. https://www.theses.fr/2015ESAE0026

Modelling of electrostatic discharge inception conditions in presence of multipactor effect in HF spatial components

Q. Peysson [1,*], P. Sarrailh [1], M. Belhaj [1], N. Fil [2], D. Payan[2]
[1] ONERA-DPHY, Toulouse, France
[2] CNES, Toulouse, France

Abstract:
The payload of satellites, especially telecommunications, uses High-Frequency (HF) components and high power. In vacuum, these components can be subject to the multipactor effect which is likely to create a degradation of the component performances and partial or complete deterioration. More generally, the multipactor risk is also present in all the HF devices that operate under vacuum conditions, as for example, in particle accelerators and nuclear fusion reactors.
The multipactor effect occurs at a certain power HF threshold for a given frequency and geometry. It is a resonating electron avalanche phenomenon coming from the electron emission of the HF component and the acceleration of these electrons by the HF wave. With the increase of the number of channels and the transmitted power densities of HF components, it is then necessary to improve our understanding in the physical phenomena involved and the related power threshold.
Today the multipactor effect is well described for metallic waveguide and simple geometries. Its study remains difficult with HF components using dielectric materials that are usually used to reduce the RF payload weight . The dynamic of the multipaor phenomenon is affected by the presence of the dielectric able to charge under an electron flux. The charging dynamic occurs in the same time scale as the electron synchronization with the RF field and the multiplication by secondary emission on the surfaces[1]. In this situation, this initial multipactor effect can results in a self-extinction of the phenomena (as presented in Figure 1) or degenerate into a corona discharge or into an electrostatic discharge enhanced by the HF field. The aim of this work is to predict the conditions resulting into these different phenomena.
We present simulations results of the multipactor effect in the presence of dielectric using a new module developed in an open source software, SPIS (Spacecraft Plasma Interaction System)[2].
The effect of the initial electrostatic charge of dielectrics on the multipactor dynamic is presented. We will point different cases that could potentially lead to corona or electrostatic discharge following the multipactor. For example, figure 1 presents the temporal evolution of elctron volumic density and dielectric surface potential in a metal-dielectric wave guide. A self-extinction of multipactor is occurring . This self-extinction occurs only in presence of dielectric. It is caused by the fact that the electron avalanche is inhibited by the increase of the electrostatic charge of the dielectric. In other situations, a space charge saturation is observed. Even in the case of a multipactor extinction, we observe a residual surface potential that remains. It is probable that this residual charge can produce an electrostatic discharge.

Keywords: Particle in Cell, Multipactor, dielectric, ESD

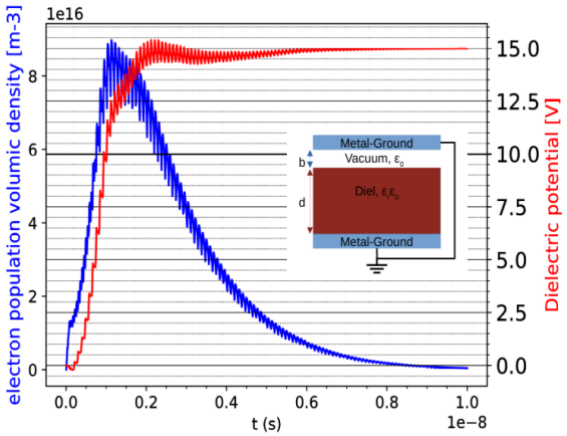


Figure 1: Impact of dielectric charging on multipactor dynamic. Electron cloud density (in blue) is first raising with dielectric surface potential (in red) before the electrostatic field becomes important enough to inhibate the multipactor.

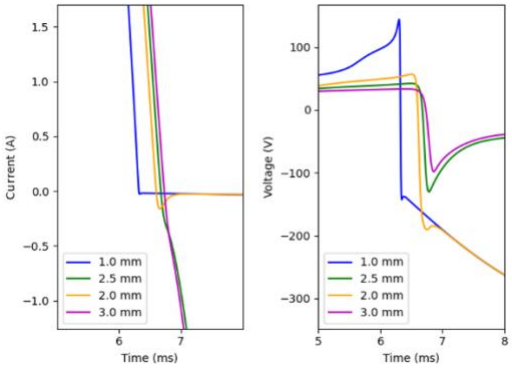
References:

1. E. Sorolla, M. Belhaj, J. Sombrin et J. Puech, New multipactor dynamics in presence of dielectrics, Physics of Plasmas, 24 (10), p. 103508 (septembre 2017), Publisher : American Institute of Physics.
2. “SPINE network web page.” https://www.spis.org/. Accessed: 2022-07-13.

Thermal & Dielectric Breakdown Criterium for Low Voltage Switching Devices

T. Merciris [1,2], M. Masquere [1], Y. Cressault [1], P. Petit [2]
[1] LAPLACE, Université de Toulouse, CNRS, INPT, UPS , Toulouse, France
[2] Electropôle, Schneider Electric, Eybens, France

Abstract:
The goal of an AC switching device is to cut an. electric arc (created during the opening phase of the contacts) at the current zero phase. Criticals parameters which influence the performance of a switching device are well known : The plasma temperature rate of cooling down [1], the electrical characteristic of the arc (current – voltage) and the rise rate of the Transient Recovery Voltage (TRV) [2].
In order to simulate the thermal extinction of the arc and to obtain qualitative data on the processes responsible of this phenomenon, a 1D MHD fluid model in the air was developed and coupled to an external electric circuit. Figure 1 represents the influence of the plasma radius on the extinction states (case of a wall-stabilized arc with temperature boundary condition of 300K).
After thermal extinction, the dielectric strength of the hot air was estimated using the Bolsig+ software [3] and the critical electric fields method [4] according a temperature profile obtained beforehand from MHD simulation. The influence of copper and silver vapors was investigated on the thermal and dielectric part of the simulation with various current intensities (from 100A to 1kA).
Finally, simulated dielectric strengths and experimental values were compared in the case of two separating silver contacts [5]. The preliminary results indicate the dielectric strength after hundreds of microseconds is the same order of magnitude than experimentally found.



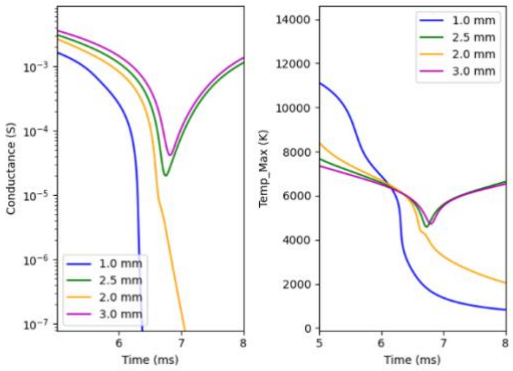


Figure 1: Evolution of different characteristics (Current – Voltage – Conductance – Maximum Température) vs time, close to the current zero phase, for a 300A-AC arc in air, obtained from a 1D radial MHD simulation with different plamsa radii

Keywords: MHD Simulation, dielectric recovery, Bolsig+, silver vapors, copper vapors, breakers, electric arcs

References:

1. Teulet, P., Gonzalez, J. J., Mercado-Cabrera, A., Cressault, Y., & Gleizes, A. (2009). One-dimensional hydro-kinetic modelling of the decaying arc in air—PA66—Copper mixtures : II. Study of the interruption ability. *Appl. Phys.*, 11.
2. Slepian, J. (1928). Extinction of an A-C. Arc. *Transactions of the American Institute of Electrical Engineers*, 47(4), 1398-1407.
3. Hagelaar, G. J. M., & Pitchford, L. C. (2005). Solving the Boltzmann equation to obtain electron transport coefficients and rate coefficients for fluid models. *Plasma Sources Science and Technology*, 14(4), 722-733.
4. Tanaka, Y. (2005). Influence of copper vapor contamination on dielectric properties of hot air at 300-3500 K in atmospheric pressure. *IEEE Transactions on Dielectrics and Electrical Insulation*, 12(3), 504-512.
5. Bentounes, H. A. (1984). Influence de la nature des électrodes sur la vitesse de rétablissement de la rigidité diélectrique d'un millieu post-arc. *Université de Paris-Sud*.

Internal

SICT 2023 / Tribology 2023 Joint Session I.C: Surface Engineering, Coatings and Tribology

Importance of contact temperatures for tribology of polymer contacts

M. Kalin
Laboratory for Tribology and Interface Nanotechnology, University of Ljubljana, Ljubljana, Slovenia

Abstract:
The use of polymer materials has grown rapidly in many engineering applications e.g. gears and bearings because they are light in weight, have good corrosion resistance, excellent tribological properties and can often operate without lubrication. In particular, small dimensions polymer gears are often used in automotive applications for various actuators due to their low weight. However, when compared to metals, polymers are much more sensitive to temperature changes due to poorer thermal resistance and also their thermal isolating properties. This is the reason why tribological contacts involving polymers experience higher contact temperatures due to the frictional heat, which affects their tribological behaviour by causing their softening or even melting [1,2].
We show inthis work examples of thermal effects on tribological behaviour of steel/polymer contacts, which are often used in applications just because of the heat-sink property of steel counterbody. An empirical method with several parameters weas developed to anticipate the tribological behaviour and risk of thermal degradation of polymer in such contacts.
Moreover, a ready-to-use contact temperature model was developed that very well simulate the contact temperatures in steel/polymer contacts, focused primarily on the contacts typical for pin-on-disc tests that are often studied in polymer materials research. The model facilitates understanding the tribological behaviour ofpolymer/steel contacts, as well as enables prediction of contact temperatures in such contacts.

Keywords: polymer, steel, contact temperature

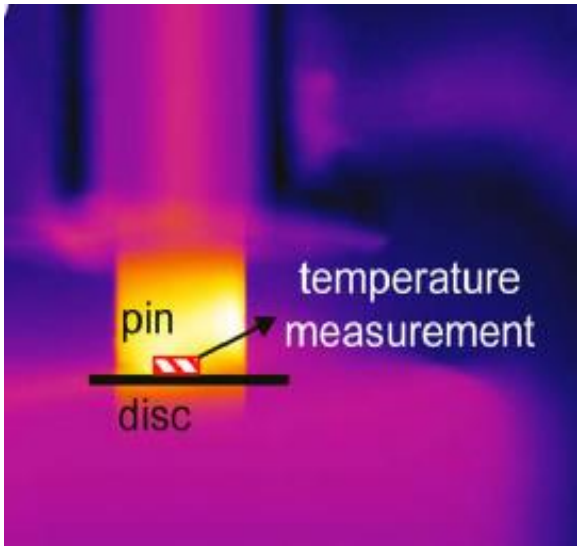


Figure 1: High thermal load in polymer contacts affects the behaviour dramatically and may cause degradation of materials.

References:

1. Matkovič, S, Kalin, M. Effects of slide-to-roll ratio and temperature on the tribological behaviour in polymer-steel contacts and a comparison with the performance of real-scale gears. *Wear*, 2021, 477, 1-13.
2. Siddiqui, S. N., Pogačnik, A., Kalin, M. Influence of load, sliding speed and heat-sink volume on the tribological behaviour of polyoxymethylene (POM) sliding against steel. *Tribology international*, 2023, 178, 1-12.

Metallurgical features and functional properties of NiW coatings deposited onto low alloyed steel

Dewis Figuet[1], Alain Billard[2], Catherine Savall[1], Juan Creus[1] and Jean-Luc Grosseau-Poussard[1]
[1] LaSIE, UMR 7356 CNRS, Université de La Rochelle, LA ROCHELLE, FRANCE
[2] Université de Technologie de Belfort-Montbéliard, MONTBÉLIARD, France

Abstract:
Nanocrystalline nickel-tungsten coatings are being investigated as an eventual alternative to hard chromium coatings. However, their functional properties are still onto discussion. The aim of the present approach is to better understand the influence of the microstructural states on both mechanical characteristics and wear properties of such materials and to compare two deposition methods. Nickel-tungsten coatings are elaborated by direct currents electrodeposition (ED) through an experimental procedure described in [1]. Magnetron sputtering technique (PVD) is also used to deposit nickel-tungsten coatings with a wider range of tungsten composition [2]. Ni based coatings are characterized by several techniques in order to access to their metallurgical state (composition and contamination, grains size, texture, morphology, rugosity, ...). It is only afterwards that mechanical experiments (hardness, adhesion, friction and wear) are performed to correlate the metallurgical features to the durability of the materials.
The nature of the chemical contaminations, and the solute content are the main effects that drive the grain size of the coatings (both for ED and PVD). In consequence, the hardness increases with the tungsten content up to 12 at. %, which corresponds to the solubility limit in nickel. However, hardness is higher for the PVD coatings, due to a contamination by argon during the sputtering process. The hardness evolution holds the Hall and Petch relation up to a grain size around 20 nm. Below, hardness tends to stabilize.
Tribology and micro-scratch tests were able to demonstrate a correlation between friction, wear and metallurgical parameters. Ni based coatings show several domains of friction and different types of wear, depending on the tungsten concentration. High tungsten content generate few debris and so the lowest wear volumes. Some oxidized products are also formed on the surface due to the heating of two bodies in friction. The metallurgical evolution is investigated thanks to analytical tools (Raman spectroscopy, EDS, SEM, ...). All these data implicate several friction and wear mechanisms and so, allow to link them to metallurgical features, e.g. some plastic deformation is observed under the damaged surface which is able to locally modify the microstructure in relation with the different friction domains.

Finally, NiW 15 at.% coating appears as a good candidate for being an alternative to hard chromium.

Keywords: adhesion and abrasion resistance; electrodeposition; hardness and modulus; microstructure; nanocrystalline alloys; Ni–W; sputtering.

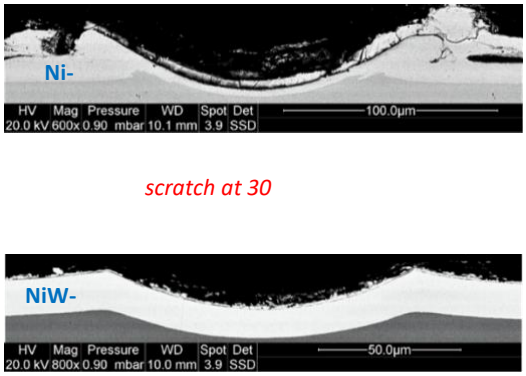


Figure 1: Figure illustrating the influence of tungsten addition on the mechanical durability of the coatings. SEM cross section views of the scratchs after progressive loading. The SEM images correspond to a final load at 30N, for 2 electrodeposited coatings (ED) : a) Ni ; b) NiW

References:

1. Figuet D., Billard A., Savall C., Creus J., Cohendoz S., Grosseau-Poussard J.L., (2022), A comparison between the microstructure and the functional properties of NiW coatings produced by magneton sputtering and electrodeposition, *Materials Chemistry and Physics*, 276, 125332
2. Lagarde M., Billard A., Creus J., Feaugas X., Grosseau-Poussard J.L.,Touzain S., Savall C. (2018), Electrochemical behaviour of Ni-W alloys obtaned by magnetron sputtering, *Surface and Coatings Technology*, 352, 581-590

Experimental investigations on wear performance of PVD hard coatings using Micro scratch testing method

Maryam Alizadeh Zolbin[1]*, Ramin Aghababaei[1]

[1.]Department of Mechanical and production engineering, Aarhus University, Aarhus, Denmark
*Corresponding author: maz@mpe.au.dk

Abstract
PVD hard coatings are using increasingly on components and tools for improving the performance in different severe situation of wear and abrasion. An experimental method based on micro scratch testing and visual observation is used to evaluate the wear performance of two hard coatings of CrN and TiAlN obtained from PVD magnetron sputtering process deposited on stainless steel 304 substrates. This experimental investigation is devoted to the analysis of the influence of coating's thickness on several micro mechanical parameters including fracture toughness, scratch hardness, plastic deformation resistance and wear coefficient in which the samples are investigated over several ranges of coating thicknesses. The samples were characterized in terms of their thickness, chemical composition and fracture patterns after scratching by scanning electron microscopy. Fracture patterns and critical failure points, which arise during scratch testing have also been classified and discussed in order to, better understanding of wear performance of coatings. The results show that the coating's thickness has a great impact on the micro mechanical properties determination of the coatings while the coating thickness requirement for the test specimen is to ensure that all measurements are done before buckling happens. Based on the experimental results of coatings, it is predicted that TiAlN hard coating with 3 µm thickness to be the best promising candidate for better wear performance under the conditions of intensive wear and abrasion problems.

Keywords: Wear performance, Scratch testing, Micro mechanical properties, hard coatings, PVD magnetron sputtering.

Hard anodizing of diecast AlSi10MnMg alloys

G. Scampone[1,*], A. Russo[2], R. Muzzani[2], A. Carminati[3], G. Timelli[1]

[1] Department of Management and Engineering, University of Padova, Vicenza, Italy
[2] Alfa Ossidazione – Gaser group, Borgosatollo, Italy
[3] Gaser Ossido Duro– Gaser group, Rozzano, Italy

Abstract:
The current requirement to produce lightweight and electrically insulated castings is leading to the request of diecast and anodized Al alloy components. Due to the high content of alloying elements, the diecasting alloys are difficult to anodize, and further research is needed to deeply understand their behavior during this treatment. The present work is aimed to study the hard anodizing response of an industrial diecast component produced by AlSi10MnMg alloy (Figure 1). The castings were anodized at -4.5 or +5°C in a sulfuric acid electrolyte. The morphology and the thickness of the anodic layer were characterized using metallographic and image analysis techniques. Abrasion and scratch tests were carried out to investigate the influence of anodizing parameters on the surface mechanical properties. The wear track and the wear mechanisms were studied by means of scanning electron microscopy. The influence of the initial substrate microstructure on the growth of the anodic layer was discussed in detail. It was shown that thicker anodic layer increases the wear resistance, while the scratch resistance is mainly affected by the surface roughness.

Keywords: anodizing; Al alloy; high-pressure die casting; wear; microstructure

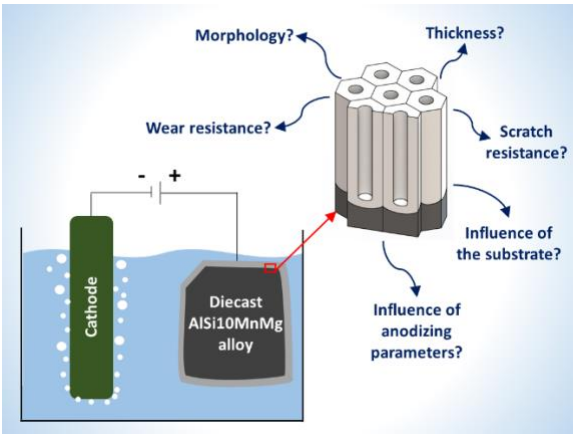


Figure 1: The illustration represents the questions that guided the development of the present work. Specifically, these questions concern the morphological and mechanical characterization of the anodic layer formed on a diecast AlSi10MnMg alloy after hard anodizing.

References:

1. Runge, J. M. (2018) The Metallurgy of Anodizing Aluminum, Springer, Cham.
2. Henley, V. F. (1982) Anodic Oxidation of Aluminium and Its Alloys, Pergamin Press.
3. Scampone, G., Timelli, G. (2022) Anodizing Al–Si Foundry Alloys: A Critical Review, *Adv. Eng. Mater*., 24, 2101480.

Tribological Characteristics of Hybrid Thermally Sprayed Coatings using Graphene Family Nanomaterials

D. Skaltsas [1], G. N. Rossopoulos [1], D. Giasafaki [2], P. Ioannou [2], D. Andreouli [2], C. I. Papadopoulos [1], Ch. I. Sarafoglou [1], I. Georgiopoulos [2]

[1.] School of Naval Architecture and Marine Engineering, National Technical University of Athens, Zografos, Greece

[2.] *MIRTEC S.A., Thiva Branch, 72nd km of Athens-Lamia National Road, 34100, Chalkida, Greece.*

*Corresponding author: dskaltsas@mail.ntua.gr

Abstract:

The progressive degradation, due to wear and corrosion, of engineering components eventually leads to loss of their operational efficiency and reduction of their lifetime [1]. Sub-optimal performance of critical rotating and/or contact components such as bearings, seals, shafts, pistons, and barrels influence the reliability of major industrial parts. Most frequently failure of such components is associated with friction, which becomes more intense when sufficient lubrication is not properly maintained.

Numerous methods have been proposed for reducing friction and wear of mechanical components, such as surface modification, lubrication improvements and mechanical design. Currently, lubricating oil additives, such as carbon nanotubes or lubricant microcapsules, have gained considerable research interest [2]. The study of self-lubricant coatings is a rapidly developing research field that is expected to address major issues arising from operation under high loads and thermal stresses of machine parts. It is of utmost importance that various critical tribological pairs such as crankshaft bearings, piston rings, etc. maintain their integrity, thus contributing to the engines efficient and reliable operation for long periods of time. Therefore, a choice of high-strength metals is required, with special treatments and/or coatings in combination with sufficient lubrication.

The current study investigates the tribological characteristics, namely wear rate and friction coefficient, of a number of different Co-based coatings, which have solid (carbon nanotubes) or liquid (microcapsules) lubricant additives. The proposed coatings are proven to have better tribological properties than both specimens with plain coating (no additives) and plain steel. The feedstock materials chemical composition along with the thermal spray parameters during coatings deposition are correlated with their respective friction coefficient and wear rate. Dynamic measurements are collected, utilizing the BRUKER UMT-3SYS Tribometer, and more particularly in reciprocating motion module. In the experimental test rig, a prototype setup was designed and 3D-printed on an iSLA300 to support the moving components enabling simulations similar to the piston motion. The developed coatings hybrid behavior is studied. The metal (e.g Mo, Co-based) alloys anti-wear performance along with the promoted lubrication conditions during operation is revealed. All three categories of coatings (plain coating, coating with carbon nanotubes, and coating with lubricant microcapsule) are shown to have a significant decrease of friction and corresponding wear rate, with respect to the plain specimen (steel).

Keywords: Self Lubrication, Thermal Spraying, Carbon Nanotubes, Lubricant Microcapsules, Hybrid Coatings, UMT Tribometer

References:

1. Pantelis D. I., et al. (2007), “Tribological Properties of Atmospheric Plasma Sprayed Cr2O3 Coatings: Effect of NiAl Bond Coating”, *Surface Engineering*, Vol. 23, No. 3, p 201-208
2. Wong V., et al. (2016), “Overview of Automotive Engine Friction and Reduction Trends – Effects of Surface, Material, and Lubricant-Additive Technologies”, *Friction*, Vol. 4, No. 1, p. 1-28

Tribological Behaviour of TiAlN and AlCrN coatings deposited over martensitic stainless steel

E. L. Dalibon[1*], A. J. Maskavizan[1], S.P. Brühl [1,2]

[1]Surface Engineering Group (GIS), National University of Technology (UTN),
Faculty of Concepción del Uruguay, Argentina.
[2]CONICET (National Council of Scientific and Technology Research), Argentina

Abstract:
Martensitic stainless steels are exposed to different wear mechanisms when used in multiple applications. In order to improve the surface properties, several treatments or coatings can be used.
Nitride coatings have high hardness, wear and erosion resistance. The addition of aluminium to binary nitrides increases their corrosion resistance and improves their tribological performance [1,2]. TiAlN and AlCrN coatings are widely used in applications that require high stress resistance, for example, cutting and forming tools and moulds for metal and plastic processing, automotive parts and precision components. Furthermore, these coatings can be used to improve the tribological properties of machine parts in general.
In this work, the tribological behaviour of PVD TiAlN and AlCrN coatings deposited on AISI martensitic stainless steel is studied. The coatings were deposited by cathodic arc PVD in Oerlikon Balzers Argentina.
The microstructure of the coatings was analized by OM, SEM and DRX. The nanohardness was measured by nanoindentation. The pin on disk tests, according to G99 standard, were performed using 5 N and 10 N, 500 m and alumina balls as counterparts. The abrasive wear tests were carried out according to ASTM G65. The adhesion was evaluated using Rockwell C Indentation and Scratch Test.
The thickness reached approximately 3 µm in both coatings. The wear volume loss was twenty five times lower for the AlCrN than the TiAlN in pin on disk tests, under low and high loads, and the steady friction coefficient value was also lower. This indicated that the AlCrN coating has better performance under sliding conditions. However, the mass loss was similar for both coatings under abrasive wear. In the scratch tests, the TiAlN coating failed under less load than the AlCrN, which would indicate lower critical load. Nevertheless, deformation was greater for AlCrN than TiAlN coating as can be observed in Figure 1 and it was measured by a mechanical perfilometer. This could suggest that the fracture toughness was higher for the latter under the same load.

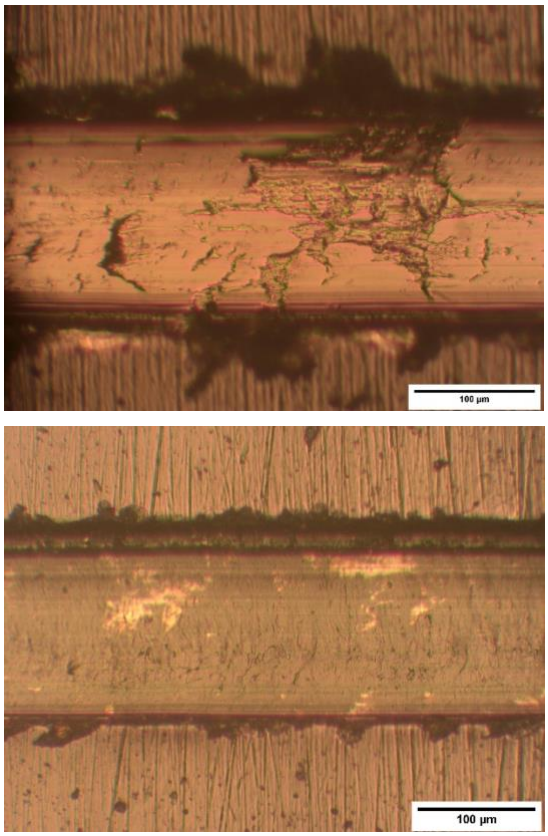


Figure 1: Optical micrographs of scratch tests tracks under 85 N for both coatings.

Keywords: TiAlN, CrAlN coatings, tribological behaviour.

References:

1. Warcholinski, B., Gilewicz, A., Myslinski, P., Dobruchowska, E. and Murzynski, D. (2020), Structure and Properties of AlCrN Coatings Deposited Using Cathodic, *Coatings*, 10, 793-815.
2. Falsafein, M., Ashrafizadeh, F., Kheirandish, A. (2018), Influence of thickness on adhesion of nanostructured multilayer CrN/CrAlN coatings to stainless steel substrate, *Surf. Interfaces* 13, 178-185.

Atomic-scale understanding of the amorphous/crystalline interface evolution in DLC/WC coatings via different quenching rates

Li Ma [1], Narguess Nemati [1], Ramin Aghababaei [1,*]
[1] Department of Mechanical and Production Engineering, Aarhus University, Aarhus, Denmark

Abstract:
Mechanical properties of amorphous/crystalline nanoscale multilayer coatings are to a large extent governed by the number of interfaces and their characteristics. The current understanding of the degradation of multilayered nanofilms, the mechanical properties of coating decrease again when the thickness is reduced below a certain critical value [1], is that component intermixing already occurs during the thin film and annealing process [2, 3]. Here, the structure and mechanical properties of amorphous-crystalline multilayered nanofilms are studied in an atomistic model of the diamond–like carbon (DLC) amorphous layers with the hexagonal close-packed Tungensten-Caribide (WC) crystalline layers. We report that the degree of intermixing of the amorphous-crystalline interfaces (ACIs) decreases with the increase of the quenching time after DLC and WC layers merge together. The centrosymmetry parameter (CSP) is used to characterize the degree of intermixing at the interfaces. Additionally, nanoindentation, commonly used to determine the properties of hard coatings, is conducted to study the plastic deformation behaviour of DLC/WC multilayer coatings with different intermixing degrees. The results show that the hardness and elastic modulus decrease with the increase of the degree of the intermixing. The coordination analysis (CN) and dislocation analysis (DXA) reveal the shear strain induced by indenter spreads through the interface, resulting in the extension of the intermixing regime and further degradation of mechanical properties.

Keywords: MD simulations, amorphous-crystalline interfaces, intermixing, nanoindentation, plastic deformation, hardness and elastic modulus.

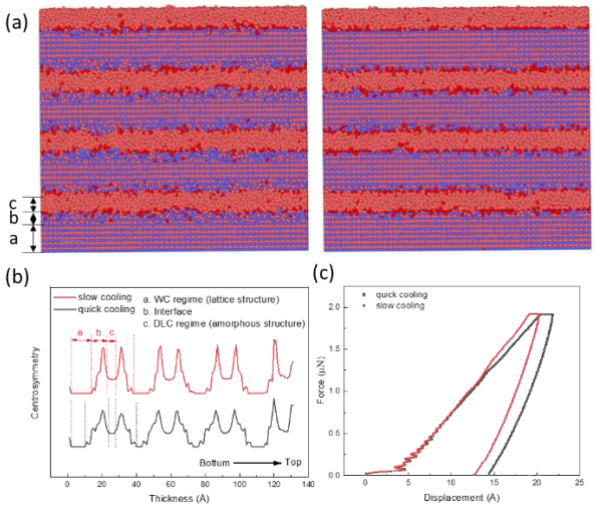


Figure 1: Figures illustrating that the degree of the intermixing at the interface, governed by the quenching rate, determine the mechanical properties of DLC/WC multilayer coatings.

References:

1. Kim, G. S., Lee, S. Y., & Hahn, J. H. (2003). Synthesis of CrN/AlN superlattice coatings using closed-field unbalanced magnetron sputtering process. Surface and Coatings Technology, 171(1-3), 91-95.
2. Barshilia, H. C., Jain, A., & Rajam, K. S. (2003). Structure, hardness and thermal stability of nanolayered TiN/CrN multilayer coatings. Vacuum, 72(3), 241-248.
3. Hultman, L., Engström, C., & Odén, M. (2000). Mechanical and thermal stability of TiN/NbN superlattice thin films. Surface and Coatings Technology, 133, 227-233.

Fatigue behaviour of diamond-like carbon coatings with various adhesion layers

J. Vetter[1,3], M. Günther[2], P. Hofmann[2], S. Grosse[2], S. Schmauder[3]
[1] Robert Bosch GmbH, [2] Robert Bosch Manufacturing Solutions GmbH,
[3]Institute for Materials Testing, Materials Science and Strength of Materials, University of Stuttgart

Abstract:
Diamond-like carbon (DLC) coatings are used to enhance wear performance and increase the lifetime of components in a tribological system. In the application the coatings are subjected to single acting impacts as well as cyclic loads. In addition, the coatings are exposed to high temperatures due to the operating environment. Adhesion systems based on carbides or nitrides are used to prevent load-induced delamination between the DLC layer and the steel substrate. Depending on the selected intermediate layers, mechanical properties of the functional layer and the occurring loads the performance of the system may vary. Therefore, precise adhesion and fatigue measurements are mandatory.
In the present study, DLC coatings with different adhesion systems based on titanium and chromium deposited by PECVD and PVD techniques are investigated. The thickness and hardness of the DLC functional layer were varied to analyze the influence on the damage behavior of the different coating systems. A cyclic nanoscale test was developed to predict application-relevant fatigue properties. Lower static loads lead to a more fatigue-like testing of the functional DLC coatings themselves, where fatigue limits can be extracted from static displacement curves in dependence of the number of cycles (Figure 1). Higher loads provoke delamination processes of the coating system in the testing area which is suitable for cyclic adhesion measurements. The mechanical properties of the sublayers were characterized by nanoindentation. The thermal stability of the systems was analyzed after thermal treatment up to 350 °C. All data were used as input for FEM simulation of a static impact with a spherical diamond indenter. This allows the selection of appropriate parameters and the interpretation of the results from the fatigue test.
The fatigue limit strongly increases with higher coating thickness and the selected intermediate layers. Most recent the fatigue mechanism could be evaluated through SEM analysis.

Keywords: DLC, coatings, adhesion, fatigue, vacuum, plasma, PVD, PECVD, nanoindentation, FEM

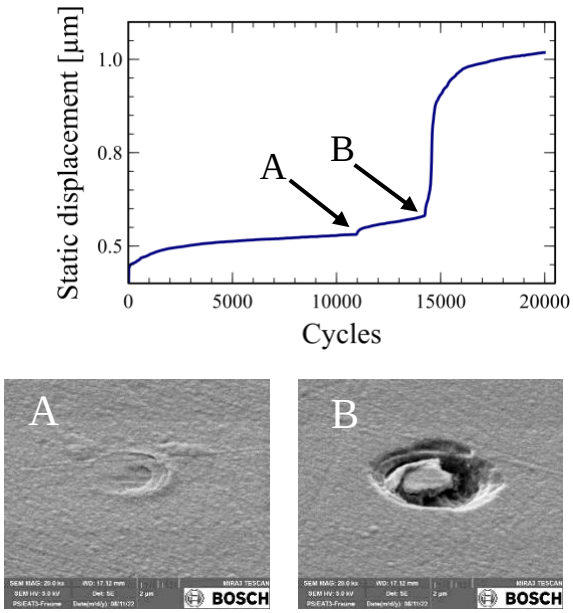


Figure 1: Fatigue test curve of a DLC coating, before reaching the total fatigue limit (B) crack initiation and circular crack propagation leads to sink in (A) of the DLC coating

Study of the application of DLC coating on cold stamping tools

E. Barba [1,2,]
[1] Public University of Navarre, Pamplona, Spain
[2] Nuadi Group, Pamplona, Spain

Abstract:
DLC coatings are widely recognized for their remarkable tribological properties combining high hardness and very low friction coefficinent. However, adhesion is the main problem compared to other coatings of nitrides and carbonitrides. Fortunately, new techniques in magnetron sputtering have been developed that have enhanced this characteristic. Recent studies demonstrate that High Power Impulse Magnetron Sputtering (HIPIMS) and the new Positive Pulse technique significantly improve the adhesion performance of DLC coatings. This study investigated the industrial applicability of DLC coatings on the cold stamping process. To achieve this, laboratory tests were performed on test specimens using scratch tests, nanoindentation, GD-OES, and wear resistance. The coatings were applied to various substrates, all of which were tool steels such as 1.2379, HWS premium, Vanadis 4, Caldie, K340, and 1.2358. Subsequently, the coatings were applied to cold stamping tools to validate the laboratory results. The results obtained in the field were highly encouraging, and the coatings demonstrated excellent performance. Consequently, the use of DLC coatings on cold stamping tools has been established as a viable option.folding, nanoporous sol-gel glasses, silica-based biomaterials, circular dichroism spectroscopy, surface hydration, crowding effects, micropatterning, biomedical applications.

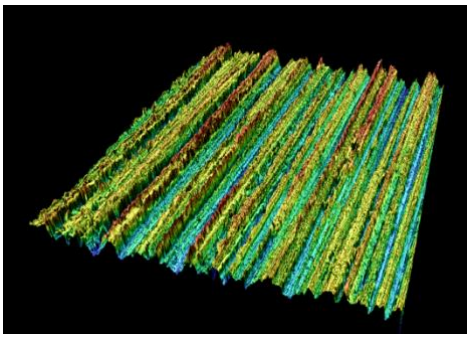


Figure 1: Sensomap image of the coated tool before.

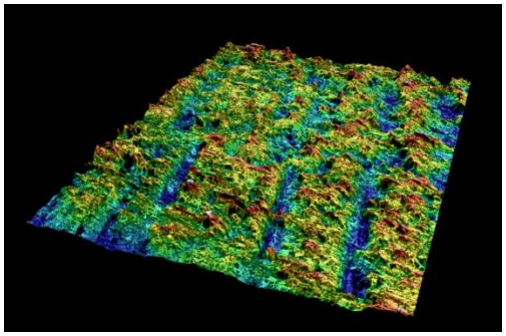


Figure 2: Sensomap image of the coated tool after 65 cycles.

Wear reduction by application of silver coatings at 1850 m/s high speed electric sliding contacts

C. Biethan [1*], F. Alouahabi [1], F. Moitrier [1], M. Schneider [1]
[1] French-German Research Institute of Saint-Louis, Saint-Louis, France

Abstract:
This study deals with the influence of silver coatings on wear phenomena occurring under extreme conditions. The electromagnetic tribometer used allows investigating sliding electric metal-metal contacts at very high speeds. For this study, sliding speeds up to 1850 m/s have been realized. The tribo partners consist of highly conductive materials. A non-reusable Al6061-T6 slider is accelerated between a pair of 3.18 m long CuCr rails by electromagnetic forces from zero speed to 1850 m/s. The corresponding electric current profile is characterized by a peak amplitude of 460 kA. Silver coatings of different layer thicknesses were applied on the slider by electrochemical deposition: 60 µm, 150 µm and 250 µm. Silver has been chosen as a wear reduction coating for the following two reasons: First, the tribo-pair silver/copper is superior to the material combination of aluminum/copper according to the model of mutual soluability [1]. Second, from the electrical point of view, a higly conductive coating is requested. Ag provides superior electrical conductivity compared to CuCr.
Wear phenomena on the rails were analyzed for the three given layer thicknesses and compared to the wear phenomena obtained after accelerating a slider without coating. Focus was set on three regions of interest characterized by the following parameters:

1. Starting region, v=0-200 m/s, I=0-370 kA
2. Middle region, v=700-900 m/s, I≈450 kA
3. End position, v=1800 m/s, I=200-175 kA

These parameters were chosen to cover a wide range of different sliding velocities and current conditions. Strongly different wear phenomena have been observed in the different regions in previous experiments using non-coated sliders.
In the starting region, severe wear is generally observed [2]. The material loss leads to rail curvature despite a debris layer formation of about 100 µm thickness. The mechanism is electrically dominated and characterized by a high dI/dt during capacitor discharge. Using a silver coating on the slider, wear reduction is very impressive for all silver layer thicknesses investigated. The remaining debris layer thickness is with about 0.1 µm reduced by a factor of 1000 (Fig.1).
In the middle region the slider reaches a medium velocity of 700-900 m/s. The current profile is quasi-constant, the amplitude is just below the peak. In this case, the rails are generally covered by a homogenious aluminum coverage with a thickness of about 20 µm after the sliding experiment. Using silver coatings of 150 and 250 µm, a high number of small gouging craters with a length of approximately 3 mm and a width of approximately 2 mm were observed. This can be explained by a strongly reduced gouging threshold of the material combination Ag-Cu compared to Al-Cu. For the 60 µm silver coating, no gouges were observed: the silver layer had been completely removed before reaching the region.
In the end region, the slider reaches its maximum velocity while the current is moderately descending from 200 kA to 175 kA. In this region, the rail surface is typically characterized by oxidation and isolated gouges of 3.5-4 mm diameter and a depth of 0.2 mm. For the 250 µm silver layer oxidation is significantly reduced. Thinner layers have no observable influence on the wear phenomena: they are completely ablated from the slider before reaching this region.
The use of a silver coating on the slider is very beneficial in the starting region and in case of oxidational wear, but leads to enhanced wear by gouging at v=700-900 m/s.

Keywords: sliding wear, electric contact, high speed, coating, wear protection, gouging.

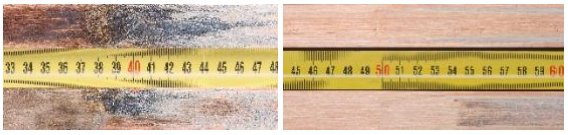


Figure 1: Wear phenomena and debris layer suppression observed by visual inspection in starting regions: using a slider without silver coating (left) and with a 250 µm silver coating (right).

References:

1. E. Rabinowicz, Friction and wear of materials, 2nd ed., New York, USA: John Wiley & Sons Inc., 1995, pp. 34-39.
2. C. Biethan et al., Influence of ambient gas conditions on wear of 1500 m/s high speed electric sliding contacts, Nordtrib, June 14th-17th 2022, Ålesund/Norway

Investigate the microstructure and wear resistance of Fe_3Al coating on GCI prepared by direct energy deposition

H. Rajaei, S. Amirabdollahian, C. Menapace, G. Straffelini, S. Gialanella
Department of industrial engineering, University of Trento, Italy

Abstract:
Environmental concerns have recently urged extensive research and development of coating materials for brake discs to reduce toxic element emissions into the environment. First protective coatings have demonstrated their potential for reducing particle emissions. However, there is a desire to utilize better environmentally friendly materials. In this study, a Fe_3Al coating material was deposited on a gray cast iron brake disc with a direct energy deposition technique (Figure 1). A suitable microstructure can be formed using laser technology while also preventing cracks and boundary problems. The dry sliding wear resistance of the coating was tested using the pin-on-disc test to simulate the braking condition for the assessment of wear mechanisms that were involved during sliding, based on worn surfaces. In the pin-on-disc test, a commercial Cu-free friction material was used as a counterpart pin. The results revealed that the coating has a good metallurgical bonding to the GCI substrate and the main phase construction on the top coating was the Fe_3Al phase with a comparable tribological properties to cast iron.

Keywords: Direct energy deposition (DED), Wear, Pin on disc, Fe_3Al, Gray cast iron

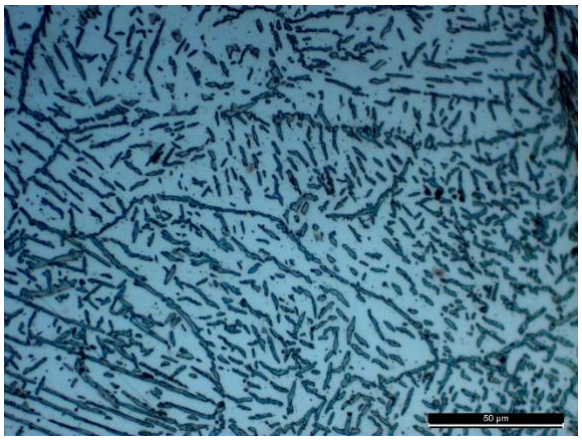


Figure 1: microstructure of the top surface of the Fe_3Al coating on gray cast iron

References:

1. Rolink, G., Vogt, S., Senčekova, L., Weisheit, A., Poprawe, R., & Palm, M. (2014). Laser metal deposition and selective laser melting of Fe-28 at.% Al. Journal of Materials Research, 29(17), 2036–2043.
2. Bax, B., Schäfer, M., Pauly, C., & Mücklich, F. (2013). Coating and prototyping of single-phase iron alu-minide by laser cladding. Surface and Coatings Technology, 235, 773–777.

A Hybrid Graphene-Reinforced Copper-Matrix/Multilayer Composite Coating for High-Load and Environment-Resistant Solid Lubrication on Steel

Nicky Savjani[1], Su Zhao[2], Lorenzo Fabbri[3], George Paterakis[4], Erik X. Johansson[2], Gabriele Bartolini[3], Vicente Orts Mercadillo[1], Emanuele Piciollo[3], George Anagnostopoulos[4], Francesco Bertocchi[3], Anna M. Andersson[2], Mark A. Bissett[1] and Ian A. Kinloch[1]

[1] The National Graphene Institute, the University of Manchester, Manchester M19 3YN, UK

[2] ABB AB, Corporate Research, Forskargränd 7, 721 78, Västerås, Sweden.

[3] Nanesa S.r.l., Via Calcutta 8, 00144 Rome, Italy.

[4] Institute of Chemical Engineering Sciences, Foundation for Research and Technology – Hellas (FORTH/ICE-HT), Patras 265 04, Greece.

Abstract:

Copper plating of solid surfaces is widely used in industry as it imbues the coated parts with properties that make it suitable for use in broader-ranging application spaces.[1,2] However, its high ductility and low shear strengths, combined with the potential for adhesive material transfer between contacts limit its application to low-load mechanical contacts (< 0.1 GPa contact pressures).[3,4] Reinforcing copper coatings on surfaces by constructing copper-metal multilayer structures[5] or by dispersing graphene nanoplatelets (GNP) within the copper-matrix[6] have shown promise in improving their physical and mechanical characteristics, yet still, fail to achieve suitable lubrication performances at contact pressures > 1 GPa (*i.e.* at engineering loads).

In this study, we combine two copper-compositing approaches to produce a hybrid (GNP-Cu)/Ni multilayer coating system (**ML1**) on DC01 steels, to understand their performances in macroscale friction (Figure 1). Pin-on-disc tribological testing of **ML1** displayed a synergy between the graphene-copper matrix and nickel multilayering, promoting a low-friction and low-wear sliding surface. At contact pressures as high as 1.2 GPa, The hybrid **ML1** system operates at a stable coefficient of friction (μ) of ~ 0.12 for > 10,000 revs; the value of μ was 73% and 84% lower than composites coatings that omit Ni (**ML2**) and GNP (**ML3**), combined with > 10^2 longer lubricating lifetimes. Furthermore, accelerated ageing studies on **ML1** (by electrochemical corrosion in $NaCl_{(aq)}$ and high-RH exposure for 42 days) showed minimal environmental effects on the coatings' overall lubricity, maintaining a long-lasting low-friction phase (μ > 0.2) at 1.2 GPa. A thorough assessment of the **ML1** coatings' tribochemical, mechanical and structural evolution over the duration of the sliding tests identified intricate interactions between its components (Ni, Cu and GNP) that establish a lubrication mechanism that combines both tribochemical and mechanical contributions of the hybrid structure to achieve its excellent solid-lubrication properties.

Keywords: tribology, wear, tribo-chemistry, tribo-surfaces, solid lubrication, test methodologies, graphene composites, metal composites.

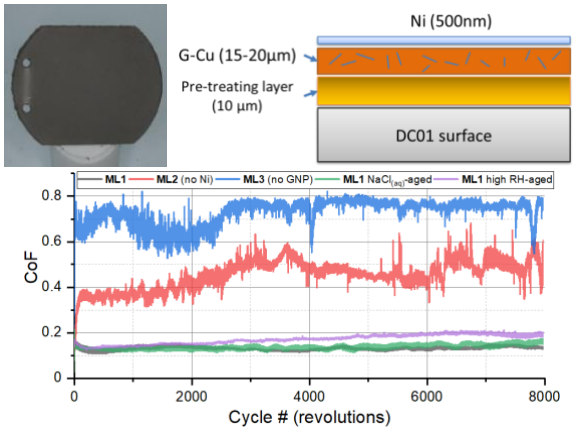


Figure 1: (a) The deposited coating and (b) the schematic of the **ML1** hybrid coating. c) Pin-on-disc tribological assessment of the multilayer system, showing that the hybrid multilayer/compositing approach promotes long-lasting, high-load lubrication when freshly produced and after accelerated ageing.

References:

1. Jadhav, S. D. *et al.* ***Mater. Des.***, *198*, **2021**, 109369.
2. Chyderiotis, S. *et al.*, ***Clin. Microbiol. Infec.***, *24* (11), **2018**, 1130.
3. Yiran, W. *et al.*, ***Emerg. Mater. Res.***, *8* (4), **2019**, 538.
4. Yao, B. *et al.*, ***Wear***, *271* (9), **2011**, 1609.
5. Wang, Y. *et al.*, ***J. Alloys Comp.***, *849*, **2020**, 156222.
6. Priyadarshi, P. *et al.*, ***Mater. Tod.: Proc.***, *62*, **2022**, 7564.

Characterization of mechanical and lubrication properties of Double network ion gels synthesized by a one-pot process

H. Arafune [1], Y. Watarai[1], T. Kamijo[1], S. Honma[1] and T. Sato[2]
[1] National Institute of Technology, Tsuruoka College, Tsuruoka, Japan
[2] National Institute of Technology, Okinawa College, Nago, Japan

Abstract:
Reducing friction is important to develop mechanical systems with high energy efficiency and long lifetime. Since human joints with gel-like structure show low friction for several decades, gel materials are known to be useful for developing low frictional materials. Double network ion gels (DNIG) composed of hard but brittle 1st network, soft 2nd network and ionic liquids possess high mechanical strength and low friction under high temperature or vacuum are one of candidates for robust lubricant gels. For their industrial application, development of one pot synthesis process is effective due to its simplicity and low cost, opening up the way to form thin film coating of gel lubricants. However, radical polymerization of 1st and 2nd network at same time results in formation of random polymer to lose characteristics of DNIG. In this study, we examined one pot synthesis of DNIG by combining polycondensation and radical polymerization to develop simple and facile fabrication process for gel lubricant coating[1)]. The DNIG was obtained by one-pot synthesis (DNIG-1) combining polycondensation of tetraethoxysilane and radical polymerization of methyl methacrylate to form silica and poly(methyl methacrylate) as a 1st and 2nd network, respectively. Such obtained DNIG-1 was characterized and compared with DNIG obtained by a conventional two-step process (DNIG-2). As friction at the glass/DNIG-1, SUS304/DNIG-1 and PTFE/DNIG-1 interface showed different tribological properties (Figure 1), change of counterface materials effectively reduced the COF at DNIG-1 which suggests the importance of the appropriate selection of tribopair

Keywords: Double network gels, ionic liquids, one-pot synthesis, low friction

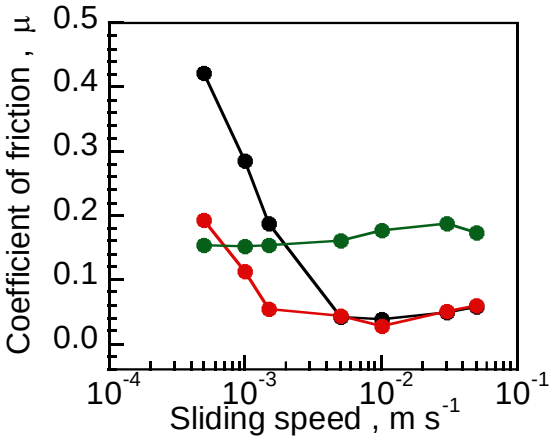


Figure 1: Sliding speed dependency of coefficient of friction measured at glass/DNIG-1(black), SUS304/DNIG-1(red), and PTFE/DNIG-1 (green)

References:

1. H. Arafune, Y. Watarai, T. Kamijo, S. Honma and T. Sato, (2022) Mechanical and Lubrication Properties of Double Network Ion Gels Obtained by a One-Step Process, Materials, 15,2113

Micro-arc oxidation of hydrostatically extruded titanium in phosphate-based electrolytes

Lukasz Maj[1,*], Faiz Muhaffel[2], Anna Jarzebska[1], Anna Trelka[1], Klaudia Trembecka[1], Mariusz Kulczyk[3], Attila Sulyok[4], Huseyin Cimenoglu[2], Magdalena Bieda[1]
[1]Institute of Metallurgy and Materials Science, Polish Academy of Sciences, Krakow, Poland
[2]Department of Metallurgical and Materials Engineering, Istanbul Technical Univ., Istanbul, Turkey
[3]Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw, Poland
[4]Institute for Technical Physics and Materials Science, Centre for Energy Research, Budapest, Hungary

Abstract:
Micro-arc oxidation of titanium-based materials is increasingly gaining in popularity in terms of their surface modification aimed at improving originally limited properties like wear resistance, bioactivity, antibacterial performance, etc. Enormous number of studies confimed that well adhering oxide layer, formed thanks to the electrochemical reactions driven by the ions exchange between the surface and electrolyte, constitutes an effective surface protection. Recent reports suggest that the plastic deformation of the substrate material introduces new challenges into the micro-arc oxidation deposition process [1]. Refined microstructure significantly affects the mechanisms of the oxidation process by creating many more sites for the oxides nucleation as compared with coarse-grained material. Plastic deformation through hydrostatic extrusion turned out to be a promising method of strengthening of commercially pure titanium, allowing for its widespread application, due to the possibility of grain refinement down to the nanometric scale [2]. However, following the formation of the coating with micro-arc oxidation on the surface of hydrostatically extruded titanium and its correlation with functional properties was not investigated so far. In this work, hydrostatically extruded titanium is used as a substrate material for micro-arc oxidation in phosphate-based electrolytes. Additionally, we proposed an innovative approach encompassing the use of a bipolar pulsed power supply (Figure 1). The latter allows for a precise control of the process of introduction of both anions and cations from the electrolyte, extending the possibilities of the deposition process, not achievable in the case of using popular DC or unipolar pulsed power supplies. An extremely important element of this work is to determine the density of high-angle (HAGB) and low-angle (LAGB) grain boundaries through the SEM/EBSD orientation mapping and, in this way, their influence on the properties of the forming oxide surface layer. The XRD, SEM, TEM and XPS studies allowed us to reveal the microstructure, phase and chemical analysis and, thus, the way of embedding of the electrolyte constituents. This study will permit to discuss a mechanism of oxide coating formation and predict applications in various sectors of industry.

Keywords: titanium, hydrostatic extrusion, micro-arc oxidation, sodium phosphate, microstructure, orientation imaging, wear resistance, tribological applications, biomedical applications.

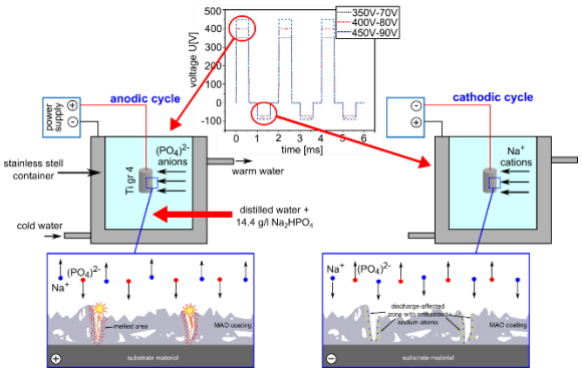


Figure 1: Figure illustrating the process of formation of the coating with micro-arc oxidation method by applying sodium phosphate-based electrolyte and bipolar pulsed power supply.

Acknowledgments
This research was funded by the National Science Center of Poland, grant number UMO-2020/39/D/ST8/01783

References:

1. Fatimah, S., Yang, H.W., Kamil, M.P., Ko, Y.G. (2019), Control of surface plasma discharge considering the crystalline size of Al substrate, *Appl. Surf. Sci.*, 477, 60-70.
2. Skiba, J., Kulczyk, M., Przybysz-Gloc, S., Skorupska, M., Niczyporuk, K. (2022) The impact of severe plastic deformations obtained by hydrostatic extrusion on the machinability of ultrafine-grained Ti grade 2 intended for fasteners, *Sci. Rep.*, 12, 16240.

Emission behavior and brake performance at mild and severe sliding conditions of a conventional cast iron disc and a cermet-coated disc

S. Candeo [1,*], F. Varriale [2], A.P. Nogueira[2], S. Gialanella[1], G. Straffelini[1]
[1]Department of Industrial Engineering, University of Trento, Via Sommarive 9, Povo, Trento, Italy b
[2]Brembo S.p.A., Stezzano, Bergamo, Italy

Abstract:
Several efforts have been made to develop strategies to reduce particulate matter emissions in urban environments and the consequent hazards for the environment and human health. A major source of particulate matter in urban areas is particle emissions due to the wear of brake materials of passenger vehicles [1]. Recently, Euro 7 regulation introduced limits also regarding brake particle emissions [2].
On this basis, the design of brake couples with lower emissions and without hazardous compounds in their formulations has become a topical issue. A direct strategy to reduce brake emissions is the mitigation of the wear of the brake disc by increasing its hardness through the deposition of a hard coating. Among other processes, the hard coating has been deposited via Direct Energy Deposition (DED) [3] or High Velocity Oxygen Fuel (HVOF) [4] processes.
Along with the environmental requirements, brake materials should fulfill their basic function. They should have excellent performance: stable coefficients of friction and low wear over a wide range of braking conditions [5].
In this work, a critical comparison is presented regarding the emission behavior at mild sliding conditions and the brake performance at severe braking conditions of two brake couples: a Cu-free friction material sliding against a conventional cast iron disc and a Cu-less friction material sliding against a cermet-coated disc. The cermet-coating was deposited by HVOF techniques and is described in the previous work [6].
The two brake couples were tested on a reduced-scale dynamometer with two testing procedures. Brake emissions are measured by an Optical Particle Sizer (OPS) and are assessed with the brake cycle developed in [7] to map the frictional, wear and emission behaviors in mild sliding conditions as a function of pressure and velocity. The brake couple having the cermet-coated disc showed lower emissions at every braking condition.
The frictional response of the brake couples is investigated, including the influence of the disc temperature, with the brake cycle developed in [8] to build *pvT-μ Maps* map at severe sliding conditions. The brake performance is discussed in terms of friction sensitivity to pressure, velocity and temperature. The two brake couples show comparable frictional behavior below 300°C. Moreover, *a posteriori* observations by Scanning Electron Microscopy (SEM) were used to explain the wear processes acting on the surfaces at the different braking conditions. For both the brake couples, the *fade effect* was found for *v-T* combinations, above 300 °C and 140 km/h, and was correlated to the primary plateaus being progressively covered at increasing *T* by a thick layer of iron oxide. Finally, a peculiar behavior, *friction instability* can be observed for the cermet-coated disc above 300 °C and was ascribed to the lower degree of compaction of the iron-oxide particles originating from the disc.

Keywords: brake emissions, brake performance, friction materials, brake cycle, high-temperature testing, fade effect, surface characterization, HVOF.

References:

1. T. Grigoratos and G. Martini, “Brake wear particle emissions: a review,” *Environ. Sci. Pollut. Res.*, vol. 22, no. 4, pp. 2491–2504, 2015, doi: 10.1007/s11356-014-3696-8.
2. “REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7) and.”
3. H. Rajaei, C. Menapace, S. Amirabdollahian, M. Perini, G. Straffelini, and S. Gialanella, “Microstructural and Tribological Evaluation of Brake Disc Refurbishing Using Fe-Based Coating via Directed Energy Deposition,” *Metals (Basel).*, vol. 12, no. 3, 2022, doi: 10.3390/met12030465.
4. M. Federici, C. Menapace, A. Moscatelli, S. Gialanella, and G. Straffelini, “Pin-on-disc study of a friction material dry sliding against HVOF coated discs at room temperature and 300 °C,” *Tribol. Int.*, vol. 115, no. March, pp. 89–99, 2017, doi: 10.1016/j.triboint.2017.05.030.
5. R. Dante, *Handbook of friction materials and their applications*. Woodhead publishing, 2015.
6. M. Federici, C. Menapace, A. Mancini, G. Straffelini, and S. Gialanella, “Pin-on-disc

study of dry sliding behavior of Co-free HVOF-coated disc tested against different friction materials," *Friction*, vol. 9, no. 5, pp. 1242–1258, 2021, doi: 10.1007/s40544-020-0463-3.
7. S. Candeo, M. Leonardi, S. Gialanella, and S. Straffelini, "Influence of contact pressure and velocity on the brake behaviour and particulate matter emissions," *Wear*, vol. 514–515, no. November 2022, p. 204579, 2023, doi: 10.1016/j.wear.2022.204579.
8. F. Varriale, S. Candeo, G. Riva, J. Wahlström, and Y. Lyu, "A Brake System Coefficient of Friction Estimation Using 3D Friction Maps," *Lubricants*, vol. 10, no. 7, p. 134, 2022, doi: 10.3390/lubricants10070134.

Tribological performance of doped-DLC coatings in the presence of functionalized copolymer

T. Omiya [1, 2, 3]*, T Vuchkov [1, 3], A. Cavaleiro [1, 3], J.F.J. Coelho [2, 3], F. Ferreira [1, 3]

[1] University of Coimbra, CEMMPRE Centre for Mechanical Engineering Materials and Processes, Department of Mechanical Engineering, Rua Luís Reis Santos, 3030-788 Coimbra, Portugal
[2] University of Coimbra, CEMMPRE, Department of Chemical Engineering, Rua Silvio Lima, 3030-790 Coimbra, Portugal
[3] LED&Mat-IPN, Instituto Pedro Nunes, Laboratório de Ensaios Desgaste e Materiais, Rua Pedro Nunes, 3030-199 Coimbra, Portugal

Abstract:
Various studies have been conducted to reduce friction and improve anti-wear performance under high load and low viscosity conditions in order to improve energy efficiency. Viscosity index improvers based on functionalized copolymers, in which a functional group is introduced into the side chain of the polymer, are currently receiving much attention as additives that exhibit friction reduction effects. These functionalized copolymers are known to reduce the coefficient of friction by maintaining a film thickness between contacting surfaces, primarily through interaction with steel. Dimethyaminoethyl methacrylate (DMAEMA) and hydroxyethyl methacrylate (HEMA) are commonly used as functional group types.
On the other hand, Diamond-Like Carbon (DLC) coatings have also been studied for many years to enhance the performance of metal surfaces in order to improve wear resistance. Although DLC coatings exhibit friction reduction effect and anti-wear performance due to the characteristic surface composed of hydrocarbons, a major challenge is the reduced interaction with conventional lubricants due to the low reactivity of the surface. To solve this problem, the development of doped-DLC coatings has attracted much attention in recent years. Alloying DLC coatings with e.g., tungsten (W), silver (Ag), copper (Cu) and silicon (Si) can improve the interaction of lubricant additives with the surface of the coatings and overcome the low reactivity of DLC coatings.
In this study, the tribological evaluation of a novel lubrication system combining functionalized copolymers and doped-DLC coatings was performed (Figure 1).

Keywords: doped-DLC, functionalized copolymer, viscosity index improver, friction reduction effect, anti-wear performance.

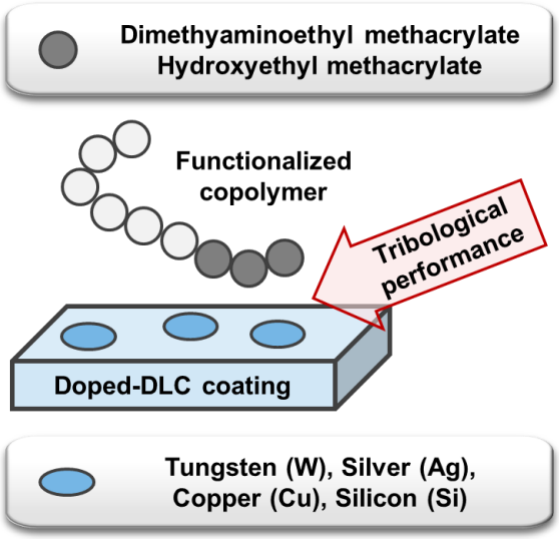


Figure 1: Schematic of a novel lubrication system combining functionalized copolymer and doped-DLC. The functional group of the copolymer and the chemical elements to be alloyed in doped-DLC are examples.

References:

1. Müller, M., Topolovec-Miklozic, K., Dardin, A., Spikes, HA. (2006), The Design of Boundary Film-Forming PMA Viscosity Modifiers, *Tribology Transactions*., 49(2), 225-232.
2. Evaristo, M., Fernandes, F., Cavaleiro, A. (2020), Room and High Temperature Tribological Behaviour of W-DLC Coatings Produced by DCMS and Hybrid DCMS-HiPIMS Configuration, *Coatings*., 10, 319.
3. Manninen, N.K., Ribeiro, F., Escudeiro, A., Polcar, T., Carvalho, S., Cavaleiro, A. (2013), Influence of Ag content on mechanical and tribological behavior of DLC coatings, *Surface and Coatings Technology*., 232, 440-446.

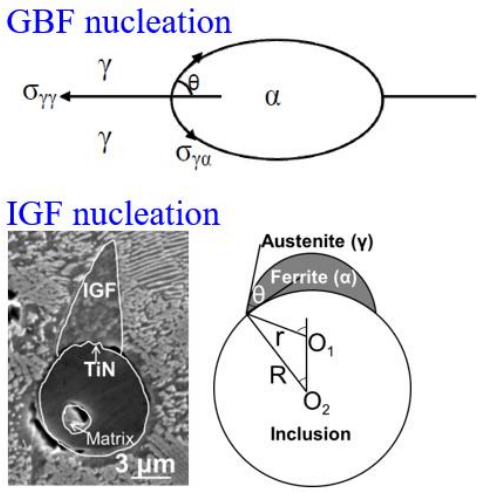
SICT 2023 Session II. A:
Surface and coatings Characterization / Properties Multifunctional composite and hybrid coatings

Nucleation and growth of intragranular acicular ferrite from the interface between NaCl-type particles and steels

Wangzhong Mu [1*]
[1] Department of Materials Science and Engineering, KTH Royal Institute of Technology, Brinellvägen 23, Stockholm, Sweden

Abstract:
Nucleation of intragranular acicular ferrite (IAF) is of vital importance for the microstructure control of engineering materials, which has a potential application to improve the low-temperature toughness of weldment of low-alloy steels. The current study presents a method to calculate the critical diameters of TiO, TiN, and VN particles (NaCl-type) for IAF nucleation in steels. Based on the calculation results, it was noted that the critical diameters of TiO, TiN, and VN inclusions for IAF nucleation will be quantitatively predicted, and the calculation results can have a good agreement with the experimental findings in the actual steel samples. Moreover, the effects of Mn, C and S contents on the critical diameters of inclusions were investigated. It was found that the critical diameters of TiO, TiN, and VN inclusions increased with the increasing Mn and C contents. In addition, it was found that S does not have a direct effect on the critical diameters of TiO, TiN, and VN inclusions. However, the increasing S content led to an increased amount of MnS precipitation in the actual steels. Last but not least, a new theoretical model considering the classical nucleation theory (CNT) and interfacial phenomenon has been established to predict the probably of IAF nucleation with different inclusion sizes. In addition, the phase-field (PF) model is applied to preict the Stress distribution surrounding the particle/steel interface. This work aims to contribute for the further development of 'Inclusion Engineering' in advanced steels.

Keywords: Intragranular acicular ferrite, interface, phase transformation, advanced steels, NaCl-type particles, inclusion metallurgy.



GBF: grain boundary ferrite; IGF: intragranular ferrite

Figure 1: Figure illustrating a theoretical model of grain boundary ferrite (GBF) and intragranular acicular ferrite (IAF) nucleation, which is from the steel/NaCl-type inclusion interface.

References:

1. Mu, W., Jönsson, P.G., Nakajima, K. (2016). Prediction of intragranular ferrite nucleation from TiO, TiN, and VN inclusions. *J. Mater. Sci.*, 51, 2168-2180.
2. Xuan, C., Mu, W. (2022). New insights of heterogeneous nucleation and anisotropic growth of acicular ferrite on non-metallic inclusion. *Mater. Design*, 221, 110892.
3. Mu, W., Mao, H., Jönsson, P. G., Nakajima, K. (2016). Effect of carbon content on the potency of the intragranular ferrite formation. *Steel Res. Int.*, 87, 311-319.

In situ study of the interlayer intercalation of 2-mercaptobenzothiazole in layered double hydroxides directly grown on AA2024 alloy

C. Neves [1*], I. Sousa [1], A. Salak [1], J. Tedim [1]
[1] Department of Ceramics and Materials Engineering - CICECO Aveiro Institute of Materials, University of Aveiro, Aveiro, Portugal

Abstract:
Layered double hydroxides (LDHs) have been investigated as conversion films for protection of metal alloys, and are suggested as prospective environmentally-friendly candidates for substitution of chromate conversion coatings on aluminium alloys. We have previously reported a successful growth of a thin multifunctional layer with anticorrosion and biocidal properties using LDH clusters as precursors.[1] It was observed that upon the exchange reaction with mercaptobenzothiazole (MBT), the basal diffraction reflections of LDHs became more diffuse and asymmetric. It was suggested that one possible reason for this observation is a fragmentation of the LDH crystallites during the anion exchange. However, mechanism of intercalation of MBT into the interlayer galleries of an LDH remains unclear. There are some indications that more than one arrangement of MBT anions, in the galleries, is possible during the exchange process.[2] Moreover, we suggest that OH anions, present in the solution, play an important role in facilitating intercalation of MBT into the galleries in the very beginning of the exchange reaction. In order to enter the gallery, the MBT anions are expected to get "flat-laying" disturbing the layer-interlayer electrostatic balance. Small anions OH^- are able to compensate the lack of negative charge. In such a scenario, MBT^- and OH^- enter the gallery together. In case of the LDH directly grown on the metal surface, the MBT intercalation is even more complicated since the LDH layer is not free to increase the gallery height. In this work we performed in situ synchrotron diffraction study of the nitrate-to-MBT anion exchange to reveal possible intermediate LDH phases in free LDH powders and in LDH structures grown on metal surface. The experiments were conducted at room temperature, and MBT-containing solution was pumped into a reaction vessel containing a diluted LDH slurry or an AA2024 substrate with grown LDH layer. Diffraction patterns were recorded every 2 s immediately after injection during the first 80 min of the exchange reation, and and then every 15 min for the next 120 min. The energy of the incident X-rays was 25 keV (λ = 0.51359 Å). Data were collected in the 1.5–24° 2θ range. Obtained results suggest that the anion exchange occurs at a very early stage (first minutes) and that, over time, two different arangments of MBT species corresponding to two basal spacing were observed. Furthermore, no traces of the parent LDH–nitrate were detected after the anion exchange.

Keywords: layered double hydroxides, interlayer arrangement, anion-exchange, conversion films, coatings.

References:

1. Neves, C.S., Bastos, A.C., Salak, A.N., Starykevich, M. Rocha, D., Zheludkevich, M.L., Cunha, A., Almeida, A., Tedim, J., Ferreira, M.G.S. (2019) Layered Double Hydroxide Clusters as Precursors of Novel Multifunctional Layers: A Bottom-Up Approach, *Coatings*, 9, 328.

2. Serdechnova, M., Salak, A.N., Barbosa, F.S., Vieira, D.E.L., Tedim, J., Zheludkevich, M.L., Ferreira, M.G.S. (2016) Interlayer intercalation and arrangement of 2-mercaptobenzothiazolate and 1,2,3-benzotriazolate anions in layered double hydroxides: In situ X-ray diffraction study, *Journal of Solid State Chemistry*, 233, 158-165.

Acknowledgments: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007417 having benefited from the access provided by SOLEIL - Synchrotron SOLEIL, Paris and CEA/LETI - Commissariat à l'Énergie Atomique et aux Énergies Alternatives/ Laboratoire d'Électronique des Technologies de l'Information, Grenoble (FR),within the framework of the NFFA-Europe Pilot Transnational Access Activity, proposal ID321. The authors also acknowledge SOLEIL for provision of synchrotron radiation at the CRISTAL beamline in frame of the experiment No 20220068.

Evaluation of surface functionalization for improved adhesion between nitinol and thermoplastic polyurethane

T. Schneiders [1*], T. Gries [1]
[1] Institut fuer Textiltechnik, RWTH Aachen University, Germany

Abstract:
High specific surface area, adjustable pore size, and scale of extracellular matrix are promising properties of polymeric nanofibers for medical applications and tissue engineering. But, the lack of mechanical strength and stability of nanofiber nonwovens often requires a substrate for bearing the load and giving stability. [1,2] Stents are an example for metallic materials as a load bearing structure in medical applications. The properties of the adhesive interface between nanofibers and stent determine the integrity of the composite. Adhesion between such a material pairing and improvement of adhesive strength has not been sufficiently researched until today. Therefore, this study aims to find methods for direct surface functionalization of the nitinol to increase the adhesive strength. [2,3]
A solution electrospinning process was used to produce nanofibers from thermoplastic polyurethane. Ultrafine fibers are drawn from a polymer solution with the use of electrostatic forces. The process was used for a direct coating on nitinol plates and flat braids with a nanofiber nonwoven. 180° peel tests according to DIN EN ISO 11339 are used to determine the peel resistance which is the peel force normalized to the width of the samples. Surface functionalization was carried out using a plasma treatment or a polymer coating process.
The plasma treatment had noch influence on the peel resistance while the polymer coating process increased it significantly. Maximum peel resistance for untreated samples was 19,2 ± 5,0 cN/cm and 57,8 ± 11,3 cN/cm for polymer coated samples. The change in structure from a plate to a flat braided nitinol wire led to a significant increase of peel restistance to 26,5 ± 3,6 cN/cm. Due to electrostatic forces during the electrospinning process, the nanofibers are wound around the single wires and increase the peel resitance although the total surface area decreases.

Keywords: electrospinning, nanofibers, nitinol, stent coating, adhesion, plasma.

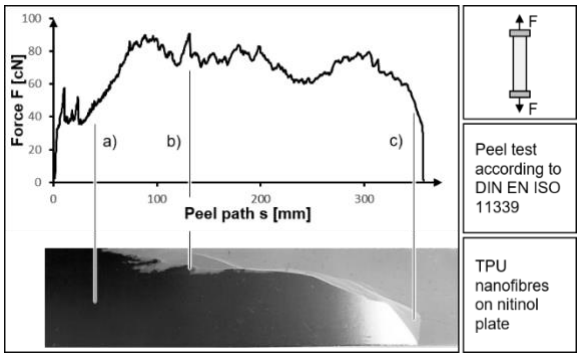


Figure 1: Curve of a peeling test for nanofibres on a nitinol plate. Corresponding points marked on sample. a) start of peeling process; b) partly rupture of nanofibre nonwoven; c) complete failure of nonwoven.

References:

1. Ballarin, F.M., Blackledge, T.A., Capitos Davis, N.L., Frontini, P.M., Abraham, G.A. and Wong, S.-C. (2013), Effect of topology on the adhesive forces between electrospun polymer fibers using a T-peel test. *Polym Eng Sci*, 53, 2219-2227.
2. Hellert C, Wortmann M, Frese N, Grötsch G, Cornelißen C, Ehrmann A. Adhesion of Electrospun Poly(acrylonitrile) Nanofibers on Conductive and Isolating Foil Substrates. Coatings. 2021; 11(2):249
3. Zhang, B., Yan, X., Xu, Y., Zhao, H., Yu, M., Long, Y. (2020) Measurement of Adhesion of In Situ Electrospun Nanofibers on Different Substrates by a Direct Pulling Method. *Advances in Materials Science and Engineering*, 2020, 8 pages

Wetting and phase electrowetting as a probe for surface chemistry of hydrophobic materials.

Manuel A. Flores Figueroa[1], Benoît Manchon[1], and Mathieu Maillard[1*]
[1] Laboratoire des Multimatériaux et Interfaces, UMR CNRS 5615, Univ Lyon, Université Claude Bernard Lyon 1, F-69622 Villeurbanne, France.

Abstract:
The combination of two methods for characterizing surface properties, two-liquid wetting and low-frequency electrowetting[1], have been used for their extreme sensitivity to surface polarity and surface charge density. Electrowetting describes the phenomenon of reversible modification of the wettability of a surface when an electric field is applied to the layer. After a brief introduction of the theory describing these methods, we will show how they can be applied to finely characterize hydrophobic surfaces.
In particular, these original methods allow to follow in real time and *in situ* the modification of the hydrophobic character of a surface as a function of the pH of the surrounding environment[2], which is very important for coating applications in real use conditions. When the pH of a solution on the surface of a hydrophobic layer is modified, the response observed in electrowetting is characterized by a modification of the signal symmetry, from which we are able to extract a charge density, characteristic for example of the deprotonation of the surface groups.

The same method was also used to characterize in situ the grafting of a coupling agent on a hydrophobic surface. (Figure 1)

Keywords: hydrophobic coating, hydrophobicity, wetting properties, electrowetting.

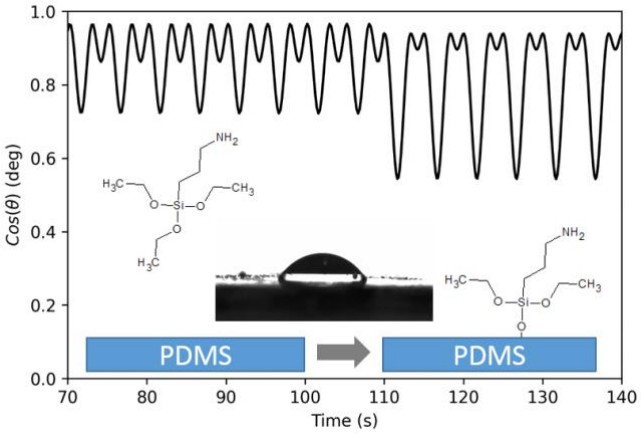


Figure 1: figure illustrating the phase shifting response of a pdms coating during the grafting of a coupling agent.

References:

1. Bonfante, G. et al. Polarization mechanisms of dielectric materials at a binary liquid interface: impacts on electrowetting actuation. Phys. Chem. Chem. Phys. 19, 30139–30146 (2017).
2. Flores Figueroa, M. A., Manchon, B. & Maillard, M. Two-liquid wetting and phase electrowetting as a probe for surface chemistry of hydrophobic materials. Phys. Chem. Chem. Phys. 24, 23323–23328 (2022).

Study of the wettability texturing hydrophobic surfaces prepared with cross-linked hybrid solutions under UV

Izabel Caldeira [1,2], Bérangère Toury[1], Christian Brylinski[1], Valentin Gâté[2], Daniel Turover[2], Mathieu Maillard[1]

[1] Laboratoire des Multimatériaux et Interfaces, UMR CNRS 5615, Univ Lyon, Université Claude Bernard Lyon 1, F-69622 Villeurbanne, France.

[2] NAPA Technologies, 382 rue Louis Rustin – Archamps Technopole, F-74160 Archamps, France.

Abstract:

Living organisms have evolved many strategies to change their color and appearance. Some of these characteristics are related to the physical and topographical properties of the surface, enabling color modifications or adding a functionalization such as hydrophobicity[1]. For instance, a patterned surface can provide hydrophobic behavior by drawing on the patterns of the Dahlia flower [Fig. 1].

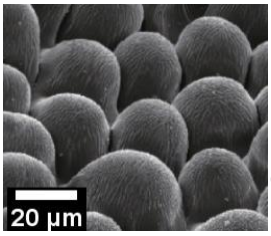


Fig. 1: Scanning electron microscope image of Velvety leaves of a Dahlia flower with convex, structured cells. [2]

The use of soft lithography techniques opened alternative routes to replace the expensive and complex methods of classical lithography. However, a central challenge is extending the size of the patterning area (from cm² to m²) and the patterning of complex surfaces (2.5-3D geometries) to achive a hydrophobity surfaces. Thus, we propose a process to produce surfaces with super hydrophobic patterns using the UV-NIL technique with hybrid solutions. An example of patterned surfaces is shown in **Fig.2**

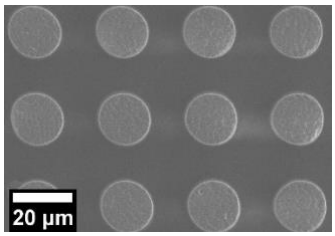


Fig. 2: Surface functionalized by nano-micro patterning.

To test the hydrophobic behavior of the sample, measurements of the contact angle with water for the textured samples and measurements of the surface energy of each of the smooth surfaces were performed. Preliminary results have shown an increase from 60° [Figure 3(a)] to 150° [Figure 3(b)] of the contact angle with water (θ) therefore, characterizing the achievement of a hydrophobic surface following Cassie-Baxter behavior. The surface energy (γ) is around 45 mN/m, which prompts further studies to understand the surface chemistry and subsequently optimize the processes to reduce the surface energy and hence obtain a super-hydrophobic surface (θ>150° and γ<20mN/m).

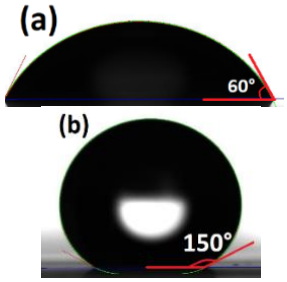


Fig. 3: Contact angle of the falling water droplet (a) non-paternal surface and (b) paternal surface.

An intermediate state between the Wenzel and Cassie-Baxter states was observed and new dynamic wetting measurements will be carried out to complement the previous results. Finally, these results will be compared with water repellency using topography of the surfaces, as well as sliding angle measurements.

Keywords: NIL, nano-imprint, wettability, contact angle, hydrophobic, UN-NIL, micropatterning, Wenzel, Cassie-Baxter, silica-based materials, hybrid materials.

References:

1. C. Credi *et al.* (2017) Stereolithography of perfluoropolyethers for the microfabrication of robust omniphobic surfaces. *Applied Surface Science*; 404 268–275
2. W. Barthlott *et al.* (2017) Plant Surfaces: Structures and Functions for Biomimetic Innovations. *Nano-Micro Lett* 9:23.

Substrate controlled hydrophobicity of Y_2O_3 thin films

Dr. Joanna Borowiec
Department of Chemistry, University College London, 20 Gordon Street, London WC1H 0AJ, UK, E-mail: j.borowiec@ucl.ac.uk

Abstract:
Significant scientific efforts have been devoted to explore the hydrophobic behavior of materials by relying on the reduction of water adhesion and surface particulates deposition from the environment.[1] For instance, the significant problem of soiling losses associated with dirt deposition on e.g. photovoltaic (PV) panels and other PV modules, can be overcome by functionalization of the glass surface used in these systems with self-cleaning coatings.[2] Recently, rare earth oxides (REOs) have attracted considerable attention as they have been proven to exhibit not only excellent hydrophobic properties but also were shown to be resistant to extreme conditions, including exposure to elevated temperatures or abrasive wear, without degradation of their water-repelling properties.[3] Most importantly, REOs films are transparent to light and are characterized by low reflectance,[4] which renders them a perfect candidate for application as an anti-soiling coating in PV modules. The above listed advantages of REOs have generated considerable scientific interest in further studies in the design of new deposition methods producing high-quality films, in addition to complementary investigations of their hydrophobicity.[5]
The Y_2O_3, which belongs to the class of REOs, will be presented as a promising candidate for the development of hydrophobic coatings on a range of a commercially available glass substrates using aerosol assisted chemical vapor deposition (AACVD) method. The influence of the deposition parameters as a function of substrate selection on the quality of the films will be discussed in detail. The developed hydrophobic Y_2O_3 coatings water contact angles grown on selected substrates was found to range between 120 and 128°. The qualitative evaluation of the film's intrinsic hydrophobic characteristics will be provided along with insights into the materials surface chemistry, which are derived the experimental results from the traditional sessile drop measurements as well as number of materials physico-chemical characterization techniques.

References:

1. M.G. Krishna, et. al., *European Physical Journal Applied Physics* 2013, 62 (3), 30001.
2. D. Adak, et. al., Renewable and Sustainable Energy Reviews 2022, 159, 112145.
3. G. Azimi, et. al., Nature materials 2013, 12 (4), 315-320.
4. A.F. Andreeva, et. al., Journal of Applied Spectroscopy 1978, 28 (5), 610-614.
5. J. Tam, et. al., Journal of Materials Chemistry A 2018, 6, 18384-18388.

Spreading Dynamics of Metal on Metal-on-Glass

Haim Taitelbaum
Department of Physics, Bar-Ilan University, Ramat-Gan, Israel

Abstract:
When a tiny droplet of mercury is transferred to a thin metal (silver / gold) film deposited on a glass substrate, it starts to dissolve and spread in a very exotic manner. This is the only known system of reactive wetting in room temperature.
We review the non-trivial spatio-temporal patterns observed in this system. It exhibits two main regimes, the bulk propagation regime and the interface kinetic roughening regime. The bulk propagating dynamics is very different from classical wetting characteristics. In the kinetic roughening regime, rich spatio-temporal patterns are observed. The latter are studied and characterized using statistical physics tools, such as the growth, roughness and persistence exponents. We compare these results with spreading dynamics in high temperatures.
We also discuss recent results for the global de-cohesion and structural instability of the thin film due to the mercury spreading, resulting in DLA-like finger patterns.

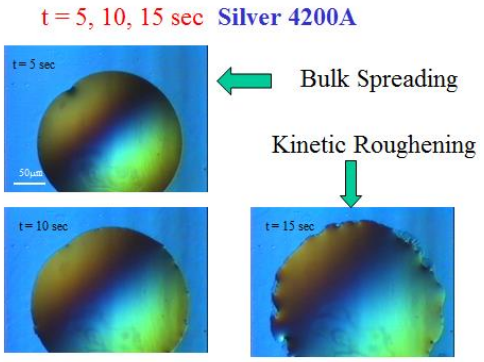


Figure 1: The two main regimes of the spreading dynamics of mercury on silver-on-glass in room temperature.

Keywords: droplet, thin film, mercury, silver, gold, metal, metal-on-glass, room temperature, high temperatures, side view, top view, bulk, spreading, reactive-wetting, kinetic roughening, roughness, growth, persistence, universality.

References:

1. A. Be'er, Y. Lereah, H. Taitelbaum, Physica A 285, 156 (2000).
2. A. Be'er, Y. Lereah, I. Hecht, H. Taitelbaum, Physica A 302, 297 (2001).
3. A. Be'er, Y. Lereah, A. Frydman, H. Taitelbaum, Physica A 314, 325 (2002).
4. A. Be'er, Y. Lereah, J. of Microscopy, 208, 148 (2002).
5. I. Hecht, H. Taitelbaum, Phys. Rev. E 70, 046307 (2004).
6. A. Be'er, I. Hecht, H. Taitelbaum, Phys. Rev. E 72, 031606 (2005).
7. I. Hecht, A. Be'er, H. Taitelbaum, FNL 5, L319 (2005).
8. A. Be'er,Y. Lereah, A. Frydman, H. Taitelbaum, Phys. Rev. E 75, 051601 (2007).
9. A. Be'er, Y. Lereah, H. Taitelbaum, Mater. Sci. Eng. A 495, 102 (2008).
10. Y. Efraim, H. Taitelbaum, Cent. Eur. J. Phys. 7, 503 (2009).
11. L. Lin, B.T. Murray, S. Su, Y. Sun, Y. Efraim, H. Taitelbaum and T.J. Singler, J. Phys. Cond. Mat. 21, 464130 (2009).
12. Y. Efraim and H. Taitelbaum, Phys. Rev. E, 84, 050602(R) (2011).
13. M. Harel and H. Taitelbaum, Phys. Rev. E, 96, 062801 (2017).
14. M. Harel and H. Taitelbaum, Europhys. Lett. 122, 26002 (2018).
15. M. Harel and H. Taitelbaum, Eur. Phys. J. E 44, 69 (2021).

Elemental and chemical depth profiling of organic-coated steel strips

D. Leidlmair [1,*], J. Duchoslav [1], G. Mayr [2], B. Strauß [2], D. Stifter [1]
[1] Center for Surface and Nananalytics (ZONA), Johannes Kepler University, Linz, Austria
[2] voestalpine Stahl GmbH, Linz, Austria

Abstract:
Organic coatings applied on steel substrates are representing a valuable enhancement in several ways, typically linked to corrosion inhibitive and aesthetic purposes. Being extensively used *e.g.* in the construction and household appliances industry and in order to meet increasingly demanding high-quality standards, extremely complex material systems are under development, thus calling for a deeper understanding of their final structure.
In order to assess the interior coating composition and microstructure of 50 µm thick single component (1K) high-build polyester-polyurethane (PU) coil coatings, ultra-low-angle microtomy (ULAM) was combined with X-ray photoelectron spectroscopy (XPS), energy-dispersive X-ray spectroscopy (EDX) and Fourier-transform infrared (FTIR) spectroscopy [1]. Elemental and chemical depth profiling was achieved by correlative analysis of fabricated extended tapers in the millimeter range. FTIR focal plane array (FPA) spectroscopic imaging enabled to determine the distribution of the isocyanurate cross-linking agent at plane-view for different depth positions. Chemical gradients were detected by recording XPS line scans on the exposed sections. Evaluation of carbon C1s high-resolution spectra showed an enhancement of nitrogen and oxygen containing functionalities near the primer/substrate interface. The distribution of embedded fillers was additionally obtained by EDX for the observed PU coating system (Fig. 1).
The linearity of the surface topography of shallow angle microtomy cuts fabricated at different preparation conditions was examined by scanning electron microscopy (SEM) and compared to cross sections created by a conical coating drill and flat milling with Ar^+ ions. Auger electron spectroscopy (AES) was additionally applied in order to evaluate the respective preparation techniques at nanoscale.
All methods in combination provide further advantages for the comprehensive analysis of organic coatings regarding the determination of structure-property relationships and to investigate their corrosion stability.

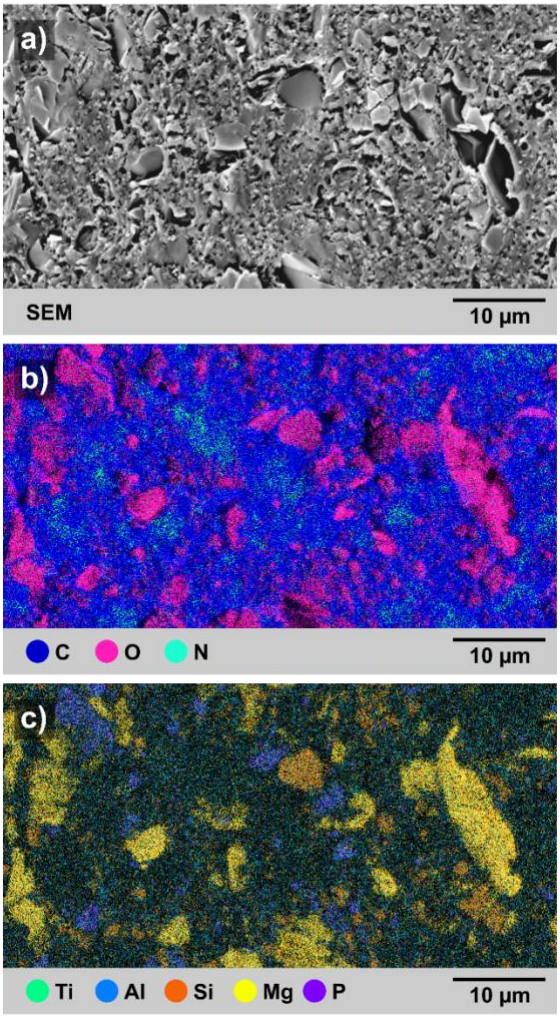


Figure 1: Plane-view (a) SEM and (b,c) EDX elemental mappings showing the interior microstructure of a PU-based primer coating layer at a selected depth position [1].

Keywords: compositional depth profiling, organic coatings, X-ray photoelectron spectroscopy (XPS), infrared spectroscopy, energy-dispersive X-ray spectroscopy (EDX), Auger electron spectroscopy (AES)

References:

1. Leidlmair D., Duchoslav J., Mayr G., Arndt M., Gsaller H., Strauß B., Stifter D., Elemental and chemical depth profiling of high-build single-component (1K) polyester-polyurethane coil coatings, *Progress in Organic Coatings*, accepted.

Analysis of Coatings by Glow Discharge Emission Spectroscopy: Light Elements

Z. Weiss
FZU - Institute of Physics of the Czech Academy of Sciences, Praha, Czech Republic

Abstract:
Glow discharge optical emission spectroscopy (GDOES) with a Grimm-type source (Figure 1) is a well-established method for elemental analysis of metals, coatings and surface-modified materials. The sample acts as cathode in a glow discharge and its atomization proceeds by cathodic sputtering. Emission intensities can be recorded as function of time, allowing thereby depth-resolved analysis (depth profiling). In most cases, a simple calibration procedure based on bulk reference materials is sufficient to interpret analytically the emission intensities.

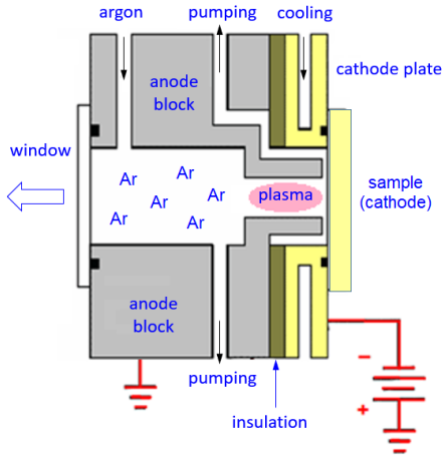


Figure 1: Grimm-type glow discharge excitation source: a flat sample to be analysed acts as cathode in a glow discharge. Emitted light is viewed end-on, in axial direction, and analyzed by optical spectrometer.

Analysis by GDOES has been reported in numerous applications involving coatings, thin films, materials after various surface treatments in reactive gases, etc. Of special interest is analysis of light elements such as H, B, C, N, O, for which some other common methods either do not work at all or yield a poor analytical performance. Typical examples of depth-resolved analyses of various coatings involving light elements will be presented, together with the corresponding methodology and some context showing the motivation for such studies.

Boron- and phosphorus-doped diamond layers prepared by plasma-enhanced chemical vapor deposition were analysed for boron and phosphorus concentration depth distributions as functions of deposition parameters [1, 2]. Typical detection limits (DLs) of boron in diamond are < 20 ppm (w/w). Phosphorus DLs in argon discharge are worse but can be improved by using neon instead of argon as the discharge gas [1].

Nitrogen depth distributions were analysed by GDOES in N-implanted Ti-base alloys (see e.g. Ref [3]). Shallow depth profiles of nitrogen may be affected by an instrument effect caused by outgassing of the inner walls of the spectral source in the first seconds after the discharge is ignited. This effect can be corrected for and a method for doing so will be presented. Besides N_2 and O_2, also hydrogen from atmospheric moisture was reported to affect the signal response. Hydrogen itself can also be analysed by GDOES [4].

GDOES is a powerful and relatively easily accessible method for depth-resolved elemental analysis of coatings, with remarkable advantages for analysis of light elements.

Keywords: glow discharge, emission spectroscopy, GDOES, diamond, boron, phosphorus, nitrogen, hydrogen

References:

1. Weiss, Z., Ashcheulov, P., Lambert, N., Taylor, A., Lorincik, J., Sung, K-D., Davydova, M., Mortet, V. (2022) Analysis of boron- and phosphorus-doped diamond layers by glow discharge optical emission spectroscopy in argon and neon, *Vacuum*, In Press.
2. Lambert, N., Weiss, Z., Klimša, L., Kopeček, J., Gedeonová, Z., Hubík, P., Mortet, V., Highly phosphorus-doped polycrystalline diamond growth and properties, *Diam. Rel. Mat.* 125 (2022) 108964.
3. Vlcak, P., Fojt, J., Weiss, Z., Kopeček, J., Perina, V., The effect of nitrogen saturation on the corrosion behaviour of Ti-35Nb-7Zr-5Ta beta titanium alloy nitrided by ion implantation, *Surf. Coat. Technol.* 358 (2019), 144-152.
4. Weiss, Z., Analysis of hydrogen in inorganic materials and coatings: A critical review, *Hydrogen* 2 (2021), 225-245.

Ex situ Raman spectroelectrochemistry of IrO_2 and Ir metal nanoparticles in as-deposited and electrochemically activated states

A.K. Surca*, L. Moriau, M. Bele, M.A. Nazrulla, A. Lončar, N. Hodnik
[1] Department of Materials Chemistry, National Institute of Chemistry, Ljubljana, Slovenia

Abstract:
The limiting process of the electrochemical splitting of water in proton exchange membrane water electrolyzers (PEMWE) is the oxygen evolution reaction (OER)[1]. The limitations encompass large overpotentials, slow kinetics, highly oxidative potentials and harsh environment. The only stable catalyst for OER in acidic conditions is iridium, though being extensively investigated[2].
It is important that all accessible measurement techniques that can give any insight into the behavior of Ir-based electrocatalysts are exploited. Therefore, in this study we investigated Raman spectroscopic approach with support of X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and OER activity determination. Although this technique is straightforward for many samples, black ones can offer a challenge. Many times signal-to-noise has to be sacrificed to preserve the stability of the sample under the laser beam.
The present study comprise two commercial compounds, i.e. rutil-type IrO_2 and Ir black (both Alfa Aesar). The Raman spectrum of Ir black shows the partial oxidation, which is confirmed by EDS. Namely, the characteristic bands of IrO_2 occurr in both spectra: E_g mode at 548 cm^{-1} and the overlapping B_{2g} and A_{1g} modes at 719 cm^{-1} (Figure 1). Both compounds, IrO_2 and Ir black, were then drop-casted to the glassy carbon electrode (GCE) and exposed to various activation and degradation protocols. After each protocol, *ex situ* Raman spectroelectrochemical measurements were made. The spectra were then correlated according to their electrochemical treatment and Raman spectra. An important finding is that the short potential range in the mostly oxidative part of the cycling region (1.1 to 1.6 V vs. RHE) contributed to the increase in intensity of B_{2g} mode.
Both Ir-compounds were then prepared with either P25 (TiO_2) or carbon black (Vulcan VC72) as substrates. These samples were then drop-casted to GCE. Since the amount of Ir is considerably lower (~20 wt.%) compared to previous samples we wanted to check whether it is possible to detect Raman spectra. It is interesting to notice that as-deposited and activated states do not reveal the presence of IrO_2. Very low-intenisty bands of Ir oxide, however, can be noted for degraded states.

Keywords: Raman spectroscopy, iridium, IrO_2, electrocatalysts, OER activity.

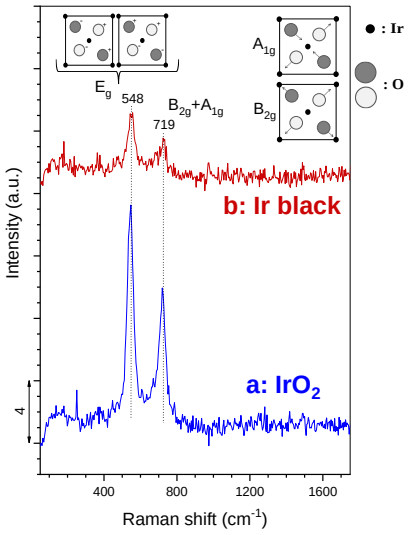


Figure 1: Raman spectra of commercial powders, IrO_2 and Ir black, on a silicon wafer substrate. The displacements of atoms are shown for E_g, B_{2g} and A_{1g} modes (along c-axis) as described by Huang et al.[3]

References:

1. Katsounaros, I., Cherevko, S., Zeradjanin, A.R., Mayrhofer, K.J.J. (2014) Oxygen electrochemistry as a cornerstone for sustainable energy conversion, *Angew. Chemie - Int. Ed.*, 53, 102-121.
2. Lončar, A., Escalera-López, D., Cherevko, S., Hodnik, N. (2022), Inter-relationships between oxygen evolution and iridium dissolution mechanisms, *Angew.Chemie – Int. Ed.*, 61, e202114437.
3. Huang, Y.S., Lin, S.S., Huang, C.R., Lee, M.C. (1989) Raman spectrum of IrO_2, *Solid state Commun.* 70, 517-522.

SICT 2023 / PlasmaTech 2023
Joint session II. B:
Bio-interfaces, Biomedical / Bioactive surfaces and coatings Plasma applications for biology, medicine, and agriculture

Design of new antimicrobial osseointegrated dental implants

S. Carvalho[1]
[1] CEMMPRE Mechanical Engineering Department, University of Coimbra, 3030-788 Coimbra
[2] IPN - LED&MAT - Instituto Pedro Nunes, Laboratório de Ensaios, Desgaste e Materiais, Rua Pedro Nunes, 3030-199 Coimbra, Portugal

Abstract:
Nowadays, the main causes of the rejection of dental implants are their poor osseointegration and the bacterial adhesion and growth, which may lead to peri-implantitis disease. The osseointegration and the bacteria adhesion inhibition can be enhanced by modifying implant surface properties.
This work is focused, in a first phase, on the surface modification of metallic tantalum (Ta), by anodization and by plasma electrolytic oxidation (PEO). This eletrochemical modification intends to promote the surface bioactivity and accelerate the osseointegration by mimetic the morphology and chemical from the bone, with the formation of micro/nano-porous structures and the incorporation of osteoconductive elements (calcium (Ca) and phosphorus (P)). In a second phase, over these bioactive surfaces, zinc (Zn) nanoparticles (NPs) with and without a thin carbon (C) layer are deposited by magnetron
sputtering to endow this surface with antimicrob ial activity.
Different quantities of NPs deposited on the bioactive surfaces were tested. Increasing the deposition time and/or decreasing the working pressure, it was possible to deposit a higher amount of Zn NPs with different morphologies and sizes. The zinc ions release increased with the amount of the NPs and decreased when the carbon layer covered the NPs. The chosen surfaces, the one with lower and the one with higher ionic release, were further studied regarding the antimicrobial activity and corrosion resistance. The presence of Zn NPs had a great impact on the improvement of the antimicrobial capacity, as the higher quantity of Zn NPs (and higher zinc ions release) showed the highest *C. albicans* growth inhibition compared to the porous Ta_2O_5 surface. The C layer did not reveal a significant difference when compared to the respective surface. The corrosion results revealed that the formation of Ta_2O_5 by the PEO lead to improvement of the corrosion behavior, compared to untreated Ta surfaces. On the other hand, the incorporation of metallic Zn NPs promoted the degradation of corrosion resistance, which improved as a function of immersion time and became closer to the porous Ta_2O_5 surface corrosion behavior. These results demonstrated that the deposition of Zn NPs onto porous Ta_2O_5 surfaces efficiently inhibits the microbial growth. Thus, the PEO and magnetron sputtering are promising surface modification techniques for functionalize Ta surfaces for dental implants.

Keywords:Tantalum; Zinc Nanoparticles; Plasma Electrolytic Oxidation; Magnetron Sputtering; Corrosion Resistance; Antimicrobial Activity.

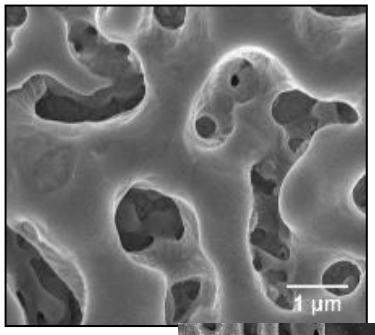


Figure 1: Bone-like Ta_2O_5 surface

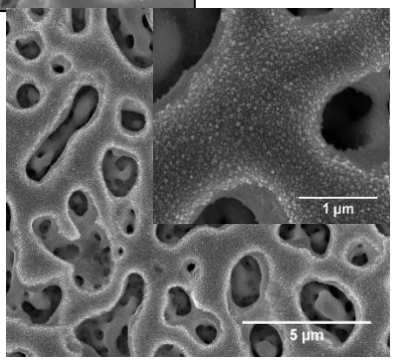


Figure 2: Bone-like Ta_2O_5 surface with antimicrobial nanoparticles

References:

1. L. Fialho, L. Grenho, M. H. Fernandes, and S. Carvalho, Mater. Sci. Eng. C. 120 (2021) 111761
2. L. Fialho, S. Carvalho, Applied Surface Science, 495 (2019) 143573
3. L. Fialho, C.F. Almeida Alves, Marques, S. Carvalho. Applied Surface Science, (2020), p. 145542.
4. C. F. Almeida Alves, L. Marques, S. Carvalho, Applied Surface Science, (2020), p. 145575
5. C. F. Almeida Alves, C. F., L. Fialho, L., S. Marques, S. Pires, P. Rico, C.Palacio, S. Carvalho, S. Materials Science and Engineering: C (2021), 112008

Drug Eluting Coatings to Enhance the Functionality of Implants

M. Zilberman [1,2]
[1] Department of Biomedical Engineering, Tel-Aviv University, Tel-Aviv, Israel
[2] Department of Materials Science and Engineering, Tel-Aviv University, Tel-Aviv, Israel

Abstract:

Active implants are drug-eluting implants, i.e. in addition to their regular role they also release drug or protein molecules to the surrounding tissue in a controlled desired manner, for various periods of time according to specific needs. However, when bioactive molecules are incorporated in implants usually the mechanical-physical properties are not preserved. Also, it is very difficult to incorporeate these molecules without affecting their acativity. Therefore, drug eluting coating have been developed and studied by us.

Any implant can be converted to an "active implant" when coated with our drug-eluting bioresorbable coatings. The coating technology is based on the "freeze drying of inverted emulsion" process, which results in porous coatings (Fig. 1). The drug molecules are encapsulated in the pores. The porous structure (pore size and porosity) strongly affects the release profile, as shown in Fig. 2.

The advantages of our drug-eluting coaings:

1. Optimal local release of any drug (water soluble, water-insoluble, protein) in a controlled desired manner.
2. The activity of any drug is preserved, due to the mild process technique used.
3. Ease of coating manufacturing and FDA approved materials.
4. Excellent adhesion between our coating and various materials (metals and polymers).
5. Excellent animal study results were achieved.

Examples for potential applications:

* Wound dressings with controlled release of antibiotics and pain killers
* Endovascular stents and local cancer treatment - controlled release of anti-proliferative agents.
* Scaffolds for tissue regeneration with controlled release of growth factors.
* Inti-inflammatory therapy.

In this talk the effects of the formulation parameters on the micro and nano-structural features of the coatings, and on the resulting drug release profile, will presented for water soluble drugs, water-onsoluble drugs and protein molecules.

Keywords: drug delivery, porous coatings, nano-structuring, micro-structuring, wound dressings, stent coatings, protein release.

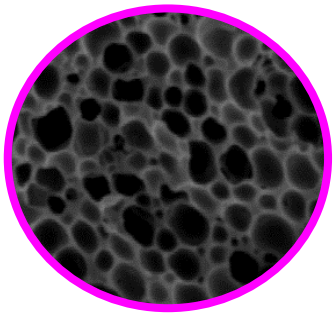


Figure 1: Environmental SEM micrograph showing the porous coating structure.

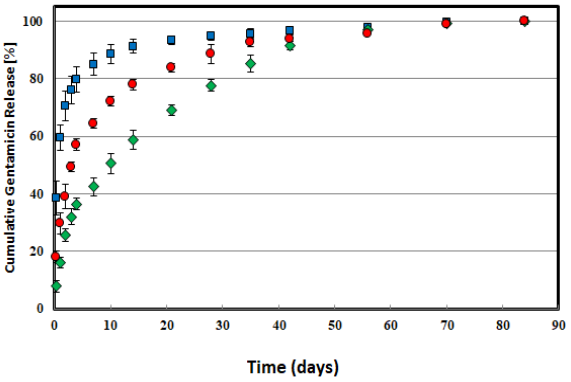


Figure 2: Antibitic release profiles from varoous coating structures.

Reference

Elsner, J., Kraitzer, A., Grinberg, O., and Zilberman, M., ”Highly Porous Drug-Eluting Structures: From Wound Dressings to Stents and Scaffolds for Tissue Regeneration", *Biomatter*, 2(4), 239-270 (2012).

Fluid interfaces as platforms for understanding the interaction of pollutants with lipid barriers

Eduardo Guzmán[1,2,*]
[1] Departmento de Química Física, Universidad Complutense de Madrid, Madrid, Spain
[2] Instituto Pluridisciplinar, Universidad Complutense de Madrid, Madrid, Spain

Abstract:
Pollution is currently a public health problem associated with different cardiovascular and respiratory diseases. This makes necessary a careful examination of their potential effect on lipid membranes, e.g., tear films, lung surfactant or skin. It is common that once pollutants enter in contact with biological barriers, they can alter their mechanical performance which can induce fails in the normail physiological performance of such barriers. Moreover, the interactions of pollutants with biological can induce the formation of an corona decorating the pollutant surface, favoring their penetration into the bloodstream and distribution along different organs. Therefore, it is necessary to understand the most fundamental aspects of the interaction of particulate pollutants with lipid barriers to mitigate their effects, and design therapeutic strategies. However, the use of animal models is often invasive, and requires a careful examination of different bioethics aspects. This makes it necessary to design in vitro models mimicking some physico-chemical aspects with relevance for specific biologica performance, which can be done by exploiting the tools provided by the science and technology of interfaces to shed light on the most fundamental physico-chemical bases governing the interaction between lipid barriers and particulate matter. It is expected that these communication can contribute to deepen on the understanding of the potential toxicological effects of the air pollution on the physiological performance of cellular barriers and biofluids. However, it should be noted that the used model systems cannot account for some specific physiological aspects of life systems.

Keywords: biomembranes, fluid interfaces, lung surfactant, interfacial rheology

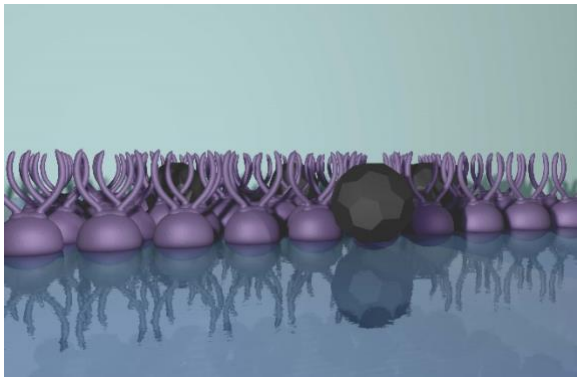


Figure 1: Figure illustrating the incorporation of pollutant to biological layers.

References:

1. World Health Organization (accessed on 1 February 2023), How Air Pollution Is Destroying Our Health. Available online: https://www.who.int/airpollution/news-and-events/how-air-pollution-is-destroying-our-health.
2. Guzmán E. (2022), Fluid Films as Models for Understanding the Impact of Inhaled Particles in Lung Surfactant Layers, *Coatings*, 12, 277.
3. Guzmán E., Santini E. (2019), Lung surfactant-particles at fluid interfaces for toxicity assessments, *Curr. Opinion Colloid Interface Sci.*, 39, 24-39.

Room vs. body temperature to evaluate electrical interface parameters of state-of-the-art PEDOT-PSS electrode for neural stimulation

K. Cysewska [1,*]
[1] Faculty of Electronics, Telecommunications and Informatics, Gdansk University of Technology, Gdansk, Poland

Abstract:
Currently, one thousand million people suffer from neurological issues, such as epilepsy, Alzheimer's and Parkinson's diseases, migraines, sclerosis, or neural infections. In most cases, restoration of the neural path can be done by the introduction of electrodes within the neural tissue.
Placing the electrode in the neural environment results in the spontaneous formation of the interface between neural tissue and the surface of the electrode [1]. Because signals transmission in the nervous system depends on the electrical carrier (ions) and chemical carrier (neurotransmitters), monitoring/stimulating the nervous system by the electrode can be obtained through the electrical and chemical interface [2].
Nowadays, the market of neural electrodes is mainly based on pure metals such as gold (Au) or platinum (Pt). Their rigid and plane structure lead to their poor integration with the tissue environment, high inflammation, degeneration of signal transmission and finally to the reduction in the effective lifetime of the electrode. Modulation of the interfacing electrode by nanostructured conducting polymer coating has recently become an attractive option for providing efficient signal transmission for neural application [3]. Among conducting polymers, poly(3,4 ethylenedioxythiophene) (PEDOT) doped with poly(styrenesulfonate) (PSS) has become the most promising coating material for neural tissue/electrode interface due to its significant stability in an aqueous environment. PEDOT:PSS was reported to significantly reduce electrochemical impedance and electrical noise and improve neural adhesion compared to bare metallic electrodes.
In the literature, an appropriate methodology for conducting the electrochemical tests of the electrodes is still being developed in order to obtain the most reliable and reproducibile measurement data. One of the parameters that can strongly affect the measured data is the temperature of the measurements.
In the literature most of the electrochemical analyses of the electrical and chemical interface of the PEDOT-based electrodes are carried out at room temperature. Since the electrochemical/electrical performance of conducting polymers depends strongly on the measurement temperature [4] it is assumed that the studies should be performed at the body temperature in simulated body fluid instead of the room temperature.
In this work the effect of the measurement temperature on the parameters of the electrical interface of state-of-the art PEDOT-PSS electrode in simulated body fluid is studied. PEDOT-PSS is synthesized by electrodeposition on graphite and gold-coated-graphite electrodes. All electrochemical measurements are performed in phosphate buffered saline aqueous solution (pH 7.4) at the room temperature (25 °C) and the body temperature (37 °C).
The results of the study will show whether and to what extent the change in the measurement temperature will affect the basic parameters of the electrical PEDOT-PSS interface, such as: interfacial impedance, double layer capacitance, potential window, charge storage capacity, and charge injection capacity.

Keywords: coatings, conducting polymers, electrochemistry, electrical interface, neural electrodes, biomedical applications.

References:

1. Cho, Y., Shin, H., Park J., Lee S. (2021), Title, *Micromachines*, 12, 1552.
2. Kim G.H., Kim K., Lee E., An T., Choi W.S., Lim G., Shin J.H. (2018), *Materials*, 11, 1995
3. Cysewska K., Karczewski J., Jasiński P. (2015), *Electrochim. Acta*, 176, 156.
4. Cysewska K., Gazda M., Jasiński P. (2017), *Surf. Coat. Tech.*, 328, 248.

Acknowledgment:
The work was supported by National Science Centre (NCN), Poland: Sonata grant based on the decision 2021/43/D/ST7/01362. K. Cysewska acknowledges the Polish Ministry of Education and Science stipend.

Plasma-deposited hydrophobic organosilicon coatings for sustainable leather in footwear applications

C. Ruzafa-Silvestre*, V.M. Serrano-Martínez, E. Orgilés-Calpena.
cruzafa@inescop.es
Adhesives Department, Footwear Technology Centre (INESCOP), 03600 Elda, Spain

Abstract:
The hydrophobic finishing treatments currently used in the leather footwear sector involve, in some cases, the use of hazardous chemicals, including halocarbon compounds considered greenhouse gases (GHG). These gases emit persistent organic compounds (POPs) that are harmful to both human health and the environment and are therefore limited or restricted by current European regulations. Therefore, the industry is looking for innovative, resource-efficient processes that enable the elimination of such chemicals to develop quality, safe and low-environmental impact products. In this sense, this study investigates the development of hydrophobic coatings on leather materials by plasma polymerisation with a low-pressure plasma system using an organosilicon compound, such as hexamethyldisiloxane (HMDSO), as a chemical precursor. For such purpose, different parameters such as system pressure, monomer flow rate, input power and deposition time of the low-pressure plasma system have been optimised and the obtained plasma-deposited coatings have been characterised by different experimental techniques, such as Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM). Furthermore, leather performance has been evaluated by standardised tests including colour-change, surface coating thickness, water contact angle (WCA) and surface roughness measurements. The obtained results indicated a complete and suitable monomer polymerisation on the leather surface, creating an ultra-thin layer based on polysiloxane. The surface modification produced a water-repellent effect on the leather that did not alter the visual appearance or haptic properties. Therefore, the application of the plasma deposition process showed promising results that make it a more sustainable alternative to conventional functional coatings, thus helping to reduce the use of hazardous chemicals in the finishing process of footwear manufacturing.

Keywords: Low-pressure plasma, plasma process, plasma polymerisation, surface modification, plasma deposition, coating, hydrophobic, leather, footwear.

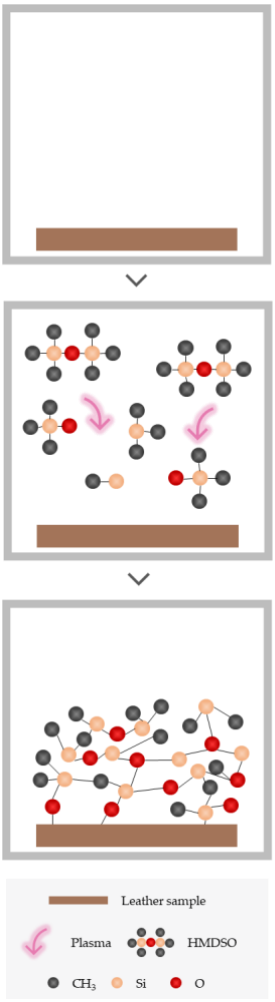


Figure 1: Plasma polymerisation coating deposition process.

References:

1. Ruzafa-Silvestre, C, Carbonell-Blasco, M. P. Ricote-López, S., Pérez-Aguilar, H., Limiñana, M. Á. P., Bañon Gil, E., Orgilés-Calpena, E., Arán-Ais, F. (2021). Hydrophobic Leather Coating for Footwear Applications by a Low-Pressure Plasma Polymerisation Process. Polymers, 13(20), 3549. https://doi.org/10.3390/polym13203549
2. Williams, J. (Ed.). (2017). Waterproof and water repellent textiles and clothing (First). [Manchester, England]: Duxford, United Kingdom; Cambridge, MA, United States: Elsevier Science.

Plasma applications for smart and sustainable agriculture (PlAgri) with the emphasis on biotechnologies

N. Puač[1], O. Jovanović[1], S. Živković[2], M. Milutinović[2], S. Jevremović[2], G. Malović[1] and N. Škoro[1]
[1]Institute of Physics-National Institute of Republic of Serbia, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia
[2] Institute for Biological Research "Siniša Stanković"-National Institute of Republic of Serbia, University of Belgrade, Bul. despota Stefana 142, 11060 Belgrade, Serbia

Abstract:
The continuous increase in demand for food caused by population growth represents a serious challenge for humankind. At the same time, the climate change is having significant impact on agricultural production and farmers are forced to adapt or change existing practices due to the change in weather patterns, pest appearance, water availability etc. Improving sustainability of agriculture and reducing adverse effects of agriculture on the environment requires efficient technologies that enhance productivity while maintaining food quality and safety. The main aim is to investigate the potential of non-thermal plasmas as a green alternative to conventional fertilizers in agriculture to improve yields, increase size and robustness of plants, to reduce (or eliminate) the need for pesticides and in the case of final products treatments of food and its packaging.
First studies pointed out that plasma created Reactive Oxygen Nitrogen Species (RONS) observed in treatments of seeds and plants led to successful application of plasmas for different aspects of agriculture and food industry [1, 2]. It was shown that, both low pressure and atmospheric pressure plasmas can be successfully used in stimulation of the seed growth, increase of germination percentage and decontamination, breaking of dormancy or lengthening of the seed sprout. In direct plasma treatments, i.e. where seeds are in direct contact with plasma or its afterglow, the surface of seeds undergoes a variety of changes. Depending on the plasma conditions the surface is activated so other functional groups can be attached (-COOH, -COH, -COO, -NH2, -OH, -NO etc.) and at the same time seed surface can be etched and/or decontaminated from various types of microbes. Plasma treatment of seeds became one of the starting points in opening of a wide area of applications of plasmas in agriculture and related biotechnologies.
The plants can be grown not just from seeds but also from plant meristematic (stem) cells or from plantlets encapsulated in synthetic seeds. We have performed the treatments of *Daucus carota* and *Iris reichenbachii Heuffel.* calli by using plasma needle that operates at atmospheric pressure. We induced significant morphological and physiological changes in non-embryonic calli toward somatic embryos (SE) formation that. Another type of discharge was used for treatment of synthetic seeds of several Chrysanthemum varieties. We have used Dielectric Barrier Discharge (DBD) that operates in air at 50Hz frequency. The difficulties related to sowing them under non-sterile conditions (common soil) are considered to be one of the main limitations of the wide practical use of Synthetic Seeds technique. Here we will show the influence of cold plasma treatment on germination, plant growth and development of plantlets sowed in sterile and in ex vitro conditions.

Keywords: atmospheric pressure plasma, Plasma Agriculture, non-equilibrium discharge, plant calli, synthetic seeds.

Acknowledgments: This publication is based upon work from COST Action "Plasma applications for smart and sustainable agriculture (PlAgri)", supported by COST (European Cooperation in Science and Technology).

References:

1. Puač, N., Gherardi, M., Shiratani, M. (2017) Plasma agriculture: A rapidly emerging field, *Plasma Process Polym.*, 15(2), e1700174.
2. Bourke, P., Ziuzina, D., Boehm, D., Cullen, P.J., Keener, K. (2018) The Potential of Cold Plasma for Safe and Sustainable Food Production, *Trends in Biotechnology*, 36(6), 615-626.

Multifuncional transparent oxide thin films for photocatalytic and antimicrobial applications

J.G. Cuadra[1], S. Molina-Prados[2], Gladys Mínguez-Vega[2], Ana. C. Estrada[3], T. Trindade[3], C. Oliveira[4], M.P. Seabra[5], J. Labrincha[5], S. Porcar[1], R. Cadena[1] , D. Fraga[1], J.B. Carda[1]

[1] Department of Inorganic and Organic Chemistry, Universitat Jaume I, Avda. Sos Baynat s/n, 12071, Castellon, Spain

[2] GROC-UJI, Institute of New Imaging Technologies, Universitat Jaume I, Avda. Sos Baynat s/n, 12071 Castellon,Spain

[3]Department of Chemistry, CICECO-Aveiro Institute of Materials, University of Aveiro, 3810-193 Aveiro, Portugal

[4] Department of Biology, CESAM, University of Aveiro, Campus Universitário de Santiago, 3810-193, Aveiro, Portugal

[5] Materials and Ceramic Engineering Department, CICECO, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

Abstract:

Over the past few years, the interest in thin film technology has grown greatly due to its wide range of applications such as photovoltaic solar cells [1], energy storage [2], heterogeneous photocatalysis or antimicrobial action [3]. In addition, as a consequence of the COVID-19 pandemic, the development of antivirus and antimicrobial materials has become increasingly relevant all over the world. Accordingly, the possibility of being able to functionalize diverse types of surfaces without changing their optical properties has become a priority. Transparent TiO_2 thin films coated with Ag NPs were synthesized using two industrially applicable techniques,pulsed laser ablation (PLAL) and spray pyrolysis without using high vacuum. These transparent thin films were deposited on glass in order to generate glass materials with photocatalytic and antimicrobial properties and a minimum loss of transparency. The structural, morphological and optical properties of the thin films were examined using Grazing incidence X-ray diffraction (GIXRD), Raman spectroscopy, Scanning electron microscopy (SEM) and ultraviolet-visible spectroscopy. Transmission electron microscopy (TEM) was used to identify the NPs on the TiO_2 surface. The transmittance value for the thin films was greater than 80%.The thin films thus synthesized were then assessed to determine their photocatalytic capacity by monitoring the degradation of Rhodamine B (RhB) under UV light irradiation. Ag NPs on the TiO2 surface ensures an improvement in the photocatalytic properties, with a 99% degradation of RhB in 210 minutes under UV light. In addition, these transparent thin films showed high antimicrobial activity on Gram-negative bacteria when irradiated by UV light for 4 hours, killing 93% of these bacteria.

Keywords: Transparent thin films; Spray pyrolysis; Laser ablation; Antimicrobial activity; Photocatalysis.

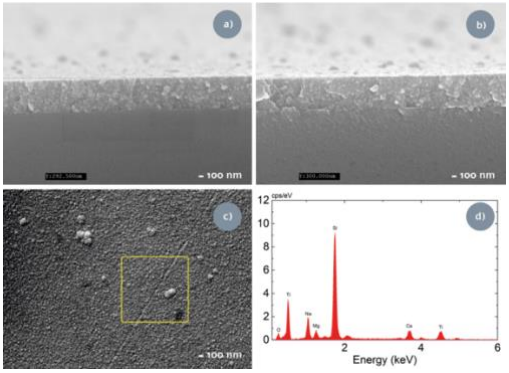


Figure 1: SEM images for the cross section of(a) TiO2 transparent thin films, (b) TiO2-Ag NPs, (c) top surface of TiO2, and (d) EDS spectra for the surface of TiO2.

References:

1. C. Doroody, K.S. Rahman, T.S. Kiong, N. Amin, Optoelectrical impact of alternative window layer composition in CdTe thin film solar cells performance, Sol. Energy. 233 (2022) 523–530. https://doi.org/10.1016/j.solener.2022.01.049.
2. S. Tyagi, A. Kumar, A. Kumar, Y.K. Gautam, V. Kumar, Y. Kumar, B.P. Singh, Enhancement in the sensitivity and selectivity of Cu functionalized MoS2 nanoworm thin films for nitrogen dioxide gas sensor, Mater. Res. Bull. 150 (2022) 111784. https://doi.org/10.1016/j.materresbull.2022.111784.

3. J.G. Cuadra, S. Molina-Prados, G. Mínguez-Vega, A.C. Estrada, T. Trindade, C. Oliveira, M.P. Seabra, J. Labrincha, S. Porcar, R. Cadena, D. Fraga, J.B. Carda, Multifunctional Silver-Coated Transparent TiO2 Thin Films for Photocatalytic and Antimicrobial Applications, Appl. Surf. Sci. 617 (2023) 156519. https://doi.org/10.1016/j.apsusc.2023.156519.

In vitro Analysis of Plasma Activated Water: A Step Toward Effective Plasma Medicine

A. Megía-Macías [1,*], O.D. Cortázar [2], , Sandra Moreno[3], Alejandro Brun[3], Yolanda Ballesteros[1] & Eduardo Gómez-Casado[4]

[1] Mechanical Engineering Department, ICAI/Institute for Research in Technology, Comillas Pontifical University, Alberto Aguilera, 23, 28015 Madrid, Spain.
[2] MEDICAL PLASMAS S.L., R&D Department, Plaza CEIN 5, Pol. Innovac. CEIN, 31110 Noain, Navarra, Spain.
[3]Animal Health Research Center (CISA, INIA-CSIC), National Research Institute of Agricultural and Food Technology (CSIC-INIA), Crta. de Valdeolmos-El Casar s/n - 28130, Madrid, Spain.
[4]Department of Biotechnology, National Research Institute of Agricultural and Food Technology (INIA-CSIC), Crta. de la Coruña, km 7.5, 28040 Madrid, Spain.

Abstract:
The medical community has recently shown a great interest in Plasma Activated Media (PAM), due to their potential for delivering Reactive Oxygen and Nitrogen Species (RONS) on surfaces without encountering the limitations posed by direct application of cold plasma. This has opened up a vast and exciting field of research in plasma medicine [1].
In this study, we aimed to explore the effects of Plasma Activated Water (PAW) on in-vitro experiments involving bacteria and viruses. Our experiments were carried out with the utmost care and precision to ensure the validity of our results.
The results of our experiments were highly encouraging. PAW was found to significantly reduce the infectivity of viruses and inhibit their replication in infected cells, without causing any measurable harm to the cells or inducing inflammation. The treatment was also lethal to the bacterium Pseudomonas Aeruginosa, demonstrating its potential for effectively targeting and eliminating harmful microorganisms.
In order to optimize the delivery of RONS and to determine the relative concentrations of different species, we used emission UV-VIS spectra obtained from the jet of cold atmospheric plasma during water activation, and absorption spectra of the PAW, to gain a deeper understanding of the molecular species present in the solution.
The results of this study have the potential to be highly impactful, not just in the field of plasma medicine, but also in the broader field of microbiology and infectious disease research. The ability of PAW to effectively target and eliminate harmful microorganisms without causing harm to healthy cells is a major advancement in the fight against infections and disease. The optimization techniques we employed in the study could also be used in the development of new and more effective plasma-based treatments, which could have far-reaching implications for human health.

Keywords: Plasma Activated Media, Reactive Oxygen and Nitrogen Species, Antimicrobial effect, Plasma medicine, Cold plasma, UV-VIS spectra, Absorption spectra.

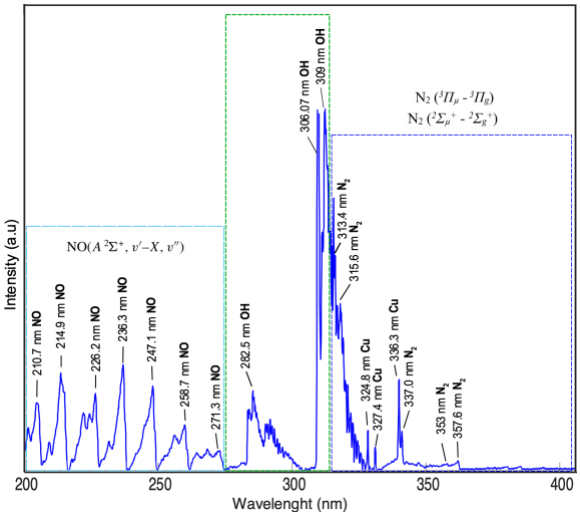


Figure 1: UV spectrum of air atmospheric plasma during the water activation process.

References:

1. Kostya (ken) Ostrikov et al., "Plasma-activated water: Generation, origin of reactive species and biological applications," J. Phys. D. Appl. Phys., vol. 53, no. 30, 2020.

A Step Forward in Ulcer Management: The Clinical Findings of Cold Plasma Therapy for Torpid Ulcers in Legs

A. Megía-Macías [1,*], O.D. Cortázar [2], B. Hontanilla[3]

[1] Mechanical Engineering Department, ICAI/Institute for Research in Technology, Comillas Pontifical University, Alberto Aguilera, 23, 28015 Madrid, Spain.
[2] MEDICAL PLASMAS S.L., R&D Department, Plaza CEIN 5, Pol. Innovac. CEIN, 31110 Noain, Navarra, Spain.
[3] Clínica Universidad de Navarra. Department of Plastic and Reconstructive Surgery. Av. Pio XII 36, 31008 Pamplona, Spain.

Abstract:
Chronic Ulcers, particularly Venous Ulcers, are prevalent in medical practices and pose a significant negative impact on the quality of life of patients and the global healthcare system. In recent years, the use of Cold Atmospheric Plasma (CAP) treatment has gained increased attention in the medical community, with promising results [1], [2].
This study presents preliminary clinical results obtained from the use of a Cold Atmospheric Air Plasma Jet device in a clinical trial of chronic ulcers in the legs at Clínica Universidad de Navarra in Pamplona, Spain. The results show several cases of successful recovery and the selection of the most challenging patients with large ulcerated areas and previous pathologies that resulted in exhausted tissues.
Additionally, the study presents two interesting cases in which previous attempts at closing the ulcers using grafts were unsuccessful. The innovation in these cases consisted of using the air plasma jet to improve the vascularization of the ulcerous tissues before performing a new graft, with the intention of increasing the likelihood of its acceptance. The results of this new technique are highly encouraging.
Overall, these preliminary results demonstrate the potential of Cold Atmospheric Plasma as an effective treatment for chronic ulcers, particularly venous ulcers, and open up new possibilities for future research in this field.

Keywords: Plasma, Cold Atmospheric Plasma, Treatment, Venous Ulcers, Torpid Ulcers, Clinical Trial, Air Plasma Jet.

Figure 1: Evolution of a Venous Ulcer in a 94 years old patient.

References:

1. B. Stratmann et al., "Effect of Cold Atmospheric Plasma Therapy vs Standard Therapy Placebo on Wound Healing in Patients With Diabetic Foot Ulcers: A Randomized Clinical Trial," JAMA Netw. open, vol. 3, no. 7, p. e2010411, 2020.
2. S. Mirpour et al., "Cold atmospheric plasma as an effective method to treat diabetic foot ulcers: A randomized clinical trial," Sci. Rep., vol. 10, no. 1, pp. 1–9, 2020.

Treatment of microalgae by gliding arc plasma and pulsed electric field

L. Marcinauskas[1,2*], K. Jonynaitė[3], R. Uscila[1], A. Stirkė[3], Ž. Kavaliauskas[1], M. Aikas[1], S. Keršulis[3], V. Stankevič[3]
[1]Plasma Processing Laboratory, Lithuanian Energy Institute, Kaunas, Lithuania
[2]Kaunas University of Technology, Kaunas, Lithuania
[3] Department of Functional Materials and Electronics, Center for Physical Sciences and Technology, Vilnius, Lithuania

Abstract:
Microalgae have been identified as a very promising candidates for energy and high-value products. A major challenge for extracting valuable compounds such as proteins, lipids, carotenoids, etc. from microalgae is their strong and rigid cell wall [1-2]. Various biological, chemical, and physical technologies are used to effectively disrupt the cell of algae and increase the efficiency of extraction of valuable compounds. The pulsed electric field (PEF) and plasma treatment could be used as an effective combination to improve the efficiency of extraction [1-3]. The main aim was to investigate the effect of a combination of PEF and gliding arc discharge (GAD) plasma treatment on microalgae.

The GAD plasma and PEF technologies were applied for treatment of *Chlorella vulgaris*. The microalgae were cultivated in a photobioreactor using BG-11 medium for 7 days before harvest. The plasma irradiation was done using GAD plasma system. The compressed air (flow rate ~22.8 L/min) was used for plasma formation. The distance between the "knife-edge" type electrodes and surface of the algae suspension was 30 mm, duration 300 s, power supply output voltages 50–250 V and frequency 270 kHz. PEF treatment was done using a high-voltage exponential wave pulse generator. The single pulse duration was ~10 μs, number of pulses 1 and 10, repetition frequency 1 Hz and electric field strength 23-25 kV/cm. Air plasma composition was determined using an acousto-optic emission spectrometer**.** The nitrate, nitrite and hydrogen peroxide concentrations in algae suspension before and after plasma treatment were investigated using commercial test and protocols. The electrical conductivity, pH values, cell permeability, extracted protein content and optical density were determined in algae suspension after GAD plasma and/ or PEF treatment.

It was obtained that the chlorophyll a content, cell density, pH values, conductivity, and viability of microalgae depended on the GAD plasma and PEF treatment conditions very strongly. The enhancement of the plasma discharge voltage increased the amount of nitrogen species in air plasma and resulted a higher concentration of nitrate and nitrite in microalgae suspension and supernatant. The pH values were reduced, while the conductivity of microalgae suspension was enhanced with the increase of plasma discharge voltage. No changes in protein concentrations were observed when considering the direct effect of plasma on the BSA protein suspension. However, the increase of signal intensity and the blue shift of the peak observed in the fluorescence spectra are indicative of a plasma-induced conformational change in the protein. The extracted protein concentration from microalgae was slightly increased when the combination of GAD plasma (at lower discharge voltages) and PEF treatment was used.

Keywords: plasma, pulsed electric field, microalgae, protein concentration, viability of the algae.

Acknowledgment: This work was supported by the Research Council of Lithuania under Grant P-MIP-22-257.

References:

1. Zhou, J., Wang, M., Saraiva, J. A. et al., (2022), Extraction of lipids from microalgae using classical and innovative approaches, Food Chemistry, 384, 132236.
2. Carullo, D., Pataro, G., Donsi, F., Ferrari, G. (2020), Pulsed Electric Fields-Assisted Extraction of Valuable Compounds From Arthrospira Platensis: Effect of Pulse Polarity and Mild Heating, *Front. Bioeng. Biotechnol.*, 8, 551272.
3. Matos, A.P. Teixeira, M.S. et al. (2019), Disruption of *Nannochloropsis gaditana* (Eustigmatophyceae) rigid cell wall by non-thermal plasma prior to lipid extraction and its effect on fatty acid composition. *Braz. J. Chem. Eng.*, 36, 1419-1428.

Cold Atmospheric Plasma treatment of in-vivo B16/F10 Melanoma cancer cells and the immunological responce

Shahriar MASHAYEKH[1] ,Shengyong YIN[2], Zhen LIU[1*], Keping YAN[1]
[1] Institute of Industrial Ecology and Environment, Zhejiang University, Hangzhou, China
[2] The First Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China

Abstract:
Cold atmospheric plasma applications in medical fields such as cancer therapy has been in center of attention for the last decade. Although the exact mechanisms are still unknown the results has been acceptable. The effectiveness of such treatments has been reported many times by different research groups especially in in-vitro conditions over different kinds of cancer cells [1-3]. The reactive oxygen and nitrogen species generated by cold atmospheric plasma has been regarded to plat the main role mostly by inserting excessive oxidative stress on the cancer cells which could lead to either apoptosis or necrosis. The situation is more complex with in-vivo studies since a series of complicated interactions are involved. In this study and thorough in-vivo research on B16/F10 cancer cells injected subcutaneously into C57 mice were implemented. Tumor growth and progression were observed in three different groups. As a possibility the effect of the melanin in skin was also considered by making a new group with skin removal before each treatment. Aside from decreasing the tumor growth the most important factor was the Immunohistology assays to evaluate the immune system involved. The Immune Histo Chemistry (IHC) assays involved were CD45 (Leukocytes-all types of WBCs) and CD8 (Cytotoxic T-cells). In both cases a significant difference were observed and was in correlation with the tumor size. Liver enzymes of the mice such as ALT, AST and LDH were also measured which could indicate a progress in the treatment process. Although other complementary studies are required to detect the exact mechanisms and effects of CAP on immune cells such as white blood cells, this results could also be implemented in unexposed cancers if an immune cell treated plasma could be more effective in the process.

Keywords: Cold Atmospheric Plasma (CAP), Melanoma Cacner, Cancer therapy, Immunological response, CD45, CD8

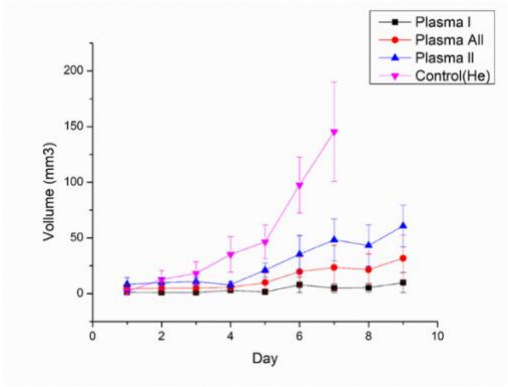


Figure 1: Tumor size progression of each group after daily treatment of CAP for 5 mins. The group of mice which their skin where removed before each treatment is indicated as Plasma I. Plasma II groups are the mice with intact skin. Plasma All is the average of the two groups.

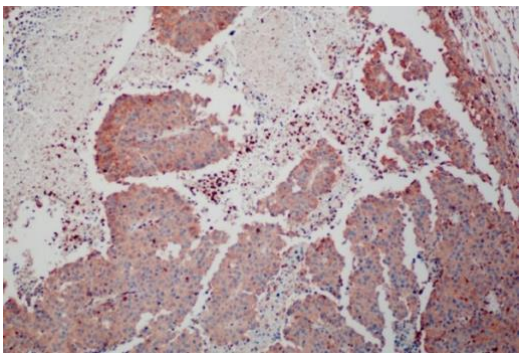


Figure 2: IHC CD8 assay for Cytotoxic T-ells of a plasma treated samples. The blue dots represents the T-cells which are highly visible within the cancer tissue

References:

1. Liedtke, K.R., et al., *A myeloid and lymphoid infiltrate in murine pancreatic tumors exposed to plasma-treated medium.* Clinical Plasma Medicine, 2018. **11**: p. 10-17.
2. Azzariti, A., et al., *Plasma-activated medium triggers cell death and the presentation of immune activating danger signals in melanoma and pancreatic cancer cells.* Scientific Reports, 2019. **9**(1): p. 4099.
3. Yan, D., J.H. Sherman, and M. Keidar, *Cold atmospheric plasma, a novel promising anti-cancer treatment modality.* Oncotarget, 2017. **8**(9): p. 15977-15995.

Plasma Polymerized Nano particles: Synthesis, Diagnostics, and Biofunctionalization

L. L. Haidar [1], M. M. M. Bilek [1,2], B. Akhavan [1,2,3]
[1] School of Physics, University of Sydney, Sydney, Australia
[2] School of Biomedical Engineering, University of Sydney, Sydney, Australia
[3] School of Engineering, University of Newcastle, Sydney, Australia

Abstract:
The functionalization of polymeric nanoparticles typically requires wet-chemical treatment followed by multiple purification steps which result in increased costs. Polymeric nanoparticles synthesized in a low-temperature plasma exhibit ideal properties for their functionalization as organic carriers of bioagents. Due to the plasma chemical reactions that govern their formation, such nanoparticles are constructed with embedded reactive radicals that facilitate their surface functionalization with therapeutic and diagnostic agents [1]. We report the dry synthesis and characterization of plasma polymerized nanoparticles (PPNs) produced in a low-pressure radio-frequency acetylene, argon, and nitrogen plasma [2]. We elucidate the relationship between parameters such as chamber pressure, applied power, and geometry, and the plasma behaviour using a continuum model of a capacitively-couple radio-frequency discharge [3]. We also utilize electrical diagnostics such as Langmuir Probe and optical emission spectroscopy of the reactive species to further understand the mechanisms behind the nanoparticle formation. We complement their synthesis with the characterization of their physical and chemical properties. We demonstrate the facile attachment of bioconjugates, such as fluorophore and protein models in a single-step incubation, through radical reactions (Figure 1). The reagent-free conjugation process on polymeric nanoparticle presented here holds enormous potential to accelerate the engineering of biomedical nanocarriers for a wide range of modern application from *in-situ* bioimaging and tumour targeting to bioactive delivery.

Keywords: plasma polymerization, nanoparticles, capacitively coupled radio frequency discharge, nanocarriers, surface functionalization, simulation, plasma diagnostics, biomedical applications.

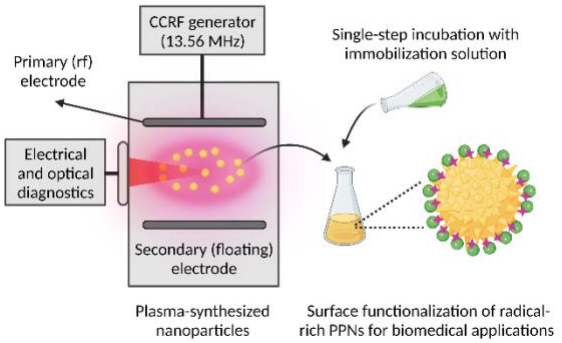


Figure 1: Figure illustrating the facile synthesis and functionalization of plasma-polymerized nanoparticles overcoming the challenges faced by traditional wet-chemistry to achieve immobilization on the surface of nanocarriers of biomedical moieties.

References:

1. Santos, M., et al., Plasma synthesis of carbon-based nanocarriers for linker-free immobilization of bioactive cargo. ACS Applied Nano Materials, 2018. 1(2): p. 580-594.
2. Haidar, L.L., et al., Surface-Active Plasma-Polymerized Nanoparticles for Multifunctional Diagnostic, Targeting, and Therapeutic Probes. 2022. 5(12): p. 17576-17591.
3. Baldry, M., et al., Continuum modelling of an asymmetric CCRF argon plasma reactor: Influence of higher excited states and sensitivity to model parameters. 2021. 18(6): p. 2000243.

SICT 2023 / Plasma Tech 2023
Joint Session II. C:
Plasma fundamentals / Modelling / Atomic and Molecular Processes
Plasma Processing / Materials Interactions / Coatings

Particle fluxes towards surfaces in plasma processing: Are probe diagnostcs still in vogue?

H. Kersten, T. Trottenberg, L. Hansen, M. Klette, F. Schlichting, V. Schneider, A. Spethmann
Institute for Experimental and Applied Physics, University Kiel, Kiel, Germany

Abstract:
The diagnostics of electrons and ions in plasmas and the fluxes of charged and neutral species toward plasma-facing surfaces by non-optical methods will be discussed. The focus is laid on the fundamentals of the most common methods and their application to non-equilibrium plasmas and ion beams. The topics include Langmuir probes (LPs), Faraday cups (FCs) and retarding field analyzers (RFA), as well as novel calorimetric and force probes (CPs, FPs) [1]. These rather simple methods are useful tools for the measurement of overall, not species resolved, ions and neutral species fluxes toward surfaces. For example, RFAs provide overall ion energy distribution functions (Fig. 1), whereas CPs and FPs can even deliver information about fluxes of fast neutrals.
Although many of these diagnostics have their roots in the beginnings of plasma research, they were gradually refined to match the requirements of plasma environments in industry, such as rf-discharges, reactive plasmas, dusty plasmas, and atmospheric pressure plasmas. Examples for novel "non-conventional" diagnostics, which are applicable in plasma processes, are the determination of the total energy fluxes from plasma to substrate by calorimetric probes [2,3] and the measurement of momentum transfer due to sputtered particles or changes of plasma pressure by force probes [4,5].
Most of the discussed methods will stay for sure a workhorse in the future plasma research, where the fast-growing computational power allows for correct analysis and simulation of more complex situations including highly collisional sheaths or magnetic fields. Furthermore, the current trend in the miniaturization of sensors, adopted from the manufacturing of MEMS, will allow measurements with high spatial resolution in miniaturized plasma sources, like plasma jets or micro discharges.

Keywords: probe measurements, plasma diagnostics, calorimetric probe, force probe, plasma surface interaction, plasma processing

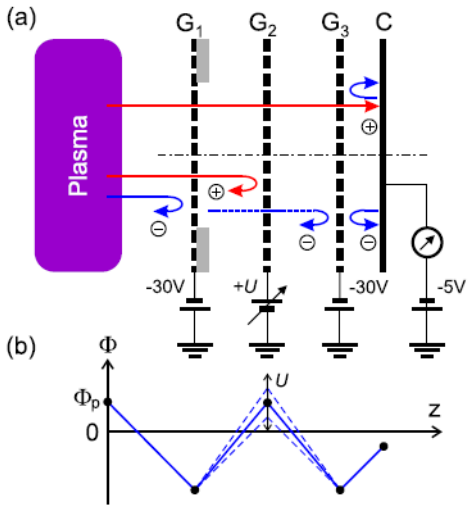


Figure 1: (a) Triple grid RFA with typical grid biases for positive ion analysis in low-temperature plasmas. (b) Schematic potential distribution. The discriminator grid G2 forms the energy barrier for positive ions [1].

References:

1. J. Benedikt, H. Kersten, A. Piel, "Foundations of measurement of electrons, ions and species fluxes toward surfaces in low-temperature plasmas", Plasma Sources Sci. Technol., Vol.30, 033001, 2021.
2. H. Kersten, H. Deutsch, H. Steffen, G.M.W. Kroesen, R. Hippler, "The energy balance at substrates during plasma processing", Vacuum, Vol. 63, pp 385-431, 2001.
3. S. Gauter, F. Haase, H. Kersten, "Experimental unraveling the energy flux originating from a DC magnetron sputtering source", Thin Solid Films, Vol. 669, pp. 8-18, 2019.
4. T. Trottenberg, A. Spethmann, H. Kersten, "An interferometric force probe for beam diagnostics and the study of sputtering", Eur. Phys. J. TI, Vol. 5, 3, 2018.
5. M. Klette, et.al., "Directionally resolved measurements of momentum transport in sputter plumes as a critical test for simulations", J. Vac. Sci. Technol. A, Vol. 38, 033013, 2020.

Studies in the sheath of an asymmetric CCP with an optically trapped microparticle

V. Schneider[1], J. Schleitzer[1], H. Kersten [1]
[1] Institute of Experimental and Applied Physics, Christian-Albrechts-University Kiel, Germany

Abstract:
Applications of low-temperature plasmas range from etching processes and coatings of solids to plasma medicine and basic research. Important plasma parameters such as density, temperature or composition of the species are diagnosed using many established methods [1]. However, it is difficult to probe the extremely important sheath region, which is only a few millimeters thick and, thus, not accessible with macroscopic probe methods, as they themselves change the plasma.
In recent years, therefore, microparticles have been qualified as probes for so-called non-conventional plasma diagnostic purposes. Due to their size and their behavior in the plasma, they, in particular, are well suited for increasing the spatial resolution and, thus, providing information in addition to common diagnostics [2].
In this study SiO2 microparticles are in an optical trap to manipulate them in the environment of a capacitively coupled asymmetric radio frequency discharge. In contrast to common plasma diagnostic tools (e.g. Langmuir probes, calorimetric probes, mass spectrometers etc.), in the µPLASMA (microparticles in a discharge with laser assisted manipulation) experiment particles can be regarded as noninvasive single probes [3,4]. The displacement of the particle in the laser trap is observed to measure a force while it is moving relatively to the plasma, either deeper into the sheath or into the plasma bulk.
Force profiles at different pressures and rf-powers have been performed in the sheath of an asymmetric capacitively coupled plasma. The force is mainly determined by the particle charge and the electric field in the sheath region. Thus, the measured force while moving a single particle from the bulk plasma towards the electrode surface show a characteristic profile with a maximum and a descrease close to the electrode (Fig. 1).

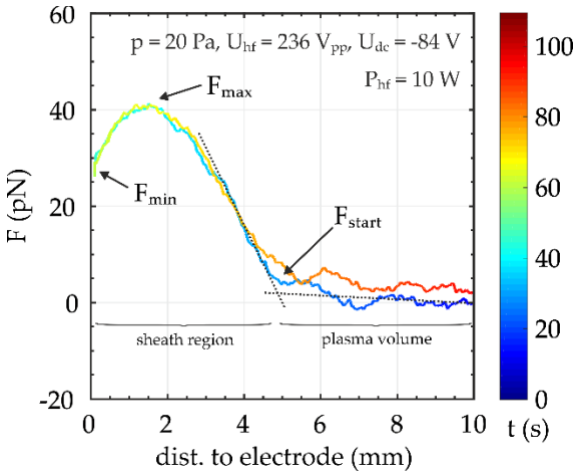


Figure 1: Measured force profile while moving a single particle in the sheath of a CCP from the bulk plasma towards the electrode surface.

Keywords: plasma diagnostics, radiofrequency discharges, plasma sheath, optical trap, force measurement, microprobe, residual charge

References:

1. J. Benedikt, H. Kersten and A. Piel 2021 Plasma Sources Sci. Technol. 30 pp 033001
2. H. R. Maurer, V. Schneider, M. Wolter, R. Basner, T. Trottenberg and H. Kersten 2011 Contrib. Plasma Phys. 51 pp 218-227
3. V. Schneider and H. Kersten 2018 Rev. Sci. Instrum. 89 pp 103505
4. J. Schleitzer, V. Schneider and H. Kersten, 2021 Phys. Plasmas 28 pp 083506

Langmuir probe measurements in a dual-frequency capacitively coupled rf discharge

J. Schleitzer [1], V. Schneider [1] and H. Kersten [1]
[1] Institute of Experimental and Applied Physics, Christian-Albrechts-University, Kiel, Germany

Abstract:
The standard (industrial) frequency for common capacitively coupled rf plasmas used in technology is 13.56 MHz. A difference in the area of the electrodes results in a negative dc self-bias voltage at the powered electrode. The gas pressure in the device and the dc self-bias mainly determine the sheath potential and, thus, the ion current density and the ion energy towards the electrode surface. An independent control of these important properties - especially in industrial applications - is desirable but usually not possible. By adding a second frequency (1st harmonic, 27.56 MHz), a so-called electrical asymmetry effect (EAE) $U_{\mathrm{rf}} = 1/2\, U_0[\cos(\omega_{\mathrm{rf}}t + \theta) + \cos(2\omega_{\mathrm{rf}}t)]$ is created, which enables the control of the bias voltage and, thus, the ion energy almost independent of the ion flux by varying the relative phase θ between the two harmonics, while other discharge parameters, e.g. gas pressure, stay constant [1].
The number of Langmuir probe measurements performed in such a discharge amounts to a minimum [2]. By using a specially designed Langmuir probe based on a passive compensation method [3-5] in this dual-frequency (2f-) plasma, it can be determined to what extend the important plasma parameters, i.e. electron density and electron temperature, change with a variation of the phase between the two harmonics. This work aims to provide data from electrostatic probes for a deeper insight into the general behavior of these parameters and a better understaning of this 2f-plasma.
The measurements have been performed in two different 2f-plasma chambers (CAU Kiel and Ruhr-University Bochum), showing different dependencies of the parameters on the phase (shown exemplarily in Fig. 1,2).

Keywords: phase variation, radiofrequency discharges, Langmuir probe, plasma diagnostics, electrical asymmetry effect, physical quantities

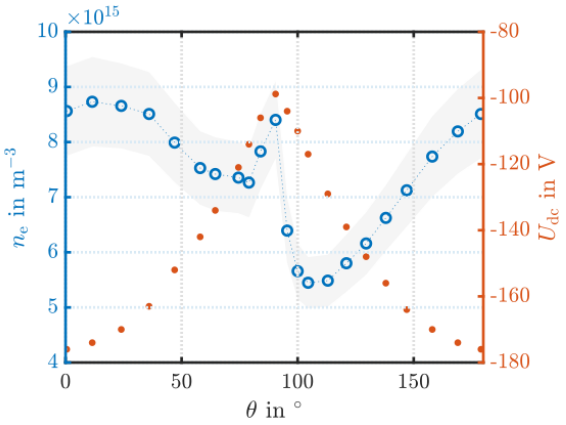


Figure 1: Figure showing the electron density n_{e} and dc self-bias U_{dc} as a function of the relative phase θ between the two harmonics at 5 Pa and $U_0 \approx 187$ V in the microsys chamber in Kiel. While U_{dc} is symmetric around $\theta = 90°$, n_{e} shows a prominent asymmetry.

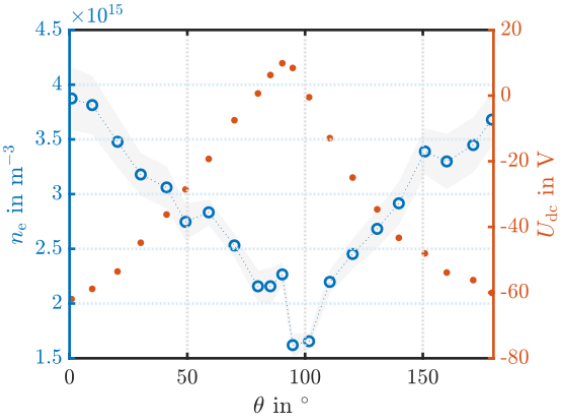


Figure 2: Figure showing the electron density n_{e} in the Bochum chamber at 5 Pa and $U_0 \approx 111$ V. Here, n_{e} is symmetric around $\theta = 90°$.

References:

1. J. Schulze et al., J. Phys. D: Appl. Phys. 42(2009), 092005.
2. S. Bienholz et al., J. Phys. D: Appl. Phys. 46(2013), 084010.
3. A. P. Paranjpe et al., J. Appl. Phys. 67(1990), 6718.
4. A. E. Wendt, Rev. Sci. Instrum. 72(2001), 2926.
5. R. R. J. Gagne and A. Cantin, J. Appl. Phys. 43(1972), 2639.

Simulation of facility effects on magnetic nozzle expansions.

Diego García-Lahuerta [*], Mario Merino , Eduardo Ahedo

[1] Equipo de Propulsion Espacial y Plasmas, Universidad Carlos III de Madrid, Leganés, Spain

Abstract:
Electrodeless Plasma Thrusters (EPTs) promise many advantages over traditional electric propulsion devices. However, this kind of thrusters is still underperforming in terms of efficiency in comparison with mature technologies such as Hall effect (HET) and gridded ion thrusters (GIT). One of the main characteritics of EPTs is the guided expansion of the low temperature plasma into a divergent magnetic field region known as the magnetic nozzle that confines the plasma radially and accelerates it axially.
Vacuum facility background pressure is known to affect the expansion of plasma in HET. However, the effect of this background pressure has not been thoroughly studied in magnetic nozzles. Here we model the expansion and acceleration of plasma in a magnetic nozzle immersed in a background of neutrals. The model consists of a two fluid plasma, consisting of mass-less, warm, perfectly-magnetised electrons and cold weakly magnetized ions[1]. Collisions are not considered except for the ionization collisions against the constant density background of neutrals. Under this assumptions the equations for the electrons are found to be algebraic while the ion equations are integrated using a Discontinuous Galerkin FEM scheme. This way we obtain the maps for the most relevant plasma properties and the thrust produced by the nozzle.

Keywords: electric propulsion, space propulsion, plasma physics, magnetic nozzles, low temperature plasmas, facility effects.

References:

1. E. Ahedo and M. Merino, “Two-dimensional supersonic plasma acceleration in a magnetic nozzle” PHYSICS OF PLASMAS 17, 073501 2010.

Acknowledgment
This project has received funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme (grant agreement No 950466).

First Characterisation of a Dual ECR Thruster

C. Boyé [1], J. Navarro [1], M. Merino[1]
[1] Plasma & Space Propulsion Team, Bioengineering and Aerospace Engineering Department, University Carlos III de Madrid, Leganés, Spain, 28911

Abstract:
Existing Electrodeless Plasma Thrusters (EPTs) such as the Helicon Plasma Thruster (HPT) or the Electron-Cyclotron Resonance Thruster (ECRT) consist of a cylindrical ionization vessel into which propellant is injected, and an external magnetic nozzle to expand the plasma and generate magnetic thrust[1,2].One of the major drawbacks is the magnetic nozzle, which imprints a high divergence angle to the plasma jet, increasing radial losses and creating a highly energetic plasma environment around the spacecraft[3]. As a consequence of this issue, EPTs have not yet proved competitive in terms of performances in comparison with mature technologies like Hall effect and gridded ion thrusters.

This work proposes and explores a new geometry for an EPT based on the interaction of two ECR sources and presents the design and experimental characterisation of its laboratory prototype.

The MAT2 thruster, illustrated in Figure 1, consists of two identical ECR sources, each constituted of four main parts: (1) a first coil meant to produce a sufficient magnetic field strength to enable Electron-Cyclotron Resonance (ECR) of the plasma, (2) a magnetic nozzle coil, (3) cylindrical ionization vessel and (4) an antenna allowing the transmission of the microwave power to ionize the neutral gas by ECR. The sources can be estranged one from another and can be tilted around their center. The main interest of this geometry lies on one key factor . The magnetic arch topology that forms outside of the thruster as the magnetic lines of the two magnetic nozzles with opposing polarity connect features a lower divergence than a single diverging, axisymmetric magnetic nozzle, and different expansion physics where the plasma-induced magnetic field is expected to play a major role. The MAT2 represents more a new type of EPTs than a simple combination of existing ones based on its magnetic arch and on the interaction in between the sources.

Moreover, the external expansion and interaction of the jointed plumes is placed at the center of this work as the new magnetic topology implies the possibility of enabling thrust vectoring and improved performances. Opposed polarity magnetic nozzles also arise new questions around the detachment of the plasma and its effects on the thruster's characteristics.

Magnetic probe, Langmuir probe and Faraday cup measurements are carried out on the plume region of the MAT2 thruster prototype to characterise key plasma properties including plasma density, electron temperature, electrostatic potential, magnetic field, and ion current density.

Keywords: electric propulsion, electrodeless plama thrusters, magnetic nozzles, space propulsion, low temperature plasmas, electron cyclotron resonance thrusters, microwaves.

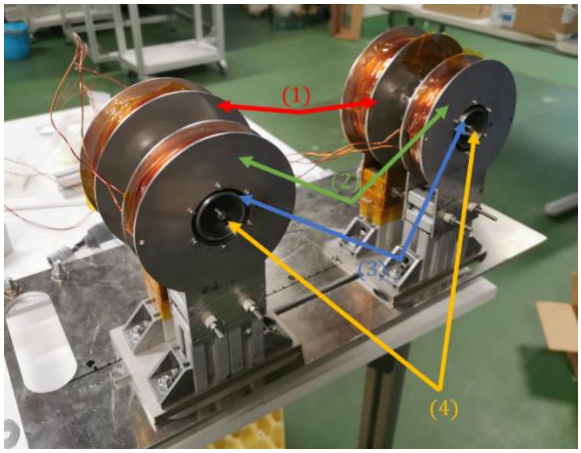


Figure 1: Photography of the prototype of the MAT2 thruster ; (1) Main coils, (2) Magnetic nozzle coils, (3) Ionization chambers, (4) Microwave power coupling system.

References:

1. Bathgate, S., Bilek, M., McKenzie, D. (2017), Electrodeless plasma thrusters for spacecraft: a review, *Plasma Science and Technology*,Vol. 19, No. 8, p. 083001.
2. Takahashi, K. (2019), Helicon-type radiofrequency plasma thrusters and magnetic plasma nozzles, *Reviews of Modern Plasma Physics*,Vol. 3, p. 3.
3. Merino, M., Ahedo, E. (2016), Magnetic Nozzles for Space Plasma Thrusters, *Encyclopedia of Plasma Technology*,Vol. 2, Edited by J. L. Shohet, Taylor and Francis, pp. 1329-1351.

Complex plasma with active Janus particles

V. Nosenko [1]
[1] Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), D-51147 Cologne, Germany

Abstract:
A two-dimensional complex plasma containing active Janus particles was studied experimentally [1]. A single layer of micrometer-sized plastic microspheres was suspended in the plasma sheath of a radio-frequency (rf) discharge in argon at low pressure. The particle sample used was a mixture of regular particles and Janus particles, which were coated on one side with a thin layer of platinum. The experiments were carried out in a modified Gaseous Electronics Conference (GEC) rf reference cell. Plasma was produced by a capacitively coupled rf discharge in argon at 13.56 MHz. The gas pressure was 1.66 Pa, the discharge rf power was 20 W.

As expected, the regular melamine-formaldehyde (MF) particles formed a two-dimensional triangular lattice (plasma crystal) in our experimental conditions. The lattice consisted of ≈ 1900 particles and was highly ordered, as evidenced by the pair correlation function for particles g(r) with the high first and split second peaks.

On the contrary, the suspension of the mixed Janus particles did not crystallize. Instead, the particles energetically moved around colliding with each other. The pair correlation function for the mixed Janus particles g(r) indicates a highly disordered (gas-like) state.

The mean-squared displacement MSD(t) of the mixed Janus particles is shown in Fig. 1(a). It scales as MSD(t) ∝ t^{α} with α = 2 at small times $t \ll \gamma^{-1}$, where γ is the neutral-gas damping rate for the particles, indicating ballistic motion. Here, the particle inertia is important. At later times, the dynamical exponent $\alpha(t)$ declines, finally reaching the value of ≈ 0.56, see Fig. 1(b). We ascribe this to the combined effect of the Janus particle propensity to move in circular trajectories due to a combination of the photophoretic force from the illumination laser and the oppositely directed ion drag force [2] and external confinement.

Keywords: complex plasma, active matter, Janus particles, plasma coating.

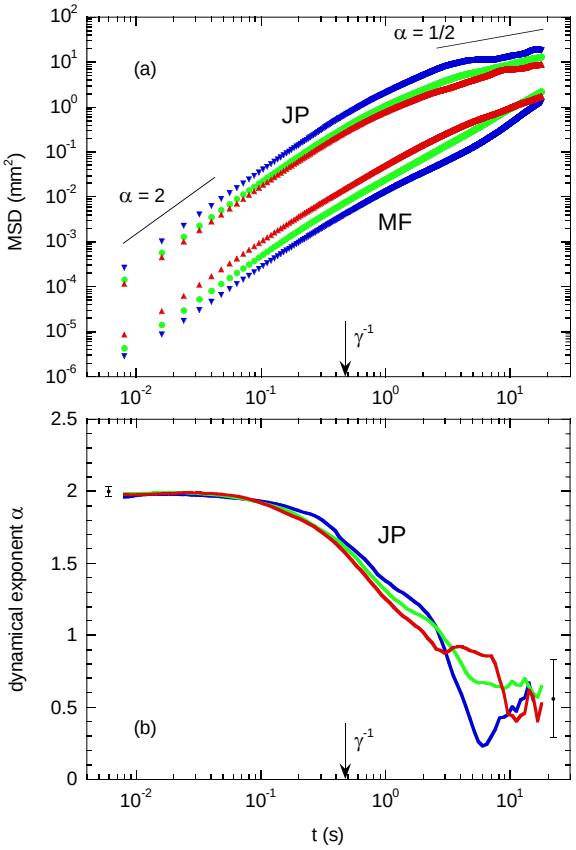


Figure 1: (a) Mean-squared displacement MSD(t) of the mixed Janus particles (upper curves) and regular MF particles (lower curves). (b) Dynamical exponent α for the mixed Janus particles. The left (right) error bars are for t < 2 s (t > 2 s). The illumination laser power was 14 mW (blue down triangles and lines), 76 mW (green circles and lines), and 99 mW (red up triangles and lines). The inertial delay time $\tau_m = \gamma^{-1}$, where γ is the neutral-gas damping rate for the particles is shown by vertical arrows.

References:

1. Nosenko, V. (2022), Two-dimensional complex (dusty) plasma with active Janus particles, *Phys. Plasmas*, 29, 123701.
2. Nosenko, V., Luoni, F., Kaouk, A., Rubin-Zuzic, M., and Thomas, H. (2020), Active Janus particles in a complex plasma, *Phys. Rev. Research*, 2, 033226.

Characterization and Modelling of Surface Plasma Devices

S. Marín-Meana[1,2,*], G. Regodon-Harkness[2], A. Palmero[2], J. Cotrino[1,2], A. R. González-Elipe[2], A. Gómez-Ramírez[1,2] and M. Oliva-Ramírez[1,2].

[1]Departamento de Física Atómica, Molecular y Nuclear, Universidad de Sevilla, Avda. Reina Mercedes, E-41012 Seville, Spain.

[2]Laboratory of Nanotechnology on Surfaces and Plasma. Instituto de Ciencia de Materiales de Sevilla (CSIC-Universidad de Sevilla), Avda. Américo Vespucio 49, E-41092 Seville, Spain.

Abstract:

Plasma actuators are Dielectric Barrier Discharges (DBD) devices that present one dielectric material covering all the space between the two electrodes[1]. The electrode configuration is usually asymmetrical to concentrate the generation of plasma on the active electrode side. Plasma actuators have been demonstrated to be useful for anti-icing and deicing in plane wings and in blades of aerogenerators[2]. Herein, we report the assembling of a surface plasma actuator (Figure 1) with a digitated active electrode using different materials as dielectric barriers (SiO_2, Al_2O_3, and $LiNbO_3$). The influence of the voltage and the frequency on their performance was assessed by applying a sinusoidal electrical signal for plasma ignition. Our results reveal that the consumed power increases with the dielectric constant of the barrier material as well as with the applied voltage and the increasing frequency. Furthermore, the consumed power also changes with the distance between the digits of the active electrode, and it was found to be maximum at a distance of 3mm. We analyzed the plasma light emission of the devices along the direction perpendicular to the digits by means of Optical Emission Spectroscopy (OES). Our measurements show a predominance of the Second Positive System (SPS) of N_2^* throughout the spectra, together with emission coming from the First Negative System (FNS) of N_2^{+*} when the device is operated in an air atmosphere. The OES also showed that the intensity of the emission relates with the morphology of the active electrode.

2D and 3D COMSOL Multiphysics simulations were carried out to depict the electrical behavior of several magnitudes for a better understanding of our devices. In particular, the electric field, the electric voltage, the electric displacement, and the current displacement were obtained. All these quantities showed a periodic behavior over the digitated electrode and the potential and electric field profiles along the y-axis revealed that these quantities are maxima at the edges of the digits, which reproduce the relation between the morphology of the electrode and the emission obtained experimentally by OES.

Keywords: surface plasma generation, optical emission spectroscopy, Comsol Multiplhysics, plasma actuator, digitated electrode, atmospheric pressure plasma.

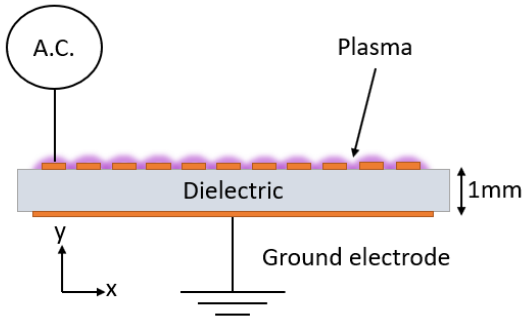


Figure 1: Scheme of the surface plasma device.

References

1. Corke, T., Lon Enloe, C., Wilkinson, S. (2010) Dielectric Barrier Discharges Plasma Actuators for flow control, *Annu. Rev. Fluid Mech.* 42:505-29.
2. Bruggeman, P., Iza, F., Brandenburg, R. (2017) Foundations of atmospheric pressure non-equilibrium plasmas, *Plasma Sources Sci. Technol.* **26** 123002 (17pp).

Acknowledgments

The authors acknowledge projects PID2020-114270RA-I00, PID2020-112620 GB-I00 funded by MCIN/ AEI/10.13039/501100011033, project TED2021-130124A-I00 and Grant IJC2020-045087-I funded by MCIN/ AEI /10.13039/501100011033 and the European Union NextGeneration EU /PRTR, and projects P18-RT-3480 and US-1380977 funded by Consejería de Economía, Conocimiento, Empresas y Universidad de la Junta de Andalucía (PAIDI-2020) and Programa Operativo Feder 2014-2020.

Modeling and experimental characterization of the extraction of a focused broad ion beam from an inductively coupled plasma source.

K. Rettig [1,2,*], T. Dunger[1], E. Loos[1], M. Nestler[1], J. Schuster[2]
[1] scia Systems GmbH, Chemnitz, Germany
[2] Fraunhofer Institute for Electronic Nano Systems ENAS, Chemnitz, Germany

Abstract:
Ion beam trimming (IBT) uses a broad focused ion beam, to locally modify the surface of processed semiconductor substrates or optics for the utilization in various applications, e. g. augmented reality devices, telescope mirrors and MEMS. Thereby, the ion beam width must be adjusted to match the respective topography error. Development and optimization of such adapted ion beams can be greatly accelerated using a simulation model of the ion source. We present approachs to calculate the ion beam properties using the source geometry and operation conditions. Thus, the beam width can be predicted, optimizations of the ion source can be investigated and the development of new source concepts can be supported.
In a first stage, we experimentally studied the extraction of a positive Ar-ion beam from an inductively coupled plasma (ICP) through a three-grid extraction-system. The results are used to verify the theoretical model. Moreover, they define input parameters for the simulation, which include beam and plasma properties. As measurements of the plasma density and electron temperature in an industrial ion source assembly are difficult to realize, we implemented an analytical model for gridded ICP [1], in addition to the experimental data. It is capable of calculating the plasma parameters from the actual applied operation conditions, e. g. Ar-gas flow rate and applied radio-frequency power. Finally, with the initial data, two simulation approaches are investigated and compared, which calculate the actual ion beam extraction numerically.
Our first simulation method is a trajectory-based approach from the code IBSIMU [2]. The interaction between ion trajectories and plasma is based on a plasma sheath approximation. The model yields a simulated ion beam, showing good qualitative and quantitative agreement with the experiment. Thus, it is suitable for trend studies of the system and simple optimizations, e. g. regarding the extraction geometry. Nevertheless, several assumptions in the model, lead to a rather simple description of the space charge compensation (SCC) and actual plasma.
To overcome limitations of the first model, we investigate a coupled particle-in-cell (PIC) and direct-simulation monte-carlo (DSMC) approach using the code PICLAS [3]. It includes multiple charged and neutral species, to ensure a physical coherent representation of the system. Yet, we used the Boltzmann relation to describe the electron population in the plasma and the beam (for SCC), to reduce the computation time. The simulated ion beam matches the experimentally observed properties well. Additionally, it provides access to actual plasma parameters (species densities and temperatures) and a more accurate depiction of SCC effects, which are analyzed, optimized, and compared to experiments.

Keywords: inductively coupled plasma (ICP), ion beam extraction, broad ion beam, focused ion beam, plasma simulation, ion beam simulation, gridded ion source, particle-in-cell (PIC).

References:

1. Chabert, P., Arancibia Monreal, J., Bredin, J., Popelier, L., & Aanesland, A. (2012). Global model of a gridded-ion thruster powered by a radiofrequency inductive coil. *Physics of Plasmas*, *19*(7), 073512.
2. Kalvas, T., Tarvainen, O., Ropponen, T., Steczkiewicz, O., Ärje, J., & Clark, H. (2010). IBSIMU: A three-dimensional simulation software for charged particle optics. *Review of Scientific Instruments*, *81*(2), 02B703.
3. Fasoulas, S., Munz, C. D., Pfeiffer, M., Beyer, J., Binder, T., Copplestone, S., Mirza, A., Nizenkov, P., Ortwein, P. & Reschke, W. (2019). Combining particle-in-cell and direct simulation Monte Carlo for the simulation of reactive plasma flows. *Physics of Fluids*, *31*(7), 072006.

Modelling of an electric arc during contact separation.

O. Ojeda Mena [1,2,*], Y. Cressault [1], P. Teulet [1], J. P. Gonnet [2].
[1] LAPLACE, Université de Toulouse, CNRS, INPT, UPS , Toulouse, France.
[2] Schneider Electric, Eybens, France.

Abstract:
The interaction of the arc with the electrodes is of high importance during the design and operation of breaking and switching devices. It is well known that the arcing can cause damaging effects on the metallic parts affecting their lifetime and performance. Some of these effects include: the erosion, welding, and surface changes of the electrodes. Similarly, hot spots formed by the arc on the electrode surface may lead to evaporation of the metal also affecting the surrounding gas atmosphere [1, 2]. The coupled effect of these complex physics will have an impact on the global behaviour of the arc and its understanding is key for the optimal tuning of circuit breakers and contactors. In particular, the use of computational tools to model the phenomena involved could help improve the development process of current interrupting devices.
This work proposes a numerical study of the arc-electrode interaction during the separation of two cylindrical electrodes. An AC model of the arc was implemented in ANSYS FLUENT following a magnetohydrodynamic (MHD) description of the plasma. The interactions between the arc and electrodes are defined as boundary conditions at the interface [3] and coupled with a description of the electrode ablation to include the effects of metal vapors on the arc.
Simultaneously, an experimental study was performed to compare with the simulation results. The setup consists of two parallel contacts that open with an electrical load to obtain an electric arc. For each test, the electrode displacement, arc voltage and arc current are measured, in addition to high-speed video recordings of the arc.
The comparison of the numerical results with the experimental data shows a good agreement of the arc voltage and arc current. Similarly, the arc traces measured on the electrode surface after the arcing correspond to the arc attachment to the electrodes resulting from the simulations. High-speed images of the arc are also compared with the calculated temperature and metal distribution. Finally, a study of the impact of the electrode material on the numerical simulations was also performed.

Keywords: Arc-electrode interaction, air-metal mixtures, contact separation, electrode ablation, high-pressure arc discharge.

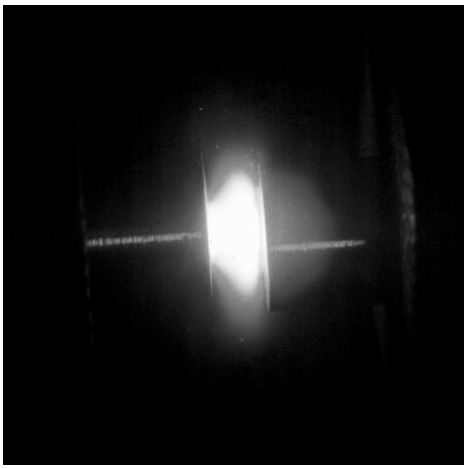


Figure 1: High-speed image of an electric arc ignited after the separation of two parallel electrodes.

References:

1. Flurscheim, C. H., Flurscheim, C. H., & Engineers, I. of E. (1982). Power Circuit Breaker Theory and Design. Peregrinus.
2. Llewellyn-Jones, F. (1963). The mechanism of electrode erosion in electrical discharges. Platinum Metals Review, 7(2), 58-65.
3. Lisnyak, M., Cunha, M. D., Bauchire, J.-M., & Benilov, M. S. (2017). Numerical modelling of high-pressure arc discharges: Matching the LTE arc core with the electrodes. Journal of Physics D: Applied Physics, 50(31), 315203.

Synthesis of High-entropy Alloy Nanoparticles by an Induction Thermal Plasma Jet

Keun Su Kim[1*], Martin Couillard[1], Ziqi Tang[2], Homin Shin[1], Daniel Poitras[1], Changjun Cheng[3], Olga Naboka[1], Dean Ruth[1], Mark Plunkett[1], Linxin Chen[3], Michel Nganbe[2], and Yu Zou[3]
[1]National Research Council Canada, Ottawa, ON K1A 0R6, Canada
[2]Department of Mechanical Engineering, University of Ottawa, Ottawa, ON, K1N 6N5, Canada
[3]Department of Materials Science and Engineering, University of Toronto, Toronto, ON M5S 3G8, Canada

Abstract:
High-entropy alloys (HEAs), consisting of five or more principal elements with a near equimolar ratio, were first demonstrated in 2004 and has become one of the most transformative concept in current alloy design[1]. Despite the tendency to segregate or order with similar elements, such alloys can be stabilized by their high configurational entropy and are named high-entropy alloys (HEAs). Homogenous mixing of large number of elements induces synergistic effects among different elements, thus results in unusual combinations of functional properties appealing to broad range of applications such as structural alloys, catalysis, sensing, and energy storage[2]. While the synthesis of bulk HEAs has been the main focus in the past decade, nano-sized HEA particles are emerging as a new class of multifunctional materials[3]. Scalable and economically viable synthetic methods for HEA nanoparticles (NPs) are of particular interest, yet the controlled incorporation of multiple elements into a tiny particle (< 100 nm) remains a significant challenge requiring extreme fabrication conditions[3]. Metal salts are often employed as precursors because of their low decomposition temperatures, yet contain potential impurities. Here, we report an ultrafast (< 100 ms), one-step method for the continuous synthesis of HEA NPs directly from a mixture of elemental metals, based on the thermal plasma jet technology[4]. A RF induction thermal plasma jet plasma jet (> 5,000 K) was employed for rapid heating/cooling (10^3–10^5 K/s), and demonstrated the synthesis of CrFeCoNiMo HEA NPs (~50 nm) at an unprecedentedly high rate approaching 35 g/h. Our thermofluid simulation reveals that the properties of HEA NPs can be tailored by the plasma gas which affects the thermal history of NPs. The as-synthesized HEA NPs were exploited as high-performance photothermal materials, and demonstrated a high light absorptance of > 96 % over a wide spectrum without noble metals, thus will make an impact in the cost-effective, large-area solar energy harvesting for thermophotovoltaics, photocatalysis, and water desalination.

Keywords: high-entropy alloy, nanoparticles, scalable synthesis, thermal plasma

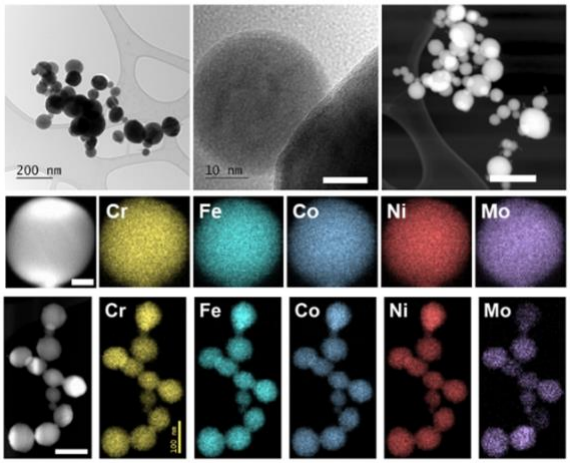


Figure 1: TEM (top-left), HR-TEM (top-middle) and HAADF-STEM (top-right) images of CrFeCoNiMo HEA NPs produced with a RF induction thermal plasma jet. Scale bar, 200 nm (TEM), 10 nm (HR-TEM) and 100 nm (HAADF). EDX elemental maps of single (middle) and multiple HEA NPs (bottom), showing homogenous distribution of the five metals in particles. Scale bar, 25 nm (single NP) and 100 nm (multiple NPs)

References:

1. Yeh, J. W. et al. (2004) Nanostructured high-entropy alloys with multiple principal elements: novel alloy design concepts and outcomes, *Adv. Eng. Mater.*, 6, 299-303.
2. Wang, X., Guo, W. & Fu, Y. (2021) High-entropy alloys: emerging materials for advanced functional applications, *J. Mater. Chem. A*, 9, 663-701.
3. Koo, W. T., Millstone, J. E., Weiss, P. S. & Kim, I. D. (2020) The design and science of polyelemental nanoparticles, *ACS Nano*, 14, 6407-6413.
4. Kim, K. S. et al. (2022) (submitted)

Atmospheric-Pressure Nanosecond-Pulsed Plasma-Induced Free-Radical Polymerization of HEMA Liquid Layers

I. Azevedo Goncalves[1,2], N. D. Boscher[1], D. Abessolo Ondo[1], R. Quintana[1]
[1] Luxembourg Institute of Science and Technology, 28, avenue des Hauts-Fourneaux, Esch-sur-Alzette, Luxembourg
[2] University of Luxembourg, 2 Av. de l'Universite, Esch-sur-Alzette, Luxembourg

Abstract:
The direct synthesis and deposition of functional thin films from the plasma-induced polymerization of liquid layers is a fast and up-scalable deposition method which offers the advantage of increasing the monomer to polymer conversion yield. In contrast to other plasma deposition processes of polymeric thin films, where the monomers are supplied from the vapour phase[2] or delivered as aerosols to the plasma zone, only a scarce number of studies have focused on the "plasma curing" of liquid layers[1,3]. In this contribution, the plasma-induced free-radical polymerization of liquid layers of 2-hydroxyethyl methacrylate (HEMA) is studied (Fig. 1a), and the chemical structure, the polymeric growth and the deposition rate of the resulting thin films correlated with the process parameters. In particular, high-resolution mass spectrometry (HRMS) investigations allowed depicting the effect of key parameters such as monomer delivery rate and plasma pulse frequency on the polymerization of HEMA (Fig. 1b). Recommendations on the parameters enabling the formation of thin films with both high retention of the monomer structure and high growth rate are provided.

References:

1. Barillas, L.; Makhneva, E.; An, S.; Fricke, K. Functional Thin Films Synthesized from Liquid Precursors by Combining Mist Chambers and Atmospheric-Pressure Plasma Polymerization. Coatings 2021, 11 (11).
2. Loyer, F.; Frache, G.; Choquet, P.; Boscher, N. D. Atmospheric Pressure Plasma-Initiated Chemical Vapor Deposition (AP-PiCVD) of Poly(Alkyl Acrylates): An Experimental Study. Macromolecules 2017, 50 (11), 4351–4362.
3. Niemczyk, E. M.; Gomez-Lopez, A.; Haler, J. R. N.; Frache, G.; Sardon, H.; Quintana, R. Insights on the Atmospheric-Pressure Plasma-Induced Free-Radical Polymerization of Allyl Ether Cyclic Carbonate Liquid Layers. Polymers (Basel). 2021, 13 (17).

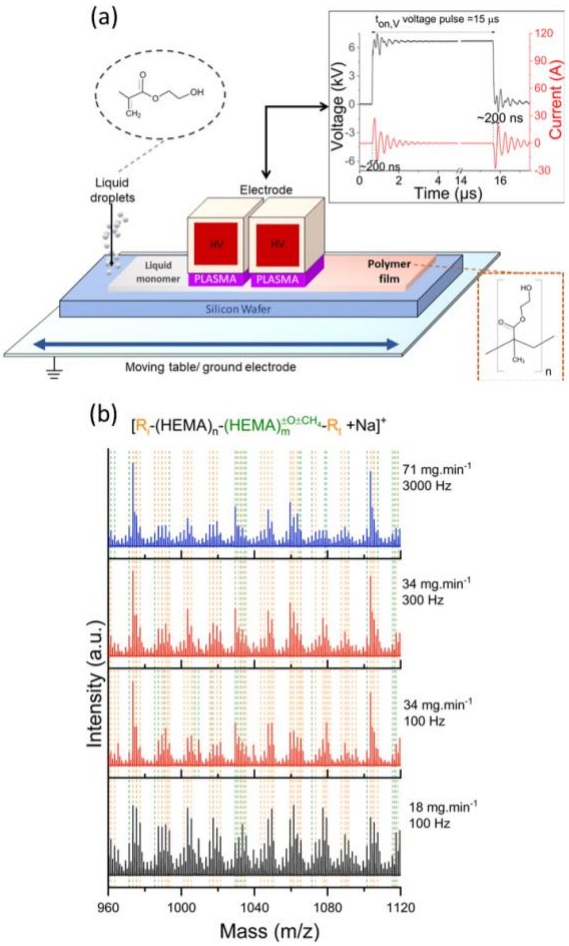


Figure 1: (a) Schematic of the atmospheric-pressure dielectric barrier discharge used in this study and (b) HRMS spectra (m/z = 960 to 1120) of the HEMA-based thin films prepared using different delivery rates and plasma pulse frequencies. Orange dashed lines indicate peaks attributed to ionized adducts correlated to a single σ-bond plasma-induced HEMA fragments introduced as end-groups. Green dashed lines indicate peaks with additional incorporation/subtraction of oxygen (side-reactions).

Large RF plasma data set for training plasma processing machine learning models

A. Fierro [1], T. Hardin [2], A. Lietz[3], M. Hopkins [2], A. Belianinov [2], B. Bentz [2]
[1] Electrical and Computer Engineering, University of New Mexico, Albuquerque, New Mexico, USA
[2] Sandia National Laboratories, Albuquerque, New Mexico, USA
[3]North Carolina State University, Raleigh, North Carolina, USA

Abstract:

Machine learning (ML) is quickly becoming a valuable tool in science and industry. In computational plasma physics, detailed simulations containing hundreds of reactions are computationally expensive, and the number of simulations required to produce a useful training data set further amplifies the computational expense. To this end, we ran Aleph, a highly parallel electrostatic particle-in-cell (PIC) code, on the super computers at Sandia National Laboratories. Aleph uses Direct Simulation Monte Carlo (DSMC) for electron-neutral and ion-neutral collisions, and our Aleph simulations were conducted in a one-dimensional, 4 cm gap containing Argon gas and an applied RF frequency of 13.56 MHz [1]. Included reactions were elastic scattering, excitation, ionization, multistep ionization, and ion charge exchange. Only two discharge parameters were explored for this particular work spanning over a pressure regime from 0.1 Pa to 50 Pa and a voltage range of 100 V to 1000 V. In total, we ran 900 simulations, corresponding to 30 data points for both voltage and pressure, to calculate various plasma characteristics such as electron and ion densities, temperatures, and ionization rates. Key to plasma processing performance, the ion energy and angle distribution functions were calculated. Approximately 3000 processing cores were used continuously for 3 months to produce this data set. This data will be made openly accecible and ultimately used to develop suragate models with ML that will predict plasma parameters within operating regimes relevant for plasma source design.

Keywords: machine learning, rf plasmas, plasma processing, ion distribution functions, electrons, density, plasma characteristics, training data, high performance computing

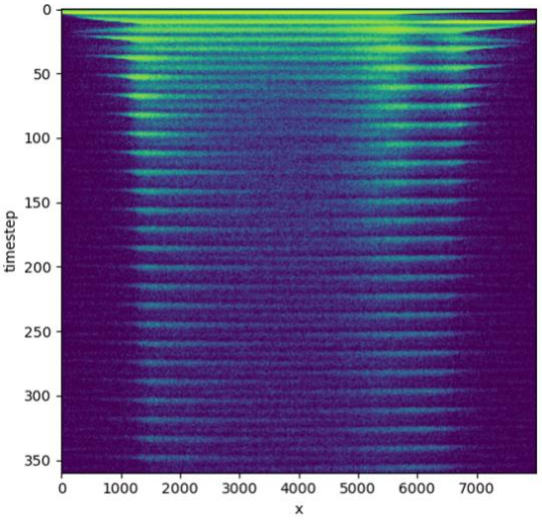


Figure 1: Ionization rate as a function of location in the gap and time for a peak-to-peak voltage of 2 kV, frequency of 13.56 MHz, and pressure of 50 Pascals. Very little ionization is observed near the edges of the plasma.

References:

1. A. Fierro, M. Hopkins, T. Hardin, A. Lietz, A. Belianinov, B. Bentz, "Analysis of a radiofrequency plasma reactor for etching," *75th Annual Gaseous Electronics Conference*, Sendai, Japan, 2022.

Acknowlegment
This work was supported by the Sandia Laboratory Directed Research and Development (LDRD) program. Sandia is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

Preparation of ceramic composite coatings by combining cold-spray deposition and plasma electrolytic oxidation

J. MARTIN[1,2], A. MAIZERAY[1,2], C. DA SILVA TOUSCH[1], G. MARCOS[1,2], M.P. PLANCHE[3], H. LIAO[3], T. CZERWIEC[1,2], G. HENRION[1,2]

[1] Université de Lorraine, CNRS, Institut Jean Lamour, F-54000 Nancy, France

[2] Université de Lorraine, LabEx DAMAS, F-57045 Metz, France

[3] Université Bourgogne Franche-Comté, CNRS, ICB-PMDM-LERMPS, F-90010, France

Abstract:

Plasma electrolytic oxidation (PEO) is widely used to improve the corrosion and wear resistance of lightweight metals such as aluminium alloys by the formation of a protective oxide coating. However, the PEO process remains ineffective for ferrous metals. To overcome these limitations, the feasibility of applying a duplex treatment combining cold-spray deposition (CS) and PEO was recently proposed [1].

In the present communication, this duplex treatment is used as a new route to prepare ceramic composite coating on steel. Among the oxide-based composites, the Al_2O_3-ZrO_2 system has demonstrated unique features to achieve synergetic protective properties combining the high hardness and high chemical inertness of alumina with the excellent toughness of zirconia [2]. As illustrated in figure 1, the proposed duplex treatement consists in first, simultaneously cold-spraying alumiunium and zirconium metallic particles on a steel substrate, and then, oxidizing part of the CS layer through PEO.

First, after cold-spray, results show the possibility to produce a dense and thick Al/Zr metallic composite coating on steel with an adequate control of the metallic particles composition and distribution throughout its thickness. Secondly, after PEO treatments, results also evidence the feasability of preparing ZrO_2/Al_2O_3 composite coatings with a right control of the oxide thickness and morphology mainly by varying the PEO processing conditions (Figure 1). Finally, wear tests and friction coefficient measurements were also performed and results will be discussed by comparing them with conventional PEO coatings.

Keywords: Duplex surface treatment, Cold spray, Plasma electrolytic oxidation, Ceramic composite coating, Alumina, Zirconia

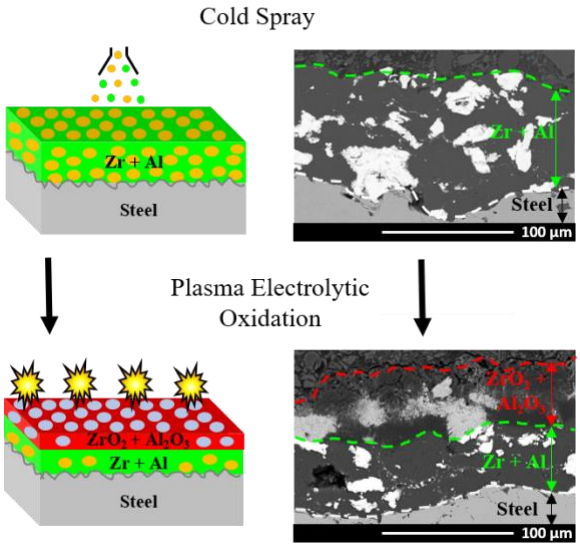


Figure 1: Preparation of a ZrO_2/Al_2O_3 ceramic composite coating by combining cold-spray deposition and plasma electrolytic oxidation.

References:

1. Martin, J., Akoda, K., Ntomprougkidis, V., Ferry, O., Maizeray, A., Bastien, A., Brenot, P., Ezo'o, G., Henrion, G. (2020) Duplex surface treatment of metallic alloys combining cold spray and plasma electrolytic oxidation technologies, *Surf. Coat. Technol.*, 392, 125756
2. Kern, F., Palmero, P., Garcia Marro, F. Maestra, A. (2015) Processing of alumina-zirconia composites by surface modification route with enhanced hardness and wear resistance, *Ceram. Int.*, 41, 889-898

New insights into the plasma electrolytic oxidation of aluminium with incorporation of carbon nanoparticles.

C. DA SILVA TOUSCH[1], L. MAGNIEZ[1], C. CZERWIEC[1,2], J. MARTIN[1,2], G. MARCOS[1,2],S. FONTANA[1], C. HEROLD[1], G. HENRION[1,2]

[1] Université de Lorraine, CNRS, Institut Jean Lamour, F-54000 Nancy, France

[2] Université de Lorraine, Laboratoire d'Excellence Design of Alloy Metals for low-mAss Structures ('LabEx DAMAS'), F-57045 Metz, France

Abstract:

Plasma electrolytic oxidation (PEO) is an electrochemical conversion process suited for producing wear and corrosion resistant oxide coatings on valve metals (e.g. Al, Ti, Mg, Zr). Recent developments have shown a growing interest for the preparation of composite coatings through the incorporation of solid nanoparticles in the growing oxide by dispersing them in the electrolyte beforehand. A large diversity of metallic ceramic or polymeric particles have been used to further increase the barrier properties of the oxide coating [1]. On the other hand, other types of particles such as carbon nanoparticles have not yet been thoroughly investigated.

As such, this work aims at investigating the PEO of aluminium achieved within a carbon nanoparticles dispersion (carbon nanotubes, nano-graphite, carbon black). More specifically, in-situ electrical monitoring of the PEO treatments and post-process coating characterizations allows studying the influence of electrical supplying with or without carbon nanotubes.

First, results show that the presence of carbon nanoparticles promote an earlier transition from the arc to the "soft" regime [2], which has never been reported before (figure 1). Meanwhile, the presence of carbon nanoparticles results in an alteration of the morphology of the oxide coating, the latter being thicker but more irregular and porous than that achieved without carbon nanoparticles [3].

Additionally, the present communication is an opportunity to expose the challenges considering the characterization of incorporated carbon nanoparticles, that are mainly addressed through the combination of complementary characterization techniques, including Raman spectroscopy, high-resolution scanning electron microscopy and transmission electron microscopy.

Finally, the correlation between the ex-situ characterization of the coatings and the in-situ electrical response during the PEO treatments allows further understanding of the mechanisms of the "soft" regime appearance as well as the mechanisms of carbon nanoparticle incorporation into the PEO oxide coating.

Keywords: plasma electrolytic oxidation, micro-arc oxidation, "soft" regime, carbon nanotubes, nano-graphite, carbon-black

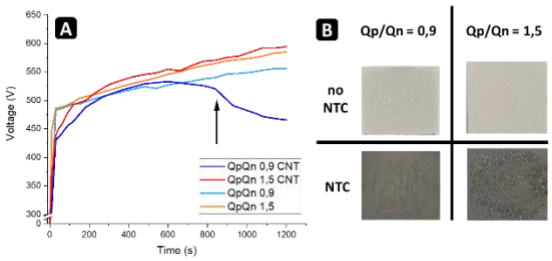


Figure 1: Figure illustrating (A) the electrical behavior during the PEO treatment of aluminium for two different charge ratios with and without carbon nanotubes and (B) respective photographs of the samples.

References:

1. Lu, X., Mohedano, M., Blawert, C., Matykina, E., Arrabal, R., Kainer, K.U., Zheludkevich, M.L. (2016) Plasma electrolytic oxidation coatings with particle additions – A review. *Surface and Coatings Technology*, 307. 1165-1182.
2. Dah-Shyang, T., Chen-Chia, C. (2018) Review of the Soft Sparking Issues in Plasma Electrolytic Oxidation. *Metals*, 8. 105.
3. Da Silva Tousch, C., Martin, J., Marcos, G., Czerwiec, T., Henrion, G. (2022) Evidence of in-depth incorporation of carbon nanotubes in alumina layers grown by plasma electrolytic oxidation. *Surface and Coatings Technology*, 440, 128489.

Development of a water repellent/anti-icing transparent plasma polymerized HMDSO coating

R. Jafari[1,*], E. Eslami[1], G. Momen[1]
[1] Department of Applied Sciences, University of Quebec in Chicoutimi (UQAC), Quebec, Canada

Abstract:
Ice adhesion and accretion on exposed surfaces is a ubiquitous and unavoidable phenomenon that occurs in nature through various types of precipitation, including frosting, condensation freezing, and frozen rain. These icing issues produce irretrievable losses, economic costs and safety issues in daily life [1]. Icephobic or anti-icing surfaces refer to a surface's capacity to repel incoming water droplets, delay ice formation, limit ice growth and minimize ice adhesion. Good correlation between hydrophobicity and reduction of ice adhesion has been reported [2]. Indeed, superhydrophobic surfaces (water contact angle $> 150^{\circ}$) have shown promising anti-icing performance. A major challenge of non-fluorinated superhydrophobic coatings is the low robustness of the infused nanoparticles in coating films compromising their non-wetting properties. In this paper we developed a transparent superhydrophobic and icephobic coating using a low pressure plasma system and an atmospheric pressure plasma polymerization technique (Figure 1). We optimized the deposition chemistry and the influence of different operational parameters (discharge power, deposition time, precursor flow rate, substrate-plasma distance, ...) on thin film properties. The surface wettability was assessed in terms of contact angle (CA) and sliding angle of water at different subfreezing temperatures. The developed superhydrophobic coating with water CA of 160º and sliding angle of 2º showed appropriate adhesion to different substrates, optical transmittance of 85% in the visible-light region, and great non-wetting properties even after various harsh environmental conditions, i.e., waterjet impacting, immersing in water and acid/base solutions and UV degradation test. Self-cleaning tests showed that the superhydrophobic surfaces could shed various contaminants in different types of contamination. To determine ice adhesion strength (IAS), we used a centrifugal instrument after an icing procedure that took place within a wind tunnel. The adhesion reduction factor (ARF) was defined as the ratio between IAS on an untreated and a coated surface. The ice adhesion strength of the superhydrophobic surface became 4.2 times lower than that of the untreated surface.

Keywords: Superhydrophobic coating, Plasma polymeri-zation, HMDSO, transparent coating, Icephobicity

Figure 1: Image of an open-air atmospheric-pressure plasma jet from Plasmatreat (Plasmatreater AS400, Plasmatreat GmbH) used for developing a transparent superhyfdrophobie and icephobic plasma polymerized HMDSO coating

References:

1. Heydarian S., Jafari R., Momen G. (2021), Recent Progress in the Anti-Icing Performance of Slippery Liquid-Infused Surfaces, Progress in Organic Coatings, vol. 151, 106096.
2. Foroughi Mobarakeh L., Jafari R., Farzaneh M. (2018), Robust icephobic, and anticorrosive plasma polymer coating, Cold Regions Science and Technology 151, 89-93.

Superhydrophobic bio-inspired stainless steel surfaces by coupling additive manufacturing and atmospheric pressure plasma coatings

K. Dourgaparsad [1], D. Balloy [1], I-C. Gruescu [1], M. Jimenez [1,2]
[1] Univ. Lille, CNRS, INRAE, Centrale Lille, UMR 8207 - UMET – Unité Matériaux Et Transformations, 59000 Lille, France
[2] Institut Universitaire de France (IUF), Paris, France

Abstract:
Microarchitectured steel surfaces are usually manufactured with a top down strategy (removing matter from the substrate), or a bottom-up strategy (adding matter over a substrate). Additive manufacturing (AM) processes using stainless steel are expensive because of the price of the stainless steel powder. Moreover, the precision of these technologies rarely goes under 200µm. The present work, inspired from jewelry processes and prothesis manufacturing, couples two technologies, ie polymer 3D printing and vacuum casting to create, using stainless steel wastes, various bio-inspired microarchitectured 316L stainless steel surfaces. Stainless steel casting for under millimetric details constitutes a technical challenge because of the high surface tension, high dynamic viscosity and high working temperature (1600°C) of the steel. Different microtextured surfaces inspired from natural shapes (fish scales, drops, honeycomb, etc.) were successfully fabricated. Their aspect, roughness and impact of the process on the final texture are discussed. In addition, a nanorough coating is applied using atmospheric pressure plasma polymerization of a bilayer using hexamethyldisiloxane and 1H,1H,2H,2H-perfluorooctyltriethoxysilane as precursors. A hyperhydrophobic behavior have been observed after this bilayer deposition.
At our knowledge, this is the first published work showing the design of microtextured stainless steel surfaces obtained by this additive manufacturing technique.

Keywords: Superhydrophobic surface, Additive manufacturing, Investment vacuum casting, Stainless steel, Atmospheric plasma pressure polymerization, Bilayer coating

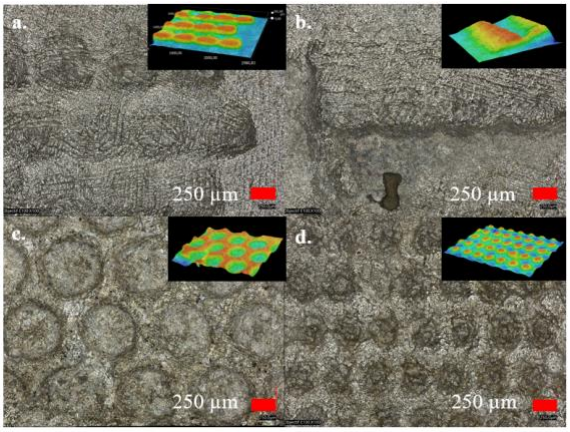


Figure 1: Different shape designs: (a) Fish scale 1, (b) Fish scale 2, (c) Honeycomb and (d) Peak (Optical Microscope)

Multi-physics multi-scale modelling of SiO2 deposition by HC-PECVD with O2/TMDSO mixture used as gaseous precursors

Jérôme Müller[1], Pavel Moskovkin[1], David Cornil[1,2], Kristína Tomanková[3], Adam Obrusník[3], Stéphane Lucas[1,4]

[1] University of Namur, LARN Laboratory, Namur, Belgium
[2] University of Mons, Mons, Belgium
[3] PlasmaSolve, Brno, Czechia
[4] Innovative Coating Solutions - ICS, Forville, Belgium

Abstract:
Thin film materials are key components in a large variety of fields including automotive and mechanical engineering, optics, micro- and nanotechnology, medical applications, photovoltaics and display technology.
Stoichiometric SiO2 is one of the most used coating deposited by Physical Vapor Deposition (PVD) for various applications. Although magnetron sputtering PVD process is widely used to deposit nanometric layers of various compounds, in the case of SiO2, it is only suitable for thin layers for industrial applications. An alternative to the magnetron sputtering process for production of thick (and thin) SiO2 coating is the Plasma-Enhanced Chemical Vapor Deposition (PECVD) process, like for example a process based on hollow cathode source (HC) where O2/TMDSO is used as gaseous precursors. Unfortunately, coating composition will vary strongly with the process parameters, and their impact on film quality and uniformity is not well understood today.
The aim of this work is to model the whole PECVD process, from the plasma simulation based on a global (zero-dimensional) plasma model of the HC process with full O2/TMDSO chemistry, to the film growth using a kinetic Monte Carlo approach using the software NASCAM[1], and finally to the prediction of the film properties (chemical composition, density,... – see Figure 1). A special attention is paid to the surface chemical reactions occurring at the surface of the sample during the deposition, by computing by DFT (Density Functional Theory) the sticking coefficients and reaction probabilities of any deposited species.

Keywords: SiO2 coating, PECVD, TMDSO, plasma modelling, film growth modelling, kinetic Monte-Carlo, Density Fonctional Theory.

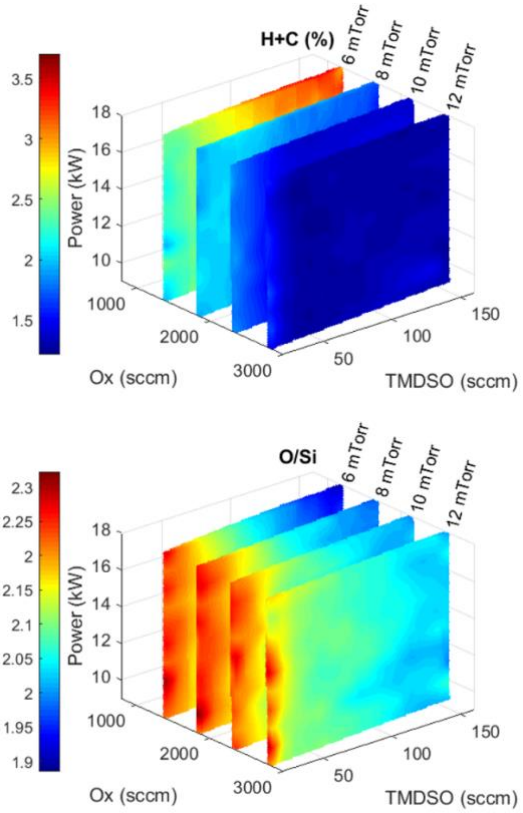


Figure 1: prediction of SiO2 thin film chemical composition in function of the TMDSO inflow, O2 inflow and the power.

References:

1. https://www.incosol4u.com/nascam-general

Low pressure cold plasma treatment and coating of expanded polypropylene beads.

Melvin Dilger[1], Séverine Bellayer[1], Sophie Duquesne[1], Maude Jimenez[1,2]
[1] Université de Lille, UMET – UMR 8207, CNRS, INRAE, Centrale Lille Institut – Lille, France
[2] Institut Universitaire de France (IUF), Paris, France

Abstract:
Expanded polypropylene (EPP) is hugely used in the automotive field because of its reasonable cost, high-impact absorption properties, and excellent strength-to-weight ratio, allowing it to replace various structural elements in cars while ensuring passenger safety. However, EPP has high flammability and low light stability. In order to reach the quality requirement for automotive applications, coatings can be used to improve both flame retardant and light stability properties. Unfortunately, EPP beads have low surface energy and no polar functional group to provide good adhesion of coatings. They must be treated to create polar functional groups (alcohol, carboxyl groups) on the extreme surface. Surface hydrophilicity and surface energy are improved, and better adhesion of the coating is obtained. In this work, EPP beads have been treated with low-pressure cold argon plasma (*Figure 1*). This process is fast (only a few minutes), efficient (decreases the contact angle from 105° down to 40° in 170s and environmentally friendly (no solvents and toxic compounds). In order to reduce the contact angle, the plasma conditions (gas flow, power and time) have been optimized, and further adhesion of coatings has been evaluated using microscopic analyses (*Figure 2*). Then, a scale-up of the surface treatment was investigated for an industrial application. Finally, the formulation of the coating and the thickness were optimized in order to further mold by thermoforming the coated beads.

Keywords: Low-Pressure Cold Plasma; Expanded Polypropylene; Functionalization; Coating; Flame retardancy.

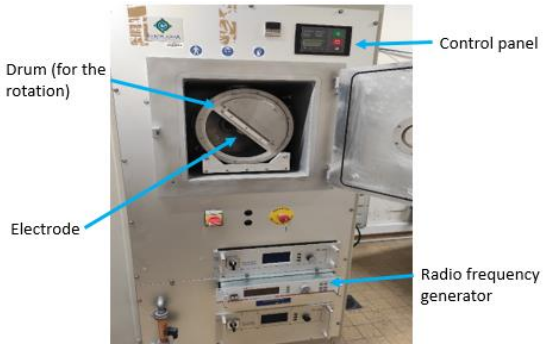


Figure 1: Image of the plasma CD 1200 device

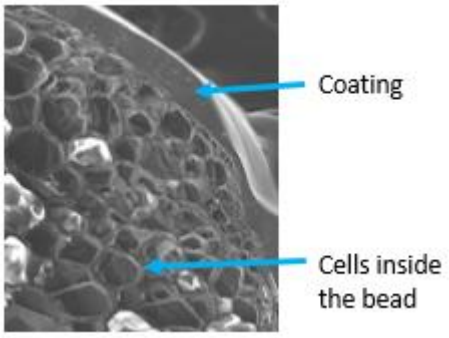


Figure 2: SEM image of the cross-section of coated EPP beads x90

References:

1. Schreier P, Trassl C, Altstädt V. Surface modification of ppolypropylene based particle foams. *American Institute of Physics*, 1593, 378-382.

Reactive DCMS vs. Reactive HiTUS of TiNbVTaZrHf-N_x Coatings

F. Lofaj [1,*], L. Kvetková [1], P. Hviščová [1], M. Kabátová [1], T. Roch [2], V. Girman [1,3]

[1] Institute of Materials Research of SAS, Košice, Slovakia
[2] Faculty of Physics, Mathematics and Informatics, Comenius University in Bratislava, Bratislava, Slovakia
[3] Faculty of Science, Pavol Jozef Šafárik University in Košice, Košice, Slovakia

Abstract:
High entropy metal sub-lattice stabilized nitride coatings based on multicomponent refractory transition metals (TM = Ti, Nb, V, Ta, Zr, Hf**)** are promising candidates for extreme conditions due to their high thermal, mechanical and corrosion properties. The aim of the current work was to compare the processes of reactive sputtering in the case of relatively novel High Target Utilization Sputtering (HiTUS) method with the case of DCMS in the deposition of multicomponent TiNbVTaZrHf–N_x coatings. The main tasks of the work included the investigations of reactive processes - target poisoning, hysteresis behavior and pressure changes in the plasma, as well as resulting coating structure, composition, stoichiometry and mechanical properties. The sputtering occurred from TiNbVTaZrHf target densified from a mix of corresponding coarse grained transition metals.

The results showed that target poisoning occurred in DCMS and HiTUS in different extent in the racetrack and in the rims outside of the zone of active sputtering. Moreover, topographies of individual TM grains substantially differed, most probably depending on the orientation of a given grain as well as its composition and presence of nitrogen. Despite target poisoning, hysteresis behavior in the studied range of nitrogen additions was negligible or within the scatter of measurement both in HiTUS and DCMS.

Structure of the DCMS deposited TiNbVTaZrHf–N_x coatings was always crystalline and textured regardless of nitrogen additions into the sputtering atmosphere whereas a transition from amorphous in metallic alloy coatings to textured nano-columnar accompanied by a formation FCC structure with the increase of nitrogen content was observed in HiTUS coatings. Despite certain deviations of TM from equiatomic concentrations, homogeneous solid solutions corresponding to single phase multicomponent nitrides analogous to nitrides with the metallic sub-lattice stabilized by high configurational entropy were obtained in both cases.

Mechanical properties were found to be proportional to nitrogen content. The highest hardness in DCMS coatings of H_{IT} ~ 40 GPa and indentation modulus E_{IT} ~ 490 GPa were slightly higher than in the HiTUS coatings (H_{IT} ~ 33 GPa and E_{IT} ~ 400 GPa) and they were obtained in slightly sub-stoichiometric (48 at % and 45 at % of nitrogen, respectively) compositions. H_{IT}/E_{IT} and limited pillar split measurements suggested these coatings exhibit low fracture toughness (around 1 MPa.$m^{1/2}$).

The work confirmed that HiTUS can produce homogeneous multi-metal solid solution nitride coatings with similar structure and mechanical properties as in those obtained by DCMS. Moreover, reactive HiTUS and DCMS were able to produce multicomponent nitrides with the metal sub-lattices stabilized by configurational entropy despite non-equiatomic TM concentrations and their (nitrogen) stoichiometry can be controlled only by the amount of nitrogen in the sputtering atmosphere without a need for the control of target poisoning.

Hard transparent oxides by High Power Impulse Magnetron Sputtering

A.W. Oniszczuk ,W. Gajewski, P. Różański
TRUMPF Huettinger Sp. z o.o., Marecka 47, 05-220 Zielonka, Poland

Abstract:
High Power Impulse Magnetron Sputtering (HIPIMS) has been well known for delivering high quality coatings with excellent mechanical properties. HIPIMS produces high density microstructures due to the delivery of an ionised metal and dissociated oxygen flux, that can be used to deposit high density transparent oxide layers. Increased film density improves the environmental viability of photovoltaics, displays and low emissivity layers in glazing. Initially, HIPIMS was used only for hard films on a small scale. Nowadays, technology development has allowed to use it in more complex processes on a large scale. HIPIMS dual-magnetron bipolar sputtering (Bipulse HIPIMS) allow use of non-conducting targets and improve arc event mitigation.

ZrO_2 films were deposited in a large-scale coater with ZrO_x rotary targets of 3852 mm length in an argon-oxygen atmosphere. Films deposited by Bipulse HIPIMS were compared with Bipolar DC & MF AC sputtering with powers up to 120 kW AC. Bipulse HIPIMS allows for a stable operation even when using high current (up to 2kA), due to the discharging of the target surface. The HIPIMS process was carried out by controlling the current within the pulse. Peak current control eliminates stability issues associated with runaway currents for all reactive sputtering states i.e., from metallic to compound mode.

Results revealed a significantly lower dynamic deposition rate (DDR) of the Bipulse HIPIMS process compared to MF and Bipolar DC with an overall lower discharge voltage (300-400V), depending on the chosen pulse conditions. However, the ZrO_2 films deposited with Bipulse HIPIMS show an overall higher hardness than reference films deposited by MF and Bipolar DC. Furthermore, the E-modulus increases for shorter HIPIMS pulses and is comparable to MF and Bipolar DC. Results demonstrate that HIPIMS is a viable alternative for transparent oxide coatings for PV applications.

Keywords: HIPIMS, transparent oxides, bipolar, Bipulse HIPIMS, high current, process control, ZrO_x

Hot active plasma treatment of ZnMgAl corrosion protection coatings

J. Duchoslav[1], D. Leidlmair[1], G. Säckl[1,2], M.Kehrer[3], T.Stehrer[3], C.K.Riener[4], M.Arndt[4], David Stifter[1]
[1] Center for Surface and Nanoanalytics (ZONA), Johannes Kepler University Linz, Altenberger Straße 69, 4040 Linz, Austria
[2] Christian Doppler Laboratory for Superimposed Mechanical-Environmental Ageing of Polymeric Hybrid Laminates (CDL-AgePol), Johannes Kepler University Linz, Altenberger Straße 69, 4040 Linz, Austria
[3] Fronius GmbH, Günter-Fronius-Straße, 4600 Thalheim bei Wels, Austria
[4] voestalpine Stahl GmbH, voestalpine-Straße 3, 4031 Linz, Austria

Abstract:
ZnMgAl coatings bring extraordinary corrosion protection to steel sheets, which enable the material to be applied also in the automotive industry. Nevertheless, besides corrosion protection the coatings must fulfill additional demanding criteria including the ability for joining with a wide range of other materials (metals, plastics etc.). This triggers the research on engineering the surface wetting and adhesion characteristics of the coating system [1].
In the presented work, we studied the effect of hot active plasma (HAP) on the chemistry and structure of the surface and sub-surface layer of Zn1.5Mg2.5Al coatings. Due to the large complexity of the coating structure and composition, as depicted in Fig. 1, several different analytical techniques had to be used. Surface sensitive techniques as x-ray photoelectron (XPS) and Auger electron spectroscopy (AES) were utilized in a complimentary way to analyze the top-most layer of the coating. XPS brought insight into the evolution of the elemental and chemical composition, whereas AES showed changes in elemental and phase structure and distribution within the surface layer. The sub-surface and bulk regions of the material were probed by energy dispersive x-ray spectroscopy (EDX) combined with cross-sectional analysis.
The obtained results showed that the effect of the HAP treatment is always a combination of two parallel acting components – heat and plasma. Both are capable of forming a new surface species, either by interaction with the generated plasma and/or by thermal decomposition. In addition, the delivered heat can fully alter the coating microstructure. Furthermore, as also demonstrated by the results, the final impact of the treatment can be elegantly tuned by operating the interaction time of HAP with the coating material.

Keywords: ZnMgAl anticorrosion coatings, surface, XPS, AES, EDX, hot active plasma (HAP).

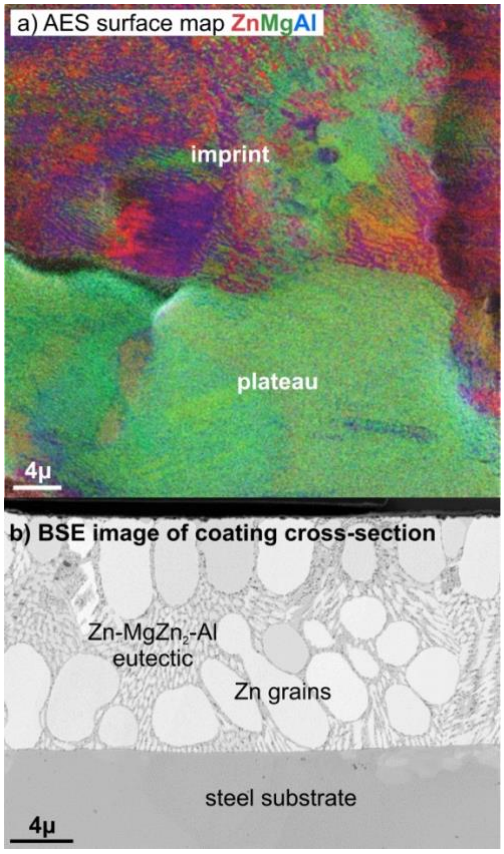


Figure 1: AES elemental map of surface structure with skin passing imprints (a), back-scattered electron image of bulk microstructure (b) of a ternary alloyed ZnMgAl coating on steel.

References:

1. Duchoslav J., Kehrer M., Truglas T., Groiß H., Nadlinger M., Hader-Kregl L., Riener C.K., Arndt M., Stellnberger K.H., Luckeneder G., Angeli G., Stehrer T., Stifter D. (2020), The effect of plasma treatment on the surface chemistry and structure of the ZnMgAl coatings. Applied Surface Science 504, 144457.

Plasma Etching of SiO_2 Using Fluorinated Ethers with Low Global Warming Potential

S. You, C. -K. Kim *
Department of Chemical Engineering and Department of Energy Systems Research, Ajou University, Suwon, South Korea

Abstract:
As the feature size is decreasing as well as the degree of multilevel interconnection is increasing, the high-aspect-ratio SiO_2 contact hole etching becomes a critical process in the fabrication of semiconductor devices. Plasma etching using perfluoro compounds (PFCs) such as CF_4 and C_4F_8 have been primarily used to perform SiO_2 etching in ultra-large-scale integrated devices. PFCs are known to be environmentally harmful because of their high global warming potential (GWP), long atmospheric lifetime, and strong infrared absorption. Because PFCs cause environmental problems, many efforts have been made to reduce PFC emissions usch as process optimization, abatement, recovery, and the use of alternative chemistries. Among them, replacing PFCs with low-GWP alternatives is an promising method. Several classes of environmentally benign chemistries have been examined as alternatives to PFCs. Among them, fluorinated ethers (either perfluorinated or partially fluorinated ethers) draw attractions because of their much lower GWPs compared to those of PFCs.
In this talk, fluorinated ethers are evaluated for plasma etching of SiO_2 and their etch characteristics are compared with those in PFC plasmas.

Keywords: plasma etching, SiO_2 etching, fluorinated ethers, PFC, global warming potential.

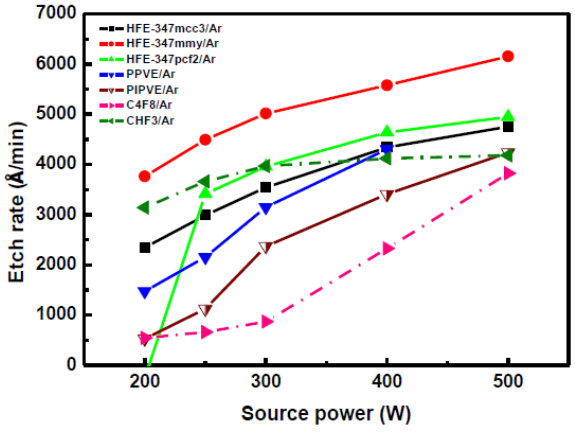


Figure 1: Etch rates of SiO_2 as a function of source power in various fluorinated ether plasmas. : Etch rates of SiO_2 in C_4F_8 and CHF_3 plasmas were also shown for comparison.

References:

1. Kim, J. -H., Park, J. -S., Kim, C. -K. (2018) Plasma etching of SiO_2 using heptafluoropropyl methyl ether and perfluoropropyl vinyl ether, *ECS Journal of Solid State Science and Technology*, 7, Q218-Q221.
2. Kim, J. -H., Park, J. -S., Kim, C. -K. (2020) SIO_2 etching in inductively coupled plasmas using heptafluoroisopropyl methyl ether and 1,1,2,2-tetrafluoroethyl 2,2,2-trifluoroethyl ether, *Applied Surface Science*, 508, 144787.

Role of low pressure plasma composition in $Zn_xMn_yO_z$ stoichiometry and electrochemical performances as Zinc-Ion Batteries cathode

L. Bekkar[1], A. Lemarchand[1], C. Bazin[2], H. Perrot[2], M. Nikravech[1]
[1] LSPM, CNRS, Université Sorbonne Paris Nord, 93430 Villetaneuse, France
[2] LISE, CNRS, Sorbonne Université, 75005, Paris, France

Abstract:
The need to develop high energy density, environmentally friendly and low cost batteries has led to a growing interest in Aqueous Zinc-Ion Batteries (AZIBs) due to the abundance of zinc and its high theoretical capacity (818 mAh/g) [1, 2]. To consider industrial production of ZIBs, It will be necessary to find the adequate cathode material assuring the reversible Zn2+ storage over prolonged cycling.
Among the most studied cathode materials in AZIBs, manganese-based oxides are promising materials due to their electrochemical performances [3]. However, it is necessary to implement structure modifications by defect engineering to enhance rate performance, reversible capacity and cyclic stability [4, 5]. It has been reported that the presence of oxygen vacancies enhances both the Zn^{2+} intercalation/desintercalation kinetics and storage capacity of a $ZnMn_2O_4$ cathode material [6].
Herein, we demonstrate that crystallized $Zn_xMn_yO_z$ thin films can be obtained without post annealing in one single step using a low-pressure plasma process. We show also the ability to control the oxygen stoichiometry in $Zn_xMn_yO_z$ thin films in order to introduce oxygen vacancies in the materials lattice in a single one step. Indeed, by varying the plasma gas composition, energetic electrons and reactive species like O, OH, CO… radicals enable the transformation of precursors into different stoichiometry nanostructured thin layers (Fig.1). In addition, the electrochemical performances of $Zn_xMn_yO_z$ and plasma composition are correlated.

References:

1. W. Xu, Y. Wang, (2019) Recent Progress on Zinc-Ion Rechargeable Batteries, *Nano-Micro Lett.*, 10.1007/s40820-019-0322-9.
2. H. Li, L. Ma, C. Han, A. Wang, A. Liu, Z. Tang, C.Zhi, (2019) Advanced rechargeable zinc-based bat-teries: Recent progress and future perspectives, *Nano Energy 62* (2019) 550-587,10.1016/j.nanoen.2019.05.059.
3. Yinlei Zhao Yunhai Zhu Xinbo Zhang Challenges and perspectives for manganese-based oxides for advanced aqueous zinc-ion batteries WILEY 2049 DOI: 10.1002/inf2.12042
4. Wen Shi, Wee Siang Vincent Lee, and Junmin Xue, (2021), Recent Development of Mn-based Oxides as Zinc-Ion Battery Cathode, ChemSusChem, doi.org/10.1002/cssc.202002493
5. Ting Xiong, Yaoxin Zhang, Wee Siang Vincent Lee, and Junmin Xue, (2020), Defect Engineering in Manganese-Based Oxides for Aqueous Rechargeable Zinc-Ion Batteries: A Review, Advanced Energy Materials; 10.1002/aenm.202001769
6. Haozhe Zhang, Jing Wang, Qiyu Liu, Wanyi He, Zhengzhe Lai, Xinyue Zhang, Minghao Yu, Yexiang Tong, Xihong Lu, (2019), Extracting oxygen anions from ZnMn2O4: Robust cathode for flexible all-solid-state Zn-ion batteries, Energy Storage Materials, doi.org/10.1016/j.ensm.2018.12.019

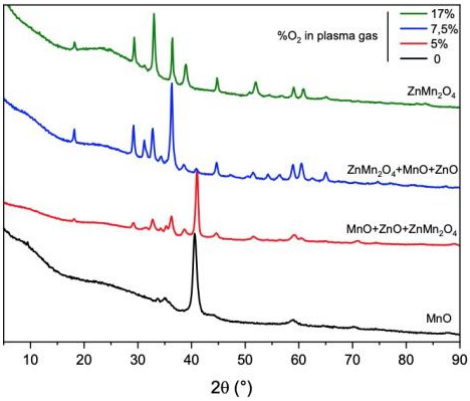


Figure 1: RX diagram of low pressure Plasma $Zn_xMn_yO_z$ at different % O_2

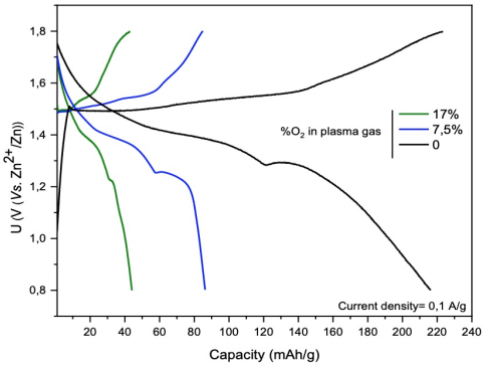


Figure 2: GCD curves of low pressure Plasma $Zn_xMn_yO_z$ at different % O_2 in 1M $ZnSO_4$+ 0,05M $MnSO_4$

The effect of electrolytic-plasma hardening on the microstructure, mechanical and tribological properties of medium carbon steel

B.K. Rakhadilov [1], D.R. Baizhan [1,2], L.G. Zhurerova [2], N.M. Magazov [2*], N.E. Berdimuratov[1]
[1] PlasmaScience LLP, Ust-Kamenogorsk, Kazakhstan
[2] Surface Engineering and Tribology RC, S.Amanzholov East Kazakhstan University, Ust-Kamenogorsk, Kazakhstan

Abstract:
One of the urgent problems of today's mechanical engineering is to provide maximum wear resistance of machine parts and tools. Surface treatment of steel parts using heating with concentrated energy flows (electron beam, laser radiation, plasma arc) is a significant saving potential for material, labor and energy costs [1]. The most promising energy-saving method among them is the method of chemical-thermal treatment in electrolytic plasma [2]. It has been established that the diffusion rate of elements in the surface layer during treatment in electrolyte plasma is much higher than in conventional processes [3]. In this study, we report on the effect of different parameters of electrolytic-plasma hardening (EPH) on the structure, hardness and wear resistance of steels. Also, we investigate and compare changes in microstructure, mechanical and tribological properties of medium carbon steel after bulk and surface hardening. It is determined on the basis of the results of SEM and X-ray structure analysis that small needle martensite with a small amount of cementite is formed after the EPH and large needle martensite is formed after bulk hardening in water and oil. After hardening changes in the structure of samples quenched with cooling in water are not observed. Microhardness of steel samples increases after bulk and surface heat treatment. After bulk hardening in water and oil the microhardness increased to 400-460 HV, and the subsequent annealing resulted in hardness decrease to 330-360 HV. At the same time after EPH the hardness of steel samples increased by 2 times and tribological properties increased. Primarily, this is due to the formation of a highly dispersed metastable structure with a higher density of dislocations in the surface layer. In EPH, only the 1-2 mm thick surface layer is hardened, while the base remains ductile. In this case the hardened layer smoothly passes to the base of the material. Due to the formation of the transition zone - the zone of thermal effect, the formed internal stress on the modified layer does not lead to the destruction of the steel material and the appearance of cracks in it. The wear resistance of the samples is characterized by the friction coefficient and the wear volume of the samples after the ball-and-disk test. The samples subjected to EPH and volume hardening with cooling in oil have low friction coefficient in comparison with the samples subjected to hardening with cooling in water. The data on the wear volume of the samples correlate well with the data on the friction coefficient of the samples. Samples after EPH, bulk hardening in oil showed a low volume of wear compared to other samples. The remaining treated samples showed a high degree of wear compared to the original sample. Thus, tribological properties of parts made of medium-carbon steel can be improved by applying heat treatment, including 900 ºC hardening with cooling in oil, followed by annealing with cooling in oil. However, bulk hardening can be an ineffective hardening method for parts operating in highly stressed and cyclically loaded applications. At the same time, surface EPH can be used for these parts. In this hardening process, only the surface layer is treated, which creates internal stresses that prevent parts from breaking. Surface EPH is a more economical and productive process than the bulk heat treatment.

Keywords: electrolytic-plasma hardening, medium-carbon steel, structure, wear resistance, microhardness.

References:

1. Belkin, P.N., Kusmanov, S.A. (2016) Plasma electrolytic hardening of steels: Review. *Surf. Eng. Appl. Electrochem.*, 52, 531–546.
2. Rakhadilov, B.K.; Buranich, V.V.; Satbayeva, Z.A.; Sagdoldina, Z.B.; Kozhanova, R.S.; Pogrebnjak, A.D. (2020) The cathodic electrolytic plasma hardening of the 20Cr2Ni4A chromium-nickel steel. *J. Mater. Res. Technol.*, 9, 6969–6976.
3. Zhurerova, L.G.; Rakhadilov, B.K.; Popova, N.A.; Kylyshkanov, M.K.; Buranich, V.V.; Pogrebnjak, A.D. (2020) Effect of the PEN/C surface layer modification on the microstructure, mechanical and tribological properties of the 30CrMnSiA mild-carbon steel. *J. Mater. Res. Technol.*, 9, 291–300.

Tribology 2023 Session II. D: Coatings and Surfaces Corrosion / Tribological Properties / Physics or Chemistry of Tribo-Surfaces/ Nanotribology

The application of a new Raman-based optical profilometry for understanding the governing factors of the tribofilm growth on a a-C:H coating

N. Xu, A. Morina*
Institute of Functional Surfaces, School of Mechanical Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom

Abstract:

The lubricant additive-derived tribofilms formed on coatings during a friction contact have the potential to determine the final wear and friction performance of the tribological system by changing the nature of the interface in contact. Hence, it is of paramount importance to understand the tribofilm formation processes so they can be optimised for different tribological systems. *In-situ* identification of tribochemical products can significantly contribute to revealing the governing factors of tribofilm growth on coating surfaces and the interaction mechanisms between the coating and lubricating additives.

In this study, an *in-situ* Raman-based profilometry (Figure 1) based on surface distinct optical properties has been developed and used to identify the tribofilms formed on a-C:H coatings. A selective growth of additive-derived tribofilms on a-C:H surface was observed for different lubricating additives. The obtained results suggest that the top oxidation layer of the a-C:H coating, caused by the catalytic oxidation of MoDTC-derived products, plays a crucial role in the growth process of ZDDP tribofilm on this coating. The oxidation process transforms the a-C:H surface from Lewis base to Lewis acid, providing active growth sites for ZDDP-derived products (phosphate-Lewis base) based on HSAB principle (Hard Soft Acids Bases). In view of the unobservable wear in the areas of tribofilm growth on a-C:H surfaces, it is suggested that the tribochemical reaction between ZDDP-derived products and a-C:H surfaces is driven by the interfacial Lewis acid-base interaction rather than the stress-dependent mechanism, highlighting the critical role of surface chemical property in the initial nucleation stage of tribofilm growth.

Keywords: Tribochemistry; tribofilm growth; additive; Raman, diamond-like carbon

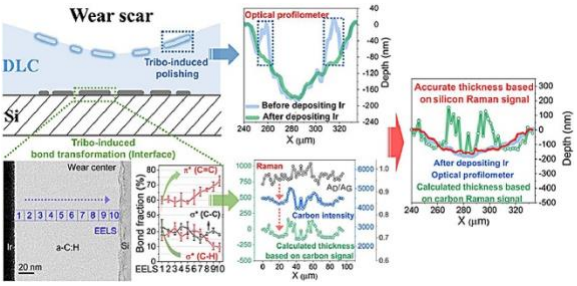


Figure 1: Schematic illustration of coating thickness quantification methods under dry friction [1]

References

1. Nan Xu, Ardian Morina, Nano-scale coating wear measurement by introducing Raman-sensing underlayer, Journal of Materials Science & Technology, Volume 96, 10 January 2022, Pages 285-294

Advancing solid interfaces and lubricants by first principles materials design

M. Clelia Righi
Department of Physics and Astronomy, University of Bologna, Bologna, Italy

Abstract:
I will present recent results on two reserch lines:

i) We apply molecular dynamics, both *ab initio* and based on reactive force fiels (tested agains *ab inito* results), to unravel the lubrication mechanism of hypericin. Hypericin, commonly used as medical treatment, posses amazing tribological properties. A hypericin concentration as low as 0.3% in glycerol reduces the friction coefficient below 0.01 (the so-called superlubricity regime) under boundary lubrication. First-principles calculations elucidate the thermodynamic driving force for graphene formation from hypericin. The process, promoted by the tribological conditions, was monitored in real-time by ab initio and classical molecular dynamics simulations. Our work suggests an exciting and unconventional way to promote the formation of a graphene-like material through tribomechanical stresses and reveals the great potential of aromatic molecules derived from the pharmacopoeia, such as hypericin, as newly emerging environment-friendly lubricant additives for industrial applications. [1]

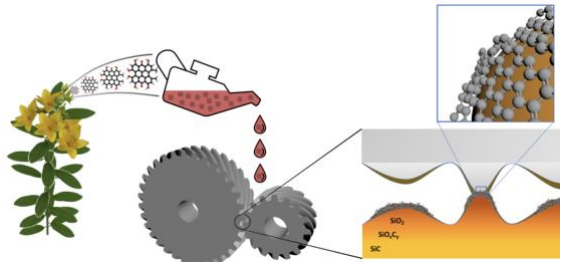


Figure 1: Schema of the superlubricity mechanism of the hypericin-lubricated steel/SiC pair (left side). The graphene formation pathway is schematized on the right side.

ii) We developed a workflow, TribChem, a modular scientific workflow connected to publicly available databases, and performed the high-throughput ab initio screening of the adhesion energy of around a hundred metallic heterostructures, ranging from transition to noble metals [2]. The dataset allowed us to identify general trends confirming a correlation of interfacial adhesion and electronic charge already observed for homogeneous interfaces [3,4]. Finally, by using a machine learning approach, we obtained a simple analytical expression for predicting the adhesion energy from the surface energy an other intrinsic properties of the two heterostructure constituents alone, which can prove useful for avoiding expensive supercell calculations.[5]

Keywords: tribochemistry, *in situ* formation of tribofilms, adhesion, solid interfaces, high throughput

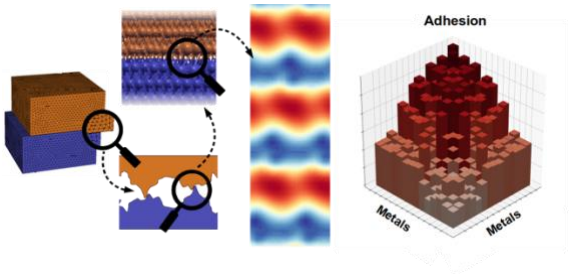


Figure 2: Nanoasperities, present in any mechanical contact, are studied atomistically considering two surface in contact.

References:

1. Yun Long, et al. Graphene-induced superlubricity through antiviral hypericin in glycerol. A new concept for green lubrication, to be published (2023).
2. G. Losi, et a., Tribchem, a high throughput package for solid interfaces, to be published (2023).
3. M. Wolloch, et al., High-throughput screening of the static friction and ideal cleavage strength of solid interfaces, Scientific Reports 9, 17062 (2019).
4. M. Wolloch, et al., Physical Review Letters **121**, 026804 (2018).
5. P. Restuccia et al. High throughput accurate prediction of interfacial adhesion energies in metal-on-metal contacts, accepted to ACS Applied Materials and Interfaces (2023).

Acknowledgments:
These results are part of the ”Advancing Solid Interface and Lubricants by First Principles Material Design (SLIDE)” project that has received funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation program (Grant agreement No. 865633).

Surface Effect : a Key to Understand and Reduce Friction in Lubricated Contacts

J. Cayer-Barrioz
Ecole Centrale de Lyon, Laboratoire de Tribologie et Dynamique des Systèmes, CNRS UMR5513, Ecully, France

Abstract:
The presence of roughness such as texturing affects the pressure field and induces local film thickness distributions which can be used to improve the lubricant efficiency in the contact [1]. The aim of our work was to deepen the understanding of the role of cavity texturing on the friction force in hydrodynamic lubrication (HL) regime under low contact pressures and in elastohydrodynamic (EHL) and mixed regimes under high contact pressures, with low-viscosity fluids.
Using the IMOTEP research platform that allows one to *in-situ* analyze the tribological mechanisms for conditions that cover 11 decades of sliding velocities and contact pressure, from 10^{-10} to 10 m/s and up to few GPa [2-5], by combining simultaneous measurements of contact forces with film thickness distribution, we investigated the influence of cavity network on lubrication and friction reduction mechanisms.
In HL regime, for an instrumented bearing of mean gap clearance of 5 µm, we showed that shallow-cavity low-density network resulted in reducing both friction and the shear-induced increase in temperature without changing the extension of the cavitation zone while modifying the shaft mean eccentricity. This behaviour was observed regardless of the fluid formulation and was finally accounted for by local flow recirculation in the shallow cavities [6].
In EHL regime, traction and Stribeck experiments were performed on a ball-on-disc MTM tribometer with simultaneous tangential and normal force measurements. The theoretical viscous friction under pressure was identified using several traction experiments. The textured surfaces presented a similar friction response as the smooth surface. However, a detailed analysis showed that in mixed regime, with a slightly higher roughness at the edge of the cavities, the number of asperity contacts increased leading to an increase in friction in this regime. In contrast, the EHL friction was lower in the case of the textured surfaces: the shallow cavities induced a local increase in the film thickness [1], inducing a decrease in viscous friction. This was also validated by traction results. In addition, the shift in the transitions to lower $\eta_0 U_e$ also confirmed this interpretation.

Keywords: friction reduction, surface, texturing, elastohydrodynamic lubrication, hydrodynamic lubrication.

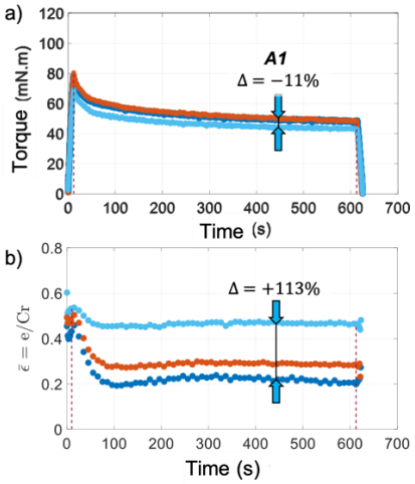


Figure 1: Friction reduction (a) associated to an increase of eccentricity (b) for the shallow-cavity low-density textured surface compared to the smooth one.

References:

1. Mourier, L., et al., Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 2010, 224(8), 697-711.
2. Crespo, A., et al. (2017), Methodology to Characterize Rheology, Surface Forces and Friction of Confined Liquids at the Molecular Scale Using the ATLAS Apparatus, *Tribology Letters*, 65, Article number 138.
3. Ernesto, A., Mazuyer, D., Cayer-Barrioz, J. (2014), The Combined Role of Soot Aggregation and Surface Effect on the Friction of a Lubricated Contact, *Tribology Letters*, 55 (2014) 329–341.
4. Bonaventure, J., Cayer-Barrioz, J., and Mazuyer, D. (2016), Transition Between Mixed Lubrication and Elastohydrodynamic Lubrication with Randomly Rough Surfaces, *Tribology Letters*, 64, 3, Article number 44.
5. Barazzutti, C., PhD thesis 2023ECDL0002, Ecole centrale de Lyon, 2023.
6. Rebufa, J., PhD thesis, 2016-LYSEC44, Ecole centrale de Lyon, 2016.

Enhanced tribological properties of Ti-6Al-4V ELI alloy through combination of slide burnishing and low-temperature gas nitriding

D. Toboła [1,*], J. Morgiel [2], Ł. Maj [2], A. Polkowska [1], A. Łętocha [1]
[1] Łukasiewicz Research Network, Krakow Institute of Technology,
Zakopianska 73 Str., 30-418 Krakow, Poland
[2] Institute of Metallurgy and Materials Science of Polish Academy of Sciences,
Reymonta 25 Str., 30-059 Krakow, Poland
*e-mail: daniel.tobola@kit.lukasiewicz.gov.pl

Abstract:
Titanium alloys, despite their high production costs, are gaining in interest because of their use in technologically advanced products, like in the combustion or jet engine. Unfortunately, such components requiring sliding or rolling contact with other parts, are subjected to fast wear which results in significantly reduced life-times [1,2]. A solution was supposed to be a gas nitriding, which indeed lowered the surface wear. However, during this treatment the roughness increases and the strength of the core material is strongly compromised, i.e. the most important property of this alloy is degraded due to necessity for its long-term exposure to temperatures only slightly below the α→β transformation point. Therefore, the influence of plastic deformation of near surface areas (induced by the slide burnishing) in enhancing the nitriding process of titanium alloys and allowing to perform it at temperatures lower than usual for that type of treatments was investigated [3,4].
Samples of Ti-6Al-4V ELI alloy were subjected to heat treatment, obtaining a hardness of ~380 HV0.03. After that, the following surface treatments were performed: turning (T), turning + burnishing (T+B), turning + burnishing + gas nitriding (T+B+GN). The slide burnishing using 130 N force, and thermochemical treatment at 540 °C for 8, 16 and 24 h were carried out. Details of the surface layer modification processes were decribed in previous works [3,4]. SEM/TEM observations, X-ray diffraction analysis, and finally ball-on-disc tribological tests against Al_2O_3 balls as counterparts provided information about wear resistance and friction values.
The lowest average values of the friction coefficient and wear rate were determined for samples subjected to sequential surface treatment of T+B+GN(16 h). In addition, it was found that the amorphous tribo-material on the Ti-6Al-4V ELI alloy constitutes a diffusion barrier for nitrogen. Only the transformation with the dominant participation of TiO_2 crystallites, opens the way to the substrate nitriding process and enables nucleation of TiN in the substrate.

Keywords: titanium alloy, surface layer, wear resistance, coefficient of friction, slide burnishing, gas nitriding

References:

1. Philip, J.T., Mathew, J., Kuriachen, B. (2019) Tribology of Ti6Al4V: A review. *Friction*, 7(6), 497–536.
2. Gupta, M.K., Etri, H.E., Korkmaz, M.E., Ross, N.S., Krolczyk, G.M., Gawlik, J., Yaşar, N., Pimenov D.Y. (2022) Tribological and surface morphological characteristics of titanium alloys: a review. *Arch. Civ. Mech. Eng.*, 22:77.
3. Toboła, D., Morgiel, J., Maj. Ł. (2020) TEM analysis of surface layer of Ti–6Al–4V ELI alloy after slide burnishing and low-temperature gas nitriding. *Appl. Surf. Sci.*, 515, 145942.
4. Toboła D., Morgiel, J., Maj. Ł., Pomorska M., Wytrwal-Sarna M. (2022) Effect of tribo-layer developed during turning of Ti–6Al–4V ELI alloy on its low-temperature gas nitriding. *Appl. Surf. Sci.*, 602, 154327.

Acknowledgment: The support from the National Science Center of Poland, Grant no. UMO-2020/39/D/ST8/02610 (SONATA-16) is gratefully acknowledged.

Improving wear and corrosion resistance of a ta-C film by sealing surface with ALD TiO_2 for biomedical applications

Guizhi Wu[1, 2*], Jian Wu[2], Ardian Morina[1], Nan Xu[1], Liuquan Yang[1*]
[1] School of Mechanical Engineering, University of Leeds, Leeds, LS2 9JT, United Kingdom
[2] State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou, 730000, China.
*Corresponding author: G.Z.Wu@leeds.ac.uk, L.Q.Yang@leeds.ac.uk

Abstract:
This paper proposes for the first time of a hybrid coating structure on Ti6Al4V substrates with tetrahedral amorphous carbon (ta-C) film followed by a dense TiO2 top layer aiming to seal the porous defects of ta-C surface. The ta-C coating was deposited from an arc ion plating (AIP) system whilst the TiO2 layer was deposited by atomic layer deposition (ALD). Results show the potential use in biological area of such approach by that wear and corrosion resistance in phosphate buffer solution (PBS) were improved simultaneously compared with Ti6Al4V substrate or ta-C coated Ti6Al4V. The reduction of the surface porosity and the barrier properties of the coating with the improved properties were discussed.

Keywords: ta-C coating, atomic layer deposition, tribological property, corrosion behavior, bio-tribology.

References

1. Ibrahim, M., et al. (2017), Biomedical materials and techniques to improve the tribological, mechanical and biomedical properties of orthopedic implants-a review article, *J. Alloys Compd.*, 714, 636–667.
2. Muller B., et al. (2016), Atomic layer deposited TiO2 protects porous ceramic foams from grain boundary corrosion, *Corros. Sci.*, 106, 35-42.

Development of Corrosion and UV Resistant Fusion Bonded Epoxy Coatings on Steel components for offshore applications

A.Madhan Kumar,
Interdisciplinary Research Center for Advanced Materials,
King Fahd University of Petroleum & Minerals,
Dhahran, Kingdom of Saudi Arabia

Abstract:
Due to its widespread practice, steel consumption in the worldwide has been raised annually by about 40% between 2012 to 2015, through the structures of steel rod, bar, wire and reinforcing bar in great demand. The corrosion protection of steel structures has always been of chief concern for current research and development in the structural engineering as it faces severe corrosion issues due to its huge economical and industrial development in the coastal zones. Fusion bonded epoxy (FBE) coatings have been utilized as protective coatings for steel structures exposed in atmospheric, marine and industrial sectors for the last 5 decades [1]. It can be utilized as a single primer layer and as a base coat in multi coat systems. Though FBE coatings have been subjected to vast improvement for the past few decades, still there are some shortcomings that are not completed solved such as the less UV resistance, inadequate abrasion resistance and insufficient multi-functional characteristics including super hydrophobicity, antifouling, self-healing etc [2]. These issues can be the productive approach in concentrating the development on FBE coatings to get the desired features.

This current investigation demonstrates the feasibility of multifunctional FBE coatings with desired features (UV and Corrosion resistant) on steel structures including transmission pipelines, tanks and rebar in concretes through systematic approach. The complete cycle of fabrication from raw materials will be developed and full characterization in terms of hydrophobicity, mechanical, corrosion, fouling and UV resistance performance will be performed to evaluate the developed FBE coatings in stage by stage. All industrial sectors that are involved in manufacturing and utilizing steel structures will be benefit from the proposed FBE coatings. In particularly, the steel structures exposed in atmospheric conditions have been availed this proposed multifunctional FBE coatings as the operating conditions of these components are highly aggressive with UV exposure. The successful execution of this possible plan will enable us to develop these materials locally as the only step left would be to apply them for the protection of steel structures in real exposure condition (of course, after passing all required testing to be used in real exposures to the marine environment).

Keywords: Fusion bonded epoxy coatings; corrosion mitigation; UV resistant; steel.

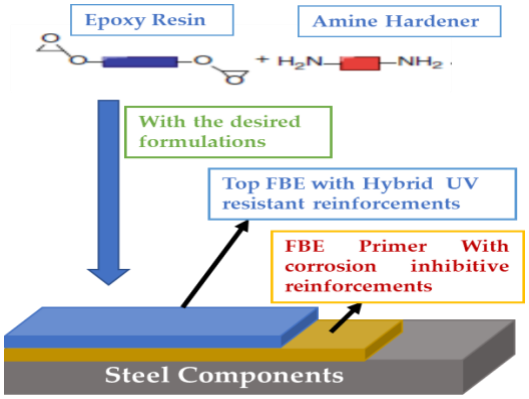


Figure 1: Figure illustrating the schematic representation of the current research work

References:

1. D.K. Kamde, R.G. Pillai, Effect of sunlight/ultraviolet exposure on the corrosion of fusion bonded-epoxy (FBE) coated steel rebars in concrete, Corros. 76 (2020) 843–860.
2. Deepak K. KamdeRadhakrishna G. Pillai, Corrosion initiation mechanisms and service life estimation of concrete systems with fusion-bonded-epoxy (FBE) coated steel exposed to chloride. Cons. Build. Mater. 277 (2021) 122314.

Use of the parallel and normal SVET vibration modes and data recollection for the direct investigation of corrosion processes

J. Izquierdo [1,2,*], A. Abreu-García [1], R.M. Souto [1,2]
[1] Departmento de Química, Universidad de La Laguna, La Laguna, Spain; *jizquier@ull.edu.es
[2] Institute of Materials and Nanotechnology, Universidad de La Laguna, La Laguna, Spain

Abstract:
The scanning vibrating electrode technique (SVET) has become common for locally revealing anodic and cathodic activity at corroding surfaces, including coated metals, defects at protective coatings and cut edges.[1] The technique takes advantage of the enhanced sensitivity provided by the piezoelectric-driven vibration of a microreference electrode while sensing electrical voltage distributions, next translated into associated ionic current densities arising from the reactive material. Vibration in two axes, namely perpendicular and one parallel direction with respect to the surface under study, are commonly used for the determination of the vectorial current density distribution, although typically only the perpendicular component is analized to localize anodes and cathodes evolving in the sample below. Flat surfaces imbedded in insulating material are preferred so that such perpendicular contribution may reflect the main current flow arising from the active spots. This has enabled the characterization of the activation/passivation events at cut edges, where one or two micrometric-width Zn-based galvanized areas are coupled with the core steel surface.[2] However, actual corrosion problems convey coupling and interaction of sites placed at differently oriented facets of the same material simultaneously exposed, as occurs in actual cut edges of machined galvanized steels in the building and automotive industries. Even the presence of assymmetries between the two exposed sides, either just galvanized or additionally coated with polymers, has been reported to play a role in the resulting events occurring on the cut edge.[3] However, no attempts have been made to characterize the local electrochemical activity simultaneously arising from the galvanized side (Figure 1), that is also exposed to the environment and reacts under real operation conditions.

In this contribution, the SVET technique has been exploited to extend the conventional data analysis of vertical ionic current densities, so that the current flow in the parallel direction becomes also accessible. A model sample consisting of a current point source was used to illustrate the SVET ability to discern anodic and cathodic activity in different orientations. Next, cut edge systems were investigated while sequentially analizing and correlating the cathodic current distribution at the steel-base cut edge, and the anodic activity of the galvanized layer revealing localized anodic activation.

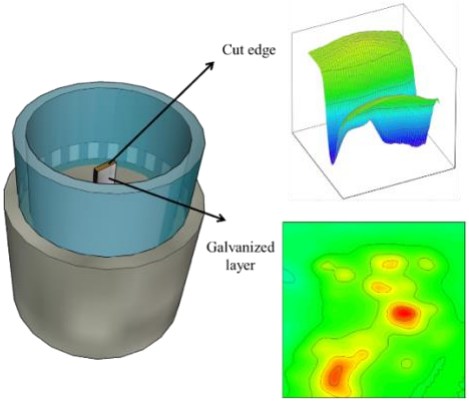


Figure 1: Cell assembly used for the characterization of the top (cut edge) and side (galvanized) surfaces exposed to the aggressive envornment. Yellow-red color palette reflects local anodic activity, found over the galvanized layer. Blue color palette reflects cathodic activity, sensed over the steel-matrix at the cut edge.

Keywords: SVET, galvanized steel, corrosion, cut edge, scanning probe techniques.

References:

1. Bastos, A.C., Quevedo, M., Karavai, O. (2017) Review—On the application of the scanning vibrating electrode technique (SVET) to corrosion research, *J. Electrochem. Soc.*, 164, C973-C990.
2. Filotas, D., Izquierdo, J., Fernández-Pérez, B.M., Nagy, L., Nagy, G., Souto, R.M. (2022), Contributions of microelectrochemical scanning techniques for the efficient detection of localized corrosion processes at the cut edges of polymer-coated galvanized steel, *Molecules*, 27, 2167.
3. Worsley, D.A., Williams, D., Ling, J.S.G. (2001), Mechanistic changes in cut-edge corrosion induced by variation of organic

coating porosity, *Corros. Sci.*, 43, 2335-2348.

Graphene derivatives as solid lubricant in polymer-tribology, Challenges and opportunities

Nazanin Emami and Julian Somberg
Polymer-tribology group, Division of Machine elements, Luleå University of Technology, Sweden

Abstract:
Graphene as 2D material is considered an promising solid lubricant for polymer composites while simulatniously enhancing mechanical thermal and electrical properties. By the introduction of graphene to low friction polymer, wear is often reduced significantly although the friction, which highlights the lubricity is often unaffected [1]. Furthermore, graphite being ascribed to its multilayer morphology, has been used traditionaly as solid lubrixant in order to reduce coeficent of friction [2], though, graphene is not an obvious choice as solid lubricant. It is therefore important to understand the effect of the degree of exfoliation as well as oxidation of graphite/graphene on its properties as soluid lubricant. In our study, graphene oxide (GO), reduced graphene oxide (rGO), chemically expanded graphite (CEG) and graphite were tested in ultrahigh molecular weight polyethylene (UHMWPE) composites at 1 and 5 wt%. Friction and wear were measured using a reciprocating pin-on-plate tribometer while sliding against a stainless steel counter surface with a contact pressure of 10 MPa and a sliding velocity of 0.02m/s.
Under dry sliding conditions, the friction increased for all composites with respect to the pure polymer. No clear transfer film was observed on counter surface. The composite pin surfaces did however show a rippled pattern (see figure 1), indicating stick-slip sliding, resulting in the higher friction. This was in contrast to the pure polymer which only showed abrasive wear grooves. Graphite provided the highest increase in friction which corresponds with a more pronounced ripple pattern. By comparing the GO with rGO, no clear differences in friction performance were observed indicating that a lower oxygen content did not have any significant impact towards macro-scale lubricity in UHMWPE. By differential scanning calorimetry, a clear dependence of the polymer degree of crystallinity was found with respect to the appearance of stick-slip sliding and corresponding increase in friction for the composite materials.
The specific wear rates were significantly lower than the pure polymer for the CEG and graphite composites. Similar to the friction, no clear difference was found between GO and rGO with both enabling an increase in wear. 1wt% CEG reduced the wear rate by over 75%.
The results indicated that obtaining a significant friction reduction using both graphene derivatives and graphite is challenging in low friction polymer such as UHMWPE. The presence of graphene can obstruct the crystallisation of the polymer and also its low friction mechanisms. Due to the their exfoliation, this effect was limited for GO and rGO enabling a lower increase in friction coefficient than the multilayer CEG and graphite. However, only CEG and graphite reduced the wear of the polymer which can be ascribed to the better lubricity of multilayer graphite as well as the strain hardening of the sliding surface.

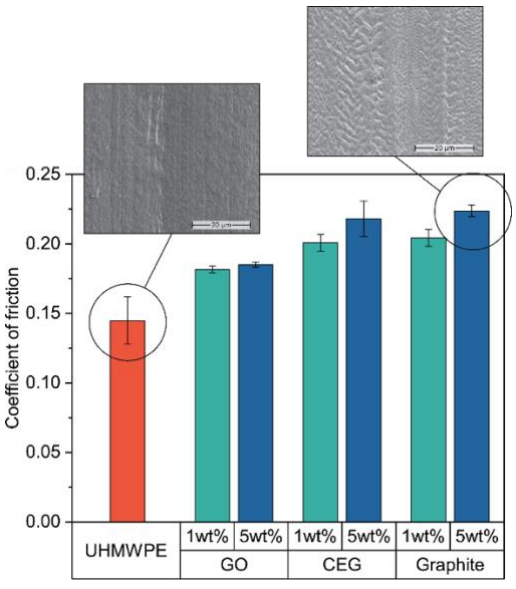


Figure 1: Friction coefficients from dry sliding experiments and surface morphology of the UHMWPE and 5wt% graphite sample pins

Keywords: Graphene, expanded graphite, solid lubricant, polymer composites

References:

1. Z. Tai, Y. Chen, Y. An, X. Yan, Q. Xue, Tribological behavior of uhmwpe reinforced with graphene oxide nanosheets, Tribology Letters 46 (2012) 55.
2. T.W. Scharf, S.V. Prasad, Solid lubricants: a review. J Mater Sci 48, 511–531 (2013).

Investigation of Modification with GLYMO and Carbodiimide on Thermomechanical Properties of Two-Component Castor Oil Based Polyurethane Adhesives

A. Yıldırım [1*], N.K. Mermer [1], M.A. Özkan [1]
[1] Kalekim Construction Chemicals Co, Avcılar, Istanbul, Turkey.

Abstract:
Polyurethane adhesives (PUA) are preferred for their many advantageous features, including, high mechanical properties, low temperature performance, and adjustable cure times. The most of adhesives are made from petroleum-based raw materials, a well-established technique that raises environmental issues during both manufacture and use. In that regard, it is necessary to use renewable resources to make adhesives. Castor oil has a wide range of industrial uses, which has resulted in steadily rising demand for it on the global market. Although they have good mechanical properties and are more environmentally friendly with the use of castor oil, polyurethanes have a very low heat resistance. It can maintain the appropriate mechanical properties up to 80-90°C and above 250°C, thermal breakdown begins. The polyurethane material becomes more temperature resistant as the quantity of crosslinking in its structure increases. To achieve maximum strength and thermal stability, PUAs must have precise adhesion control with the matrix. To a large extent, the thermal stability of polyurethanes is proportional to the degree of chain mobility present in the material.
This study focuses on the preparation of PUAs with higher thermal resistance using polyols derived from castor oil modified using 3-Glycidyloxypropyltrimethoxysilane (GLYMO) and carbodiimide as an adhesion promoter. Various NCO/OH ratios have been employed to evaluate its impact on the characteristics of the adhesives. The effect of different GLYMO and carbodiimide ratios on the performance of the adhesive was also investigated. The characterization of the raw materials was performed by using FTIR and STA instruments. In order to determine the performance of the samples shear adhesion strength test were carried out according to EN 12004 standard of Adhesives for ceramic tiles. The shear adhesion strength after thermal shock value, which increased with the addition of GLYMO, reached its maximum value with the use of carbodiimide.

Keywords: Castor oil, Polyurethane adhesive, Thermomechanical properties, Carbodiimide

References:

1. Manjeet, M., Raminder, K. (2016), Mechanical and Thermal Properties of Castor Oil–Based Polyurethane Adhesive: Effect of TiO_2Filler, *Advances in Polymer Technology*, Vol. 00, No. 0,
2. Senthilkumar, N., Raghavan, A. and Nasar, A.S., (2005). Novel metalcontaining Polyurethane elastomers prepared using tetradentate Schiff base metal complexes, *Macromolecular Chemistry and Physics*, 206, 2490-2500.
3. Sriram, V., Sundar, S., Dattathereyan, A. and Radhakrishnan, G., (2005). Synthesis and characterization of cationomeric AB crosslinked polyurethane polymers based on different chain extenders, *Reactive & Functional Polymers*, 64, 25-34.

Why Teflon is so slippery while other polymers are not

Hans Terwisscha-Dekker [1,*], Bart Weber [1,2], Daniel Bonn [1]
[1]Institute of Physics, University of Amsterdam, Amsterdam, the Netherlands
[2] Advanced Research Center for Nanolithography (ARCNL), Amsterdam, the Netherlands

Abstract:
PTFE (polytetrafluoroethylene, better known as Teflon) is known for its low friction, with a friction coefficient similar to that of a skate on ice, and much lower than other polymers. A key difference with other polymers is that PTFE is non-sticky: its surface energy is the lowest of commonly used engineering materials. It is tempting to explain its slipperiness from the lack of adhesion – friction in polymers is often governed by adhesion, and might thus vanish for a non-sticky polymer. Although this sounds reasonable, research has shown that in fact, PTFE friction is accompanied by transfer of a PTFE film adhering to the substrate [1-2]. The fact that PTFE transfers does not, however, offer a direct explanation of its slipperiness: numerous other polymers transfer, yet their friction is much higher than that of PTFE.

So why is PTFE so exceptionally slippery compared to other polymers? We use state-of-the-art contact visualisation experiments to look inside the PTFE-substrtate contact, and we resolve the formation of transfer film *in situ.* We show quantitatively that an unusually low PTFE-PTFE shear strength in the sliding contact is the key factor for low friction and transfer. This very weak shear cohesion allows for low friction despite large contact area and robust transfer despite modest adhesion. These results provide the first quantitative understanding of low friction transfer film formation, which may lead to transformative applications in tribology such as rational design of low friction materials.

Keywords: Teflon, PTFE, transfer film, polymers, friction, adhesion, fluorescence microscopy

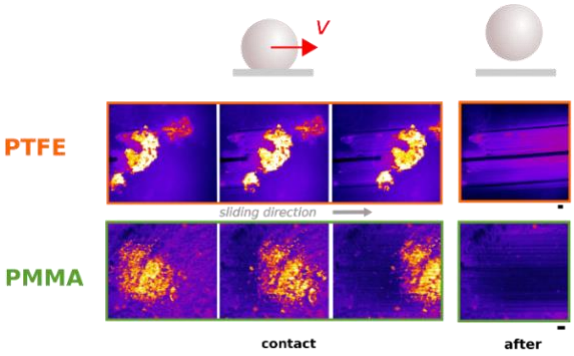


Figure 1: Fluorescent contact probes emit strongly when confined, which reveals the area of contact between a PTFE sphere and a DCDHF-coated glass coverslip. After the contact is broken, fluorescence emission uncovers the presence of a residual transfer film , which only forms in a sliding PTFE contact, not when PMMA is the contacting polymer. Scale bar indicates 10 µm.

References:

1. S. K. Biswas and K. Vijayan (1992), Friction and wear of PTFE - a review, *Wear* 158, 193.
2. T. A. Blanchet and F. E. Kennedy (1992), Sliding wear mechanism of polytetrafluoroethylene (PTFE) and PTFE composites, *Wear* 153, 229.

Influence of different deterministic surface texturing processes on friction and tool life for load collectives in sheet metal forming

P. Schumann[1], R. Lindner[1], P. Groche[1]
[1] Institute for Production Engineering and Forming Machines, Technische Universität Darmstadt, Darmstadt, Germany

Abstract:
Sheet metal processes such as blanking or deep drawing are usually characterized by high production volumes and dynamically stressed tools. These complex, time-variant tribological challenges can be partially mastered by tailored tool surfaces in the submillimeter range. A reduction regarding lubricant demand, coefficient of friction, and an increase in service life are possible results. However, the production of textured surfaces is very challenging. Production time, the definition of texture geometry, reproducibility, and tool life for texturing processes are inhibiting factors for the introduction into industrial applications.
Therefore, this study investigates the benefits of deterministic surface texturing of a typical cold-forging steel by two different texturing processes in comparison with the industrial standard of manual polishing. The resulting deterministic topography of a laser textured surface is compared with a machine hammer peened surface structure while using a tool with a micro tip. Differences in the production time as well as the resulting surface quality are investigated. Using a continuous strip drawing test the microtextured tool surfaces under varying levels of surface coverage are investigated. The resulting coefficient of friction and tool lifetime for changing contact normal stresses reaching from 5 to 25 MP are compared with an industrial polished surface. Eventually, the influence of tribological performance is evaluated. A reduction of the friction coefficient, as well as an improvement in surface hardness due to the investigated processes, are shown.

Keywords: sheet metal forming, surface modification, friction, tool life, strip drawing, machine hammer peening

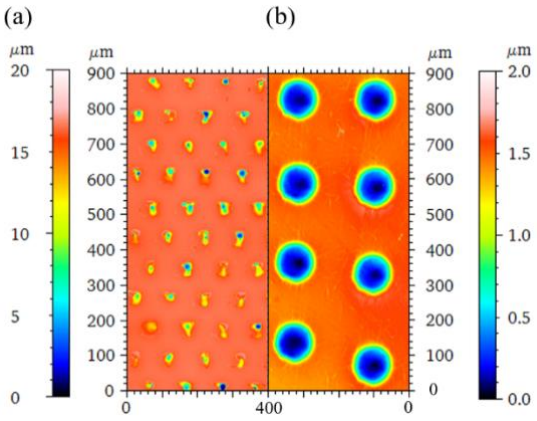


Figure 1: Surface topographies for different texturing processes: (a) laser texturing and (b) machine hammer peening

References:

1. Bruzzone, A.A.G; Costa, H. L.; Lonardo P. M.; Lucca, D. A. (2008), Advances in engineered surfaces for functional performance, *CIRP Annals*, 57, 750 -769.
2. Shimizu, T., Kobayashi, H., Vorholt, J., Yang, M. (2019). Lubrication analysis of micro-dimple textured die surface by direct observation of contact interface in sheet metal forming. *Metals*, *9*(9), 917.

Dedicated Hybrid Turbo GDI Engine with Low Friction Loss

Q. Zhou
Changan UK R&D Centre, 3700 Parkside, Birmingham Business Park, B37 7YG, UK

Abstract:
The Dedicated Hybrid Engine (DHE) development attracted increased attentions from OEMs. With the reduced engine power demand and narrowed engine operating speed range, it created a friendly environment for the low friction technologies to be implemented without further cost implication. This paper presented the friction road map from the current production engine to the new dedicated hybrid engine. At 2000 rpm, 2 bar BMEP condition, the new DHE will have the FMEP <0.29 bar according to the well correlated prediction.

The conventional gasoline engines' typical operation range covers from idle (~600 to 750 rpm) to max speed of 6300 to 7000 rpm. Usually, the moving parts, such as the piston, conrod, bearing, spring, valve, cam, tappet or follower etc., are designed to survive the max speed and max power condition. In other words, these components are likely over-engineered when operating away from these design limits.

For the DHE, especially for P13 platform with dual powerful e-Motors on board, the engine's operating range can be reduced significantly. For example, the operating speed of the new DHE presented in this paper is from 1200 to 4800 rpm, much narrower than that of the conventional engine. To utilize this new operating boundary, all the moving parts are re-designed with reduced bearing size and much reduced valve spring load. Helped with the newly optimized valvetrain layout, the new DHE's valve spring preload can be reduced from production engine's 190 N to 107 N, a reduction of 44%. Furthermore, the valve spring's stiffness is reduced from 25 to 9.8 N/mm. For the maximum valve lift of 10 mm, the peak spring load of the DHE is 205 N only, a 55% reduction from the production engine's 460 N peak valve spring load. This converted to a 28% friction reduction for the valvetrain alone at 2000 rpm engine speed.

Figure 1 shows the predicted friction from piston + conrod, crankshaft and valvetrain of the production NE engine and new DHE. The NE engine is a conventional 4-cylinder 1.4L turbocharged GDI engine with 73.5 mm bore diameter and 82 mm stroke. The new DHE is also a 4-cylinder turbocharged GDI engine but with smaller bore (69 mm diameter) and much longer stroke of 100 mm , making the stroke to bore ratio to be 1.45. On the crankshaft, the main and big bearings are sized with negative overlap. The small end used DLC coated pin without brass bush. The three piston rings total tangential load is 22% less than that of production NE engine.

Furthermore, the DHE used fully synthetic 0W12 oil, compared with NE's 0W20 oil. This 0W12 oil was carefully selected by considering the engine operating condition change and subsequent moving part design changes. It also has the unique additive packages to balance the low friction, durability and knock suppression requirement. Adding these changes, plus the use electric oil pump, the estimated total engine FMEP for DHE is less that 0.29 bar, making it the lowest friction engine in company's engine portfolio

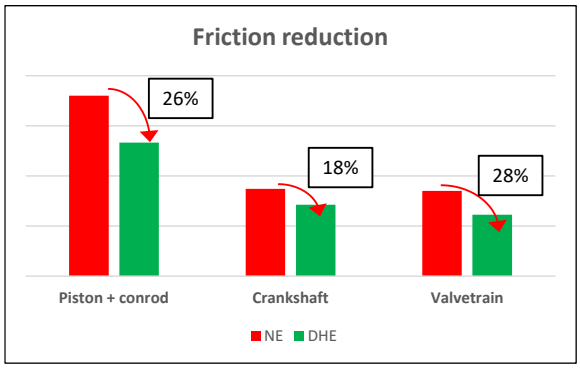


Figure 1: Major friction reduction from moving parts, 2000 rpm, 2 bar BMEP

Keywords: Low friction valvetrain & cranktrain, thin oil.

References:

1. Zhou, Q., Zhang, X. (2018) From Low Friction Concept to Reality–Changan NE14 Engine, *2018 Wuxi ICE Congress, China*

Nanoscale study of the growth of ZDDP tribofilm based on compression/shear stress

K. Sato [2], S. Sasaki [1]
[2] Department of Mechanical Engineering, Graduate School of Tokyo University of Science, Tokyo, Japan
[1] Department of Mechanical Engineering, Tokyo University of Science, Tokyo, Japan

Abstract:
Atomic force microscopy (AFM) is widely used to investigate friction mechanisms at the nanoscale due to making it possible to directly measure friction force from AFM tip twist. Recently, Gosvami et al. have used AFM for in-situ observation of the growth process of tribo-chemical reaction films in lubricant 1). Gosvami et al. also reported that the growth of tribofilm increases exponentially with increasing temperature and compression stress using the in-situ AFM method 1). However, Gosvami et al. evaluated the growth of tribofilm as an average value on a microscale friction surface and did not investigate the effects of compression/shear stresses on the growth process of reaction film on a single asperity. The purpose of this study is to investigate the effect of compression/shear stresses on the formation process of reaction films by observing the formation process of reaction films on a single asperity. In this paper, we investigate the growth process of the tribofilm on a single asperity by correcting small misalignment using image analysis on the results of in-situ AFM methods. We also investigated the effect of compression/shear stresses on the growth process of tribofilm on a single asperity by measuring the friction coefficient and the compression stress distribution on the single asperity using the finite element method. Figure 1 shows (a) AFM images, (b) growth of tribofilm, (c) compression stress distribution, (d) shear stress distribution (e, f) correlation between compression/shear stresses and tribofilm thickness. These results show that the growth points of tribofilm were consistent with compression stress. In addition, from correlation between compression/shear stresses and tribofilm thickness, only compression stress correlated with tribofilm thickness. Therefore, we consider that compression dominates the growth of tribofilm at initial tribofilm formation process.

Keywords: Tribo-chemical reaction; Atomic Force Microscopy; In-situ Observation; Tribofilm

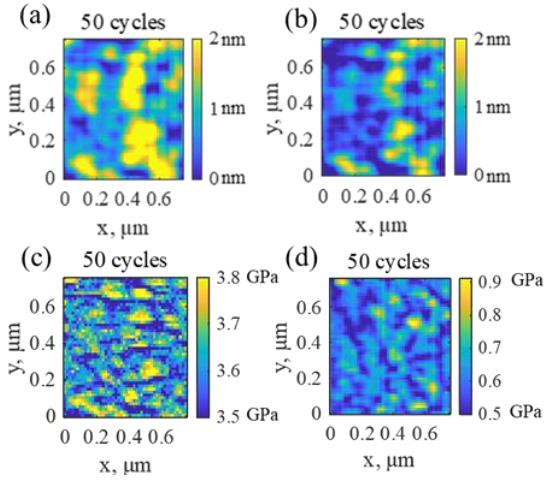


Figure 1: Results of in-situ AFM ((a) AFM images, (b) growth of tribofilm, (c) compression stress distribu-tion, (d) shear stress distribution

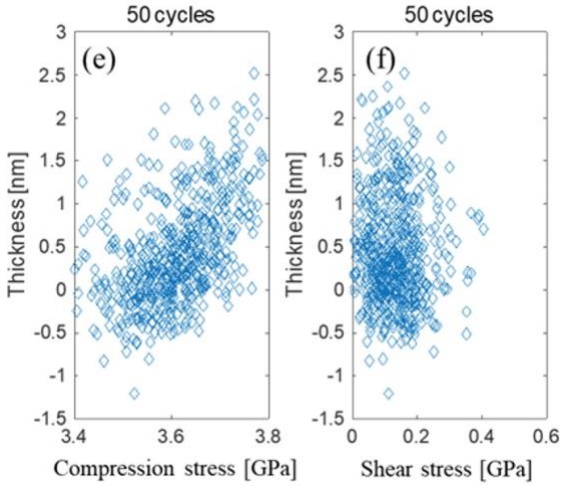


Figure 2: and (e, f) correlation between compression/shear stresses and tribofilm thickness

References:

1. Gosvami, N. N., Bares, J. A., Mangolini, F., Konicek, A. R., Yablon, D. G., Carpick, R. W., "Mechanisms of antiwear tribofilm growth revealed in situ by single-asperity sliding contacts", Science, Vol. 348, (2015), pp. 102-106.

Research on Pitting Fatigue Properties of Diamond-like Carbon Films under Pure Rolling Contacts

K. Nakayama [1,*], S. Watanabe [2], A. Harada [2], K. Sato [2], S. Sasaki [1]
[1] Department of Mechanical Engineering, Tokyo University of Science, Tokyo, Japan
[2] Department of Mechanical Engineering, Graduate School of Tokyo University of Science, Tokyo, Japan

Abstract:
Electric vehicles (EVs) are being attracted due to growing interest in environmental issues. In EVs, higher speed motor rotation is required to obtain the equivalent output as conventional engine; therefore, it is required that motor of EVs become smaller and lighter. In addition, high rotational speed reduces the fatigue life until pitting occurs because the number of contacts increases compared with the case at low rotational speed. Diamond-like carbon (DLC) film is a type of amorphous hard thin film consisting of sp^2 and sp^3. DLC has various excellent tribological properties such as low friction and high hardness. High hardness is known to reduce the occurrence of cracks that cause pitting; therefore the application of DLC is expected to improve pitting resistance of bearings and gears. Furthermore, sliding and rolling contact occur simultaneously on the contact surface of gears and bearings. Therefore, it is important to identify the effects of sliding and rolling contact on fatigure occurance. However, it has been reported that the rolling fatigue surface can be eliminated by sliding wear [1]. Therefore, pure rolling test is important to clarify the effect of rolling contact on pitting because it is less affected by sliding. In this study, two types of DLC films (ta-C and a-C:H) were applied to the ball surface, and three types of balls were used: uncoated, a-C:H coated, and ta-C coated. To investigate the influence of these DLC films on pitting resistance, we conducted ball-on-disc tests for 40 h and 96 h under base oil lubrication under pure rolling contacts and performed nano-indentation and Raman spectroscopy. As results, pitting occurred on uncoated balls (Figure 1), which indicated that pitting can be evaluated under pure rolling contacts. The a-C:H type DLC film was peeled off immediately after the test began. In addition, no pitting occurred on the ta-C type DLC film (Figure 2). Thereby, we found the ta-C film has an excellent property of pitting resistance due to high hardness. However, to extend the sliding test duration from 40 h to 96 h, pitting occured on the ta-C film. Then, the hardness of ta-C film changed to 68 GPa before sliding test, 42 GPa at 40 h, and 51 GPa at 96 h, and the I_D/I_G ratio changed 0.14 before sliding test, 0.19 at 40 h, and 0.14 at 96 h, respectively. This tendency showed that the structural change of ta-C is related to hardness. Therefore, the decrease in hardness due to the graphitization in ta-C may have increased the cracks which cause pitting.

Keywords: Tribology, EV, gear, bearing, DLC, pitting, pure rolling, MTM.

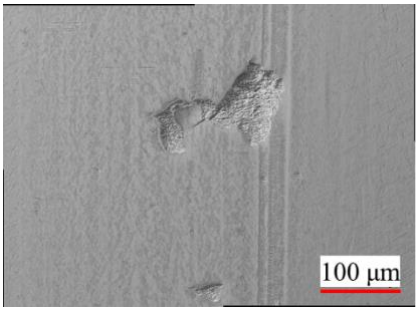


Figure 1: Figure shows the laser microscope image of the SUJ2 disc surface after 40 h testing under pure rolling contacts in PAO4. This shows that pitting occurred on uncoated ball.

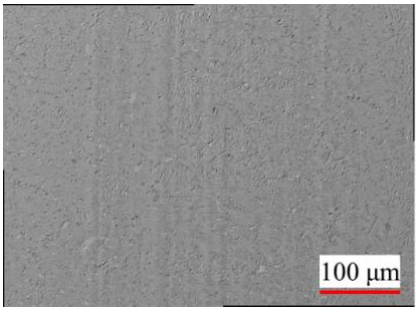


Figure 2: Figure shows the laser microscope image of the ta-C disc surface after 40 h testing under pure rolling contacts in PAO4. This shows that no pitting occuerd on the ta-C coated ball.

References:

1. Vrcek, A., Hultqvist, T., Baubet, Y., Björling, M., Marklund, P., Larsson, R., "Micro-pitting and wear assessment of engine oils operating under boundary lubrication conditions", Tribology International, Vol. 129, (2019), pp. 338-346.

LUBGEAR – Increased Lifetime of Gears under Loss of Lubrication

L. Braumann [1,*]
[1] Research, Advanced Drivetrain Technologies, Vienna, Austria

Abstract:
Aerospace gearboxes, as used in the geared turbofan propulsion system, are required to work even in the most unfavourable conditions such as temporary loss of primary lubrication. Such conditions can arise during certain flight manoeuvres or during windmilling when the aircraft is on ground. To avert the catastrophic damage associated with loss-of-lubrication, a secondary lubrication system is currently in service. The utilization of such a secondary lubrication system leads to higher mass and complexity of the drivetrain and stands in contrast to the demand for highest power density and efficiency. In the European research project LUBGEAR, different materials and surface finishes for gears which have high potential to increase the service life under loss-of-lubrication are investigated as an alternative to the secondary lubrication system used for aerospace gearboxes. LUBGEAR is a European research project which is funded by the Clean Sky 2 Joint Undertaking with support from the European Union's Horizon 2020 research programme. The project is led by the Spanish surface technology experts CIDETEC and consists of the gear research centre FZG of the Technical University Munich as well as the tribology excellence centre AC²T and the precision drivetrain manufacturer ZOERKLER Gears & drivetrain expert ADT near Vienna. The research topic is managed by Avio Aero, a GE aviation business in Rivalta di Torino.
To find the most promising combination of material and surface treatment for aerospace gear applications under loss-of-lubrication, a pre-selection of combinations will be performed on a twin-disc tribometer. The test articles of the twin-disc tribometer are designed to closely mimic the tribology of contact between two gear flanks to allow for good transferability of the test results. Based on these results, tests on gears will be performed at the FZG facility on a gear test rig for high-speed (up to 80m/s pitch circle velocity) and high load (up to 2GPa) in lubricated conditions and under loss-of-lubrication. The results of the twin-disk and the gear testing campaign will be utilized to adapt a predictive numerical contact model for loss-of-lubrication conditions.
At the current state possible solutions for surface treatments as well as materials have been identified: These include superfinishing, coating by novel ceramic-class coatings and nitriding steels which maintain their surface hardness at much higher temperatures than regular carburizing steels. The most promising of those solutions are currently being applied on gears and tested at pitch line velocities of up to 20m/s while the best performers are being investigated on the high-speed 80m/s test rig.

Keywords: geared turbofan, LOL, loss of lubrication, scuffing, coating, nitriding, DLC, aviation

Figure 1: The LUBGEAR adapted FZG-C pinion before and after loss of lubrication. Scuffing marks and overheating are clearly visible on the tooth surface (right).

Experimental approach to evaluate the fatigue life of DLC coating based on friction and continuous wear data

M. Zellhofer [1,*], M. Jech [1], E. Badisch [1], F. Ditrói [2], A. Kübler [3], P. H. Mayrhofer [4]
[1] AC2T research GmbH, Viktor-Kaplan-Straße 2/C, 2700, Wiener Neustadt, Austria
[2] Institute for Nuclear Research, Debrecen, Hungary
[3] Robert Bosch GmbH, Feuerbach, Germany
[4] Institute of Materials Science and Technology, Vienna University of Technology, Austria

Abstract:
Diamond-like carbon (DLC) coatings protect engine parts from wear and provide low-friction [1]. Nevertheless, DLC coating systems are not invulnerable and can therefore wear prematurely, even though all conditions for a long service life (for example permanent lubrication) have been met. Especially in the automotive industry, failure due to delamination is an undesirable phenomenon [2]. There is a lack of knowledge about which wear progress occurs before DLC coating system fails and how to determine the point, at which the coating fails.

A continuous wear measurement method based on radioactive isotopes (RIC method) developed in previous studies was used to clarify these issues [3]. An experimental approach was applied using the RIC in combination with an oscillating contact tribometer to distinguish conditions using an adapted "Wöhler" diagram.

In this study, a correlation was found between the wear and coefficient of friction (COF) progress of DLC-coated steel substrate against a steel counter body in lubricated condition, see Figure 1. Finally, a methodology was established to discriminate mild and severe wear conditions and subsequently identify the point, at which DLC deteriorates. As a further investigation in relation to automotive applications, different lubricants were distinguished in such an adapted "Wöhler" diagram in order to evaluate the sensitivity of this methodology.

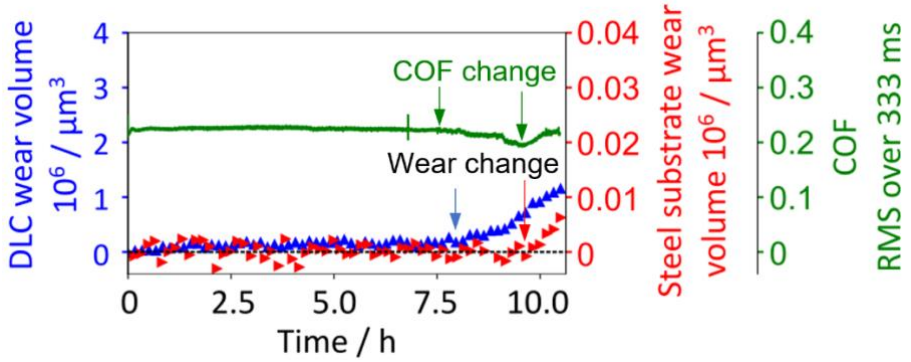


Figure 1: Example of the progress of COF (green), DLC- (blue), and steel substrate-wear (red) during the experiment.

Keywords: diamond-like carbon (DLC), radio-isotope concentration (RIC) method, friction progress, wear progress, coating failure, critical loading condition, life-time assessment.

References:

1. Holmberg, K., Erdemir, A. (2019), The impact of tribology on energy use and CO2 emission globally and in combustion engine and electric cars. Tribology International. 135, 389–396.
2. Kolawole, F.O., Tschiptschin, A.P., Kolawole, S.K., Antonio, M., Ramirez, M.A. (2019), Failure of diamond-like carbon (DLC) coatings in automobile engines—a review. 16th International Conference on Tribology, https:// doi. org/ 10. 24874/ PES01. 01. 022.
3. Zellhofer, M., Jech, M., Badisch, E., Ditrói, F., Kübler, A., Mayrhofer, P. H. (2022), Evaluation of Wear Measurement with Radioactive Isotopes for DLC Coatings Affected by Abrasive Particles, Tribol Lett 70, 55, https://doi.org/10.1007/s11249-022-01587-2.

Measuring Rolling Friction of Microparticles using Lateral Force Microscopy

S. Scherrer [1,*], S. N. Ramakrishna [1], L. Isa [1]
[1] Laboratory for Soft Materials and Interfaces, D-MATL, ETH Zürich, Switzerland

Abstract:
The introduction of colloidal probes has expanded the capabilities of atomic force microscopes (AFMs) to allow measuring interactions between particles and surfaces directly. In particular, lateral force microscopy (LFM) provides access to friction coefficient measurements at the nanoscale by determining lateral forces between surfaces as a function of applied load. Typically, experiments are limited to AFM cantilevers with fixed colloids, and thus only enable measuring sliding friction. However, for unconstrained colloidal particles in a fluid, sliding as well as rolling motion is present, but the frictional characterization of the latter remains elusive.

Using two-photon nanolithography, we have developed a colloidal probe that allows free rotation of an encapsulated particle and simultaneous imaging of the contact via fluorescence microscopy. The colloid releases from the cavity when the probe is not in contact with the substrate, making it reusable. Upon lateral calibration of the cantilever [1], a friction coefficient of the investigated colloid-substrate system can be determined. The three-dimensional rotation of the particle within the cantilever is analysed by tracking fluorescent markers on the colloid, while simultaneously obtaining the lateral forces acting on it. Direct comparison to a fixed colloidal probe is possible by gluing the particle inside the cavity, therefore restricting any rotational movement and enabling the observation of sliding and rolling friction.

The method is applied to a model system of non-adhesive, rough, 12 µm silica particles and surfaces with matching asperities [2], measuring friction coefficients of rotating and fixed colloids in aqueous buffer, where the latter is significantly higher. Rolling friction experiments performed on microparticles functionalized with a thermoresponsive polymer [3] shed light on the role of adhesion on the motion of free particles. The surface interactions are controlled via a thermal trigger, causing the particles to transition between rolling and sliding motion. Analysis of the rotational motion correlated with specific features in the friction force signals gives new insights into the behavior of contacting colloids that can be extended to a broad class of systems of direct interest for the study of the rheology of dense suspensions.

Keywords: rolling friction, lateral force microscopy, nanotribology, rough particle, adhesive particle

Figure 1: False colored SEM images of the experimental setup of the colloidal probe (blue) with rough silica particle (red) in contact with a rough substrate.

References:

1. Varenberg, M., Etsion, I. and Halperin, G. (2003) An improved wedge calibration method for lateral force in atomic force microscopy, *Rev. Sci. Instrum.*, 74, 3362.
2. Hsu, C.-P., Ramakrishna, S. N., Zanini, M., Spencer, N. D. and Isa, L. (2018) Roughness-dependent tribology effects on discontinuous shear thickening, *PNAS*, 115, 5117-5122.
3. Hsu, C.-P., Mandal, J., Ramakrishna, S. N., Spencer, N. D. and Isa, L. (2021) Exploring the roles of roughness, friction and adhesion in discontinuous shear thickening by means of thermo-responsive particles, *Nat. Commun.*, 12, 1477.

Smart Lubrication Management of Rolling Bearings using a State-Estimation-Based Control Strategy

B. Mrak [1], B. Peremans [1], Y. Perremans [1], D. Fauconnier [2], Z. Tao [1], S. Schlimpert [1]
[1] Flanders Make, Core Lab MotionS, Leuven, Belgium
[2] Flanders Make, Core Lab EEDT-MP, Ghent University, Ghent, Belgium

Abstract:
Majority of modern mechatronic systems feature a number of rolling bearings as a cost effective and performant solution to support and guide rotating shafts, and transfer the mechanical load between static and rotating machine components. Typically the bearing system is lubricated and cooled with a passive oil system, where the distribution in between different bearings is predetermined by the application's design (e.g. splash lubrication, oil recirculation, etc.), and the cooling and lubricating action of the oil is determined by a great number of operational conditions (e.g. operating speed of the machine) and design constraints (e.g. bearing type and geometry). Unfortunately, the cooling and lubrication conditions in the rolling bearings of such systems are suboptimal due to excessive oil flow rate and lowered temperatures to guarantee the desired life time of all bearings [1]. Therefore, in this work, we apply a state-estimation-based predictive control strategy on the lubrication and cooling of a bearing system such that the lubrication behavior actively adapts to the load conditions, which as a result increases the global operational efficiency of the bearing system. Preliminary simulation results demonstrate a reduction in bearing losses of 4% for a single bearing case and 8% for a multi-bearing case subject to a time-dependent speed and load profile.

Keywords: rolling bearings, active cooling and lubrication, control strategy, bearing frictional loss reduction

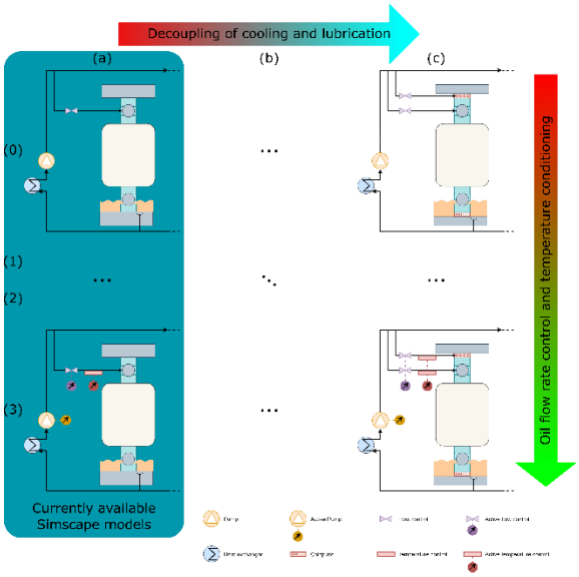


Figure 1: Simplified overview of active cooling and lubrication concepts resulting from splitting up the cooling and lubrication function (horizontal shift, [2]) and oil flow rate control and temperature conditioning (vertical shift, [1]).

References:

1. O. Janssens, M. Rennuy, S. Devos, M. Loccufier, R. Van de Walle and S. Van Hoecke, "Towards intelligent lubrication control: Infrared thermal imaging for oil level prediction in bearings," 2016 IEEE Conference on Control Applications (CCA), 2016, pp. 1330-1335, doi: 10.1109/CCA.2016.7587991.
2. Flouros, M.; Gloeckner, P.; Hirschmann, M.; Martin, M.; Cottier, F.; Papailia, D. Experimental and Numerical Investigation of the Outer Ring Cooling Concept in a Hybrid and in an All-Steel Ball Bearing Used in Aero-Engines by the Introduction of a Helical Duct. Aerospace 2018, 5, 23.

A mapping approach for the influence of the operating conditions on wheel-rail damage

N. Zani [1*], C. Petrogalli [1], A. Mazzù[1]
[1] Department of Industrial and Mechanical Engineering, University of Brescia, Brescia, Via Branze 38, Italy

Abstract:
Railroad engineering continues modernising its operations to increase efficiency and benefit the environment. In 2019, the European Union estimated that the total costs of air pollution, climate change and acoustic pollution due to railway transport was about 7.8 billion Euros. Trains impact soil and water pollution from the abrasion of brakes, wheel and rails, as well as fuel combustion and other sources. Suboptimal design of these components may cause increased costs, train delays, personal injuries, unplanned maintenance and reduced component life.
Over the years, wheel-rail wear has been widely inspected. The main damage phenomena occurring at the wheel-rail interface are rolling contact fatigue (RCF) and wear. Although they are typically studied as independent phenomena, they are strictly interlinked. If wear is reduced, cracks can grow to the point of RCF failure; on the other hand, wear is more likely to dominate if RCF cracks are truncated.
This work considers the results derived from bi-disc tests carried out at the University of Brescia. First, the collected data are reported on the shakedown maps to assess the cyclic response and calculate the fatigue index parameter (FI) used to predict the surface-initiated fatigue damage (Figure 1). Second, the fatigue index and material cyclic yield strength are related to the experimental wear rate. The proposed maps show how the wear rate and cyclic response change by varying the contact conditions (dry and with water) and the slip ratio. The proposed approach also allows to understand how a railway wheel steel behaves as a function of the working conditions and whether some operating parameters can be changed without compromising the material performance.

Keywords: shakedown maps, wear mapping, rolling contact, fatigue index, railway wheel materials, contact mechanics

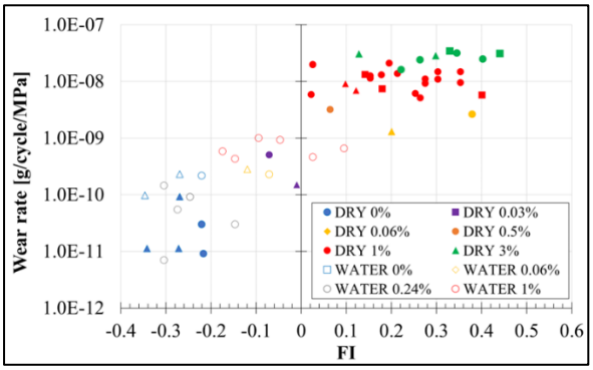


Figure 1: Figure illustrating the relationship between the wear rate and the rolling contact test parameter *FI* (shear strength, coefficient of friction and contact pressure) in dry tests and in the presence of water contaminant for different types of railway steels. The slip ratios are reported in the legend.

References:

1. Donzella G., Mazzù A., Petrogalli C. (2009) Competition between wear and rolling contact fatigue at the wheel-rail interface: some experimemtal evidence on rail steel, *Proc. Inst. Mech. Eng. Part F J. Rail Rapid Transit*, vol. 223, no. 1,31–44.
2. Makino T., Kato T., Hirakawa K. (2012) The effect of slip ratio on the rolling contact fatigue property of railway wheel steel, *Int. J. Fatigue*, vol. 36, no. 1, 68–79.
3. Ekberg A., Åkesson B., Kabo E. (2014) Wheel/rail rolling contact fatigue - Probe, predict, prevent, *Wear*, vol. 314, no. 1–2, 2–12.

Capabilities of multiphysics simulations for thrust bearings

S. Cupillard [1,*]
[1] Hydro-Québec research Institute, Varennes, QC, Canada

Abstract:
Despite their old design, spring-supported trust bearings are still used in the hydropower industry to support the weight of rotating parts. These are complex components to predict as multiphysics comes into play in a multiscale environment. All the elements must be considered in order to make accurate predictions of the thrust bearing performances. Thus, a coupling of the different physics has been carried out and makes it possible to perform high-fidelity TEHD (thermo-elasto-hydrodynamic) simulations of the thrust bearing under normal operating conditions [1] as well as during the start-up and shutdown phases. Once the high-fidelity model has been developed and validated, the opportunities are various. After describing the model, the paper gives an overview of its possible applications. First, based on the high-fidelity simulations, a reduced order model (ROM) was built (Figure 1). The ROM coupled to the continuous monitoring system of the hydropower unit is able to give live predictions of the thrust bearing performances. These predictions can help identify some abnormal behaviours and notify them to the operator. In addition, the TEHD model has been used to help in the search of root cause analysis of problematic cases. Finally, as an operator of hydraulic units who will be dealing with old designs of spring supported thrust bearing for years to come, a better understanding of them is needed to prevent failures from occurring. Since high-fidelity models allow predictions of these thrust bearings with much better accuracy than when they were designed, some proposals are emerging as to how to improve these conceptions with minor corrections.

Keywords: thrust bearing, TEHD simulations, fluid-structure interaction, reduced order model, live prediction, design improvement.

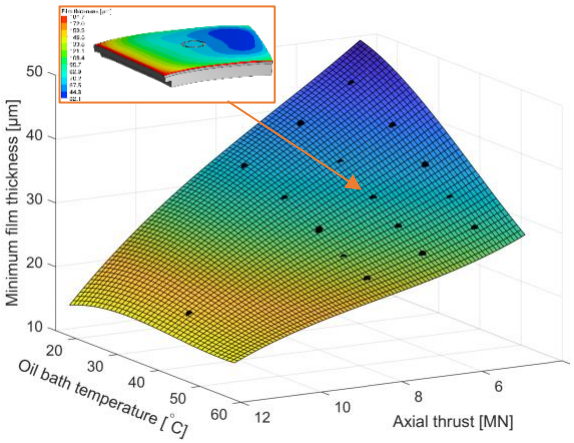


Figure 1: Reduced order model built from surface response.

References:

1. Cupillard, S., Gauvin, P. (2019), Behavior of spring supported thrust bearings: a CFD and experimental investigation, *18th EDF/Pprime Workshop*, EDF Lab Paris-Saclay, October 10-11, 2019.

A Generalized Oval Equation for the Film Thickness Calculation of Journal Bearings Operating under Heavy EHL Regime

G. N. Rossopoulos [1*], I. Pervelis[1], C. I. Papadopoulos[1]
[1] Department of Naval Architecture and Marine Engineering, National Technical University of Athens, Athens, Greece

Abstract:
Advances in material science enhanced by strict environmental regulations and the industrial need for optimized and robust journal bearing operation have brought water lubricated bearings in the spotlight. In recent years, water lubricated bearings have achieved a great success in applications such as marine propeller shaft, main guide bearings of hydro turbines or water pumps thanks to its environmental friendliness [1]. Such journal bearings are typically made of polymers or other 'soft' materials in contrast to traditional bearings with bronze or Babbitt bushings.
The large difference in the material stiffness of the shaft and the housing as well as the differences in fluid (water) viscosity, have made EHL study necessary [2]. Traditional EHL methodologies for the Reynold's equation solution are usually limited by film thickness geometry calculation for eccentricity less than 1. This paper includes an important discussion of the assumptions and limitations of recently published works. An extension of the traditional film thickness geometry calculation equation, presented in [3], is introduced to provide a new way for calculating numerically the performance of journal bearings with significantly deformable surface. The mathematical approach is followed by a numerical investigation for a case of a water-lubricated marine journal bearing. The film thickness geometry is calculated utilizing one generalized film thickness equation representing the rigid journal as an eccentric circle whereas the housing becomes an oval, comprising of four serially tangent arcs. This study is taking into consideration the bearing surface deformation, depending on assumption of geometric shape of fluid film and is extending the traditional film thickness geometry equation accordingly to enable study of regimes with eccentricity values larger than 1. To evaluate the bearing pressure distribution solving the Reynolds Eq., a fundamental driving factor is the shape of fluid film, namely, the mathematical expression of fluid film thickness "h(x,y)". This work enables (a relatively fast) convergence of the Reynold's equation solution even when it is coupled with FEM for the elastic deformation calculation.

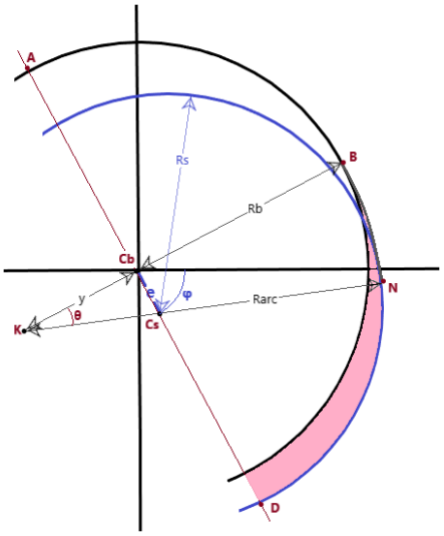


Figure 1: The extended film thickness geometry is illustrated, comprising of serially tangent arcs AB, BN, ND and is symmetric on the attitude angle. The center and radius of BN arc, angle θ, as well as the coordinates of B and N are analytically calculated.

Keywords: journal bearings, water-lubrication, elasto-hydrodynamic lubrication (EHL), film thickness geometry equation, mathematical derivation, Reynolds equation, large eccentricity.

References:

1. Ren, G. G. (2022). Hypo-elastohydrodynamic lubrication of journal bearings with deformable surface. *Tribology International*, *175*, 107787.
2. Smith, E. H. (2020). On the design and lubrication of water-lubricated, rubber, cutlass bearings operating in the soft EHL regime. *Lubricants*, *8*(7), 75.
3. Rossopoulos, G. N., Papadopoulos, C. I., & Leontopoulos, C. (2020). Tribological comparison of an optimum single and double slope design of the stern tube bearing, case study for a marine vessel. *Tribology International*, *150*, 106343.

Tribology 2023 Session III. A: Lubricants and hydrodynamic lubrication / Bio-tribology

In Situ Formation of Lubricious Phases in HIPIMS Deposited Mo-W Doped Carbon Coatings in Boundary Lubrication Conditions

P.Eh. Hovsepian[1,*], A.P. Ehiasarian[1]
[1] National HIPIMS Technology Centre UK, Sheffield Hallam University, City Campus, Howard Street, Sheffield S1 1WB, United Kingdom

Abstract:
Nonreactive High Power Impulse Magnetron Sputtering (HIPIMS) was used to deposit 2 µm thick Mo-W doped Carbon coatings [1, 2]. Low angle XRD analyses revealed that the coatings exhibited nanolayer architecture whereas broad peaks in the GAXRD patterns indicated that the overall structure was nanocrystalline almost amorphous like.
The Mo-W doped C coatings showed nanohardness of 16.5 GPa. In scratch adhesion tests critical load values exceeding 80 N were achieved due to the effective HIPIMS substrate pre-treatment.
The coating friction coefficient was determined by pin-on-disc test under dry and boundary lubricating conditions using 100Cr6 counterpart. The measurements were carried out at both room and elevated temperature of 200 °C. Highly viscous non-formulated engine oil (Mobil1 10W-60) was used as lubricant.
In lubricated conditions the Mo-W doped C coatings showed friction coefficient of $\mu = 0.033$, which was lower than that reported for a number of state-of-the art DLC coatings.
Raman spectroscopy of the wear debris was employed to better understand coating wear mechanism in boundary lubrication conditions.
The analyses revealed that in oil lubricating conditions the wear product was a mixture of MoS_2 and WS_2, with Mo and W being the Me-dopants in the coating and sulphur being basic element in the oil formulation. Graphitic wear debris was also present. Both MoS_2 and WS_2 have a graphite-like layered crystallographic structure, which due to the low shear strength atomic planes act as solid lubricants. Therefore, it could be speculated that in boundary lubrication condition, the friction behaviour of the Mo-W doped C coatings is dominated by *in situ* formation of solid lubricants at the asperity contacts, which is typical for the tribochemical reaction wear mechanism.

Keywords: High Power Impulse Magnetron Sputtering, Diamond-Like Coatings, Tribology, Boundary Lubrication, Solid Lubricants.

References:

1. Hovsepian, P.Eh., Doerwald, D., Tietema, R., Ehiasarian, A.P..(2014) "Me-doped C coating to operate in boundary lubrication conditions where the metal to C ratio does not exceed 1:4" *European Patent* 2 963 145
2. Hovsepian, P. Eh., Mandal, P., Ehiasarian, A. P., Safran, G., Tietema, R., Doerwald, D. (2016), Friction and wear behaviour of Mo-W doped carbon-based coating during boundary lubricated sliding. *Applied Surface Science*, 366, 260-274.

Influence of Ionic Liquids Admixture on Electrorheological and Tribological Properties of PAO6 and GP1 Lubricating Oils

T.J. Kaldonski [1,*], J. Juda [2], P. Wychowański [3,4], T. Kaldonski [1]
[1] Department of Engine Oils and Greases, Faculty of Mechanical Engineering, Military University of Technology, Warsaw, Poland
[2] The General Staff of the Polish Armed Forces, Warsaw, Poland
[3] Division of Oral Surgery and Implantology, Department of Head and Neck, Institute of Clinical Dentistry, Oral Surgery and Implantology Unit, Fondazione Policlinico Universitario A. Gemelli IRCCS Universita Cattolica del Sacro Cuore, 00168 Rome, Italy
[4] Department of Oral Surgery, Medical University of Gdańsk, 7 Dębinki Street, 80-211 Gdańsk, Poland

Abstract:
The results of experimental studies of electrorheological (ER) and tribological properties of lubricating oils containing an admixture of an ionic liquid as an electrically active ingredient are presented. Basic research, which consisted in determining the rheological characteristics in the presence of an external direct electric field, was carried out on a specially designed and built stand, which used a modified Brook-field DV-III Ultra viscometer. The conducted research showed that the produced mixtures generated the ER effect in the presence of a direct electric field with the intensity up to 0.2 $kV{\cdot}mm^{-1}$.

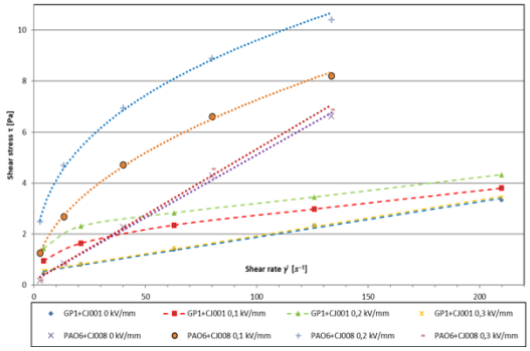


Fig. 1. Characteristics $\tau = f(\dot{\gamma})$ for mixtures GP1+ CJ001 and PAO6+CJ008

The tested mixtures showed different electrorheological characteristics (Fig. 1). A mixture composed of a silicon damping liquid GP1 containing 2 % (v/v) of an ionic liquid *1-me-thyl-3-octyloxymethylimidazole tetrafluorobo-rate* – CJ001, in the absence of an electric field, behaved like a *Bingham* liquid, and in the presence of an electric field to the value of E=0.2 $kV{\cdot}mm^{-1}$ the rheological characteristics of this liquid could be described by the Herschel-Bulkley equation. On the other hand the second mixture, composed of the base po-lyalphaolefin oil PAO6 and 2 % (v/v) of the ionic liquid *trihexyltetradecylphosphonic bis (trifluoromethylsulfonylimide)* – CJ008, in the absence of an electric field to the value of E=0.2 $kV{\cdot}mm^{-1}$ its rheological characteristics could be described by the Ostwald de Waele equation. The latter mixture showed many times better ER effect (Fig. 1). Research was also carried out in the so-called dielectric spe-ctroscopy using the Hewlett Packard HP4192 A impedance analyzer. The variability of the dielectric constans (ε) as well as resistance (R) and conductivity (κ) as a function of the frequency (f) of the direct electric field BIAS (DC) was assessed for different values of the applied voltage (U). The basis for interference was obtained about variability of the internal structure of mixtures under the influence of the external electric field, which resulted in the disappearance of the ER effect. The mechanism of generating and decaying the ER effect was diagnosed by *in situ* micro-scopy using the Nikon Eclipse LV100D optical microscope. Changes in the structure of mixtures containing ionic liquids were confir-med, consisting in the formation of *„fibrillary chains and/or streams"* and their subsequent destruction and the accumulation of ionic li-quid particles at the electrodes. In tribological tests of these mixtures, it was found that the effect of ionic liquid accumulation at the electrodes (after the destruction of *„fibril chains"* under the influence of an external electric field) facilitates the formation of permanent boundary lubricating film, which results in the improvement of the lubricity properties of such mixtures, which was confirmed in tests on the four ball apparatus.

Keywords: lubricating oils, ionic liquids as additives, electrorheological effect, lubricity.

References:

1. Kałdoński T.J., Juda J., Wychowański P., Kałdoński T. (2022), Hydrocarbon lubricating oil with admixture of ionic liquid as electrorheological medium, *Journal of Materials* MDPI, (*in Press*).

2. Kaldonski T.J.(2012) Research and evaluation alkoxymethylimidazolium ionic liquids as new lubricants for the steel tribological nodes, PhD Dissertation, Faculty of Mech. Eng., Mil. Univ. of Tech, Warsaw, Poland (*in Polish*).
3. Kałdoński T.J.(2016), Research on alkiloimidazolium ionic liquids as lubricants for steel tribological nodes, ISBN 978-83-7938-094-7, Publ. of Mil. Univ. of Tech., Warsaw, Poland (*in English*).
4. Juda J.(2022), Experimental studies electrorheological properties of lubricating oils containing ionic liquids. PhD Dissertation, Faculty of Mech. Eng., Mil. Univ. of Tech., Warsaw, Poland (*in Polish*).

Effects of Lubricant Viscosity on Rolling Contact Fatigue Damage of Bearing Steel

R. Ohashi [1], A. Harada [2], Y. Yuhara [2], K. Sato [2] and S. Sasaki [1]
[1] Department of Mechanical Engineering, Tokyo University of Science, Tokyo, Japan
[2] Department of Mechanical Engineering, Graduate School of Tokyo University of Science, Tokyo, Japan

Abstract:
In recent years, electric vehicles (EVs) have become increasingly popular, and it is required to improve the pitting resistance in reducers. In EV, a motor is used as its prime mover, and its rotational speed is much higher than that of internal combustion engine (ICE). Accordingly, EV reducers, which transmit the torque of the prime mover, are also operated at a higher rotational speed compared with ICE reducers. Thereby, the number of contact times per unit time of the gears and the bearings of EV reducer increases, which accelerates the progression of fatigue. Many studies have shown that lubricant viscosity affects the occurrence rate of gear failures such as pitting [1-2]. In conventional research for pitting, experiments were conducted under conditions where sliding and rolling contact occurred simultaneously, and the occurrence of the pitting is not divided and discussed from the influence of sliding and rolling. In addition, it has been reported that the fatigue surface is eliminated by sliding wear [3]. Therefore, testing under pure rolling condition, which is less affected by sliding wear, is considered to be effective in investigating the mechanism of the effect of lubricant viscosity on the occurrence of pitting. In this study, ball-on-disc type traction tests were conducted using a mini traction machine (MTM) (PCS-002672, PCS Instruments, UK) under pure rolling condition in poly-alpha-olefin (PAO) base-oil with different viscosities to investigate the pitting on bearing steel surface at the conditions: load of 75 N, temperature of 65°C, entrainment speed of 3.0 m/s, slide-roll-ratio of 0% and test time of 24 h. In addition, we evaluated the pitting area by binarization. As a result, we confirmed the fatigue damages on rolling contact area (Figure 1). In addition, using binarization of MATLAB, we were able to calculate pitting area (Figure 2). The pitting area lubricated in PAO4 and PAO6 were 0.531% and 0.602%. From these results, we considered that the increase of viscosities attributed the occurrence of pitting.

Keywords: Tribology, bearing, gear, lubricant viscosity, wear, pitting, rolling contact, EV.

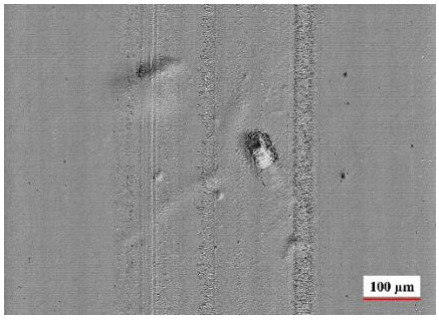


Figure 1: Figure shows the laser microscope image of the disc surface after testing under pure rolling condition in PAO4. From this figure, sliding wear and pitting were observed on the disc surface.

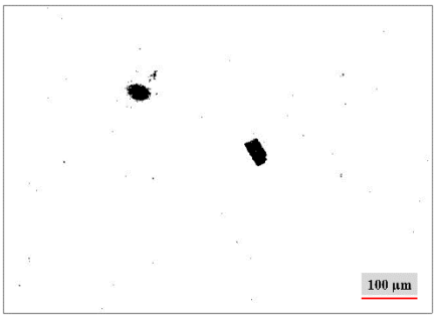


Figure 2: To quantitatively evaluate the pitting resistance of lubricant, we used MATLAB to binarize Figure 1 to clarify the pitting area. Figure 2 shows the disc surface image after binarization. In this figure, the damaged area corresponding to the pitting depth is shown in black: 0.531%.

References:

1. Höhn, B.-R., Michaelis, K. (2004) Influence of oil temperature on gear failures, *Tribology International*., 37, 103–109.
2. Johansson, J. E., Devlin, M. T., Guevremont, J. M., Prakash, B. (2014) Effects of Gear Oil Properties on Pitting Life in Rolling Four-Ball Test Configuration, *Tribology Transactions*., 57, 104-113.
3. Vrcek, A., Hultqvist, T., Baubet, Y., Björling, M., Marklund, P., Larsson, R. (2019) Micro-pitting and wear assessment of engine oils operating under boundary lubrication conditions, *Tribology International*., 129, 338-346.

Active Control of Friction Coefficient under Ionic Liquids Lubrication Using Surface Potential

S. Kawada [1,2,*], S. Tanji 3, M. Miyatake [3], S. Sasaki [3]
[1] Department of Mechanical Engineering, Kansai University, Osaka, Japan
[2] Research Institute for Science & Technology, Tokyo University of Science, Tokyo, Japan
[3] Department of Mechanical Engineering, Tokyo University of Science, Tokyo, Japan

Abstract:
It is well known that the lubricant adsorbed on the worn surface and exhibite significant effect on lubricating performances under boundary lubrication. In recent years, novel mechanical systems have been developed that active control of friction coefficient in response to changes in friction environment, such as temperature, speed, normal load [1, 2)]. This investigation focuese on method to control the adsorption sturucter of ionice liquids by appling an electric surface potential. Ionic liquids are organic salts and form the liquids phase at room temperature. Atomic force microscopy has shown that friction of ionic liquids changes by surface electric potential under nanoscale [3)]. In addition, it has also been observed that the film thickness and adsorption structe of ionic liquids were changed in static field without friction [4, 5)]. This investigation attempted to control friction on macro scale by fabricating the friction tester shown in Fig. 1.
In the case of 1-butyl-3-methylimidazolium tricyanomethanide as lubricant, the friction coefficient was increased at positive potential. However, when negative voltage was applied, that was not changed. On the other hand, other ionic liquids such as 1-butyl-3-methylimidazolium tetrafluoroborate and 1-butyl-3-methylimidazolium hexafluorophosphate, the friction coefficients were decreased when negative voltage was applied. The changed value was approximately 0.02. It is considered that the ionic species of the ionic liquids affect this performance. In addition, the response of friction behavior was different for each ionic liquid. It is considered that ion conductivity of ionic liquids is important factor in responsiveness.

Keywords: ionic liquids, friction control, surface potential, responsiveness.

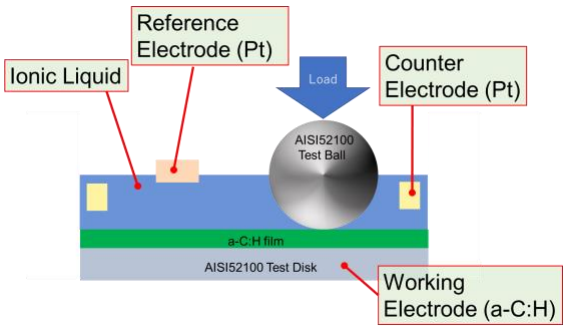


Figure 1: Friction tester.

References:

1. Murashima, M., Imaizumi, Y., Murase, R., Umehara, N., Tokoroyama, T. Saito, T., Takeshima, M. (2021), Active friction control in lubrication condition using novel metal morphing surface , *Tribol. Int.*, 156, 106827.
2. Kawada, S., Ogawa, S., Sasaki, S., Miyatake, M. (2019), Friction control by applying electric potential under lubrication with ionic liquids, *Tribol. Online*, 14, 71-77.
3. Sweeney, J., Hausen, F., Hayes, R., Webber, G. B., Endres, F., Rutland, M. W., Bennewitz, R., Atkin, R. Control of nanoscale friction on gold in an ionic liquid by a potential-dependent ionic lubricant layer, *Phys. Rev. Lett.*, 109, 155502.
4. Watanabe S., Pilkington, G. A., Oleshkevych, A., Pedraz, P., Radiom, M., Welbourn, R., Glavatskih, S., Rutland, M. W. Interfacial structuring of non-halogenated imidazolium ionic liquids at charged surfaces: effect of alkyl chain length, *Phys. Chem. Chem. Phys.*, 22, 8450-8460.
5. Reddy, A. B., Pilkington, G., Rutland, M. W., Glavatskih, S., Tribotronic control of an ionic boundary layer in operando extends the limits of lubrication, *Sci. Rep.*, 12, 20479.

Sustainable biolubricants based on recycled oils

D. Márquez [1] L. Batlle [1]
[1] Department of Surface Chemistry, Leitat Technological Center, Terrassa, Spain

Abstract:
Sustainable lubrication is currently in high demand due to the urgent need of reducing pollution caused by human activity to achieve a greener and more eco-friendly future. Starting from this point, could existing lubricants be reused and recycled? It will give them a second life and will contribute to the reduction of waste. It is vital that those lubricants that end up in the environment after being used (total loss lubricants, TTL) are formulated from renewable resources, without toxic compounds and 100% biodegradable. [1]
Based on these needs and considering that many sectors consume high quantity of lubricants, this project has the objective to formulate a biolubricant with at least 50% of recycled vegetable oil and complemented with pure vegetable oils as well as non-toxic and biodegradable additives.
This study analyses and characterizes the tribological performance of different waste vegetable oils, pure vegetable oils and green additives to obtain an entire sustainable lubricant. The main properties evaluated are the anti-wear behaviour and the corrosion performance, using the equipment Brugger and a specific method to identify corrosion [2].
First step of the project has been the physicochemical treatment of the waste recycled oils to reduce the odour and improve their properties. Afterwards, different amounts of recycled oils mixed with a selection of two pure vegetable oils are tested with the aim to achieve a base formulation containing at least 50% of recycled oil.
In addition, green additives are added and tested (natural additives such as pigments, terpenes, fatty acids, or others natural antioxidants/anti-wear compounds).
To sum up, better qualities than expected are found for the recycled oil. A specific mixture of recycled oil and vegetable oil showed an enhanced performance, proving contribution to sustainable lubrication systems. Those vegetable oils with high viscosity usually present better performance in terms of anti-wear. Taking that into account, some green additives are tested such as natural pigments and antioxidants, improving the lubricity properties of the final mixture of recycled oil and pure vegetable oil between 10-50%. On the other hand, green commercial additives show a great potential, with an expected improvement greater than 50%. Those additives are registered in the LuSC-list, confirming its biodegrability.

Keywords: sustainable lubrication, TTL, recycled oils, anti-wear, anti-corrosion, green additives, vegetables oils.

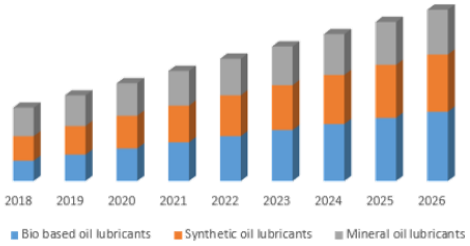


Figure 1: Global market of the lubricants industry Market analysis report, 2018.

Figure 2: Corrosion test results (left) and anti-wear results (right)

References:

1. EU Ecolabel Lubricants. (2022, March 4). Url: https://ec.europa.eu/ecat/category/en/49/lubricants
2. N. Bruun, A. Getachew Demesa, F. Tesfaye, J. Hemming, and L. Hupa, 'Factors Affecting the Corrosive Behavior of Used Cooking Oils and a Non-Edible Fish Oil That Are in Contact with Ferrous Metals' *Energies, MDPI*, 2019,
DOI: 10.1177/13506501221121896

The influence of heuristic and ad-hoc choices on the determination of lubricant viscosities from equilibrium molecular dynamics simulations

G. Toraman [1*], T. Verstraelen[2], D. Fauconnier [1,3]
[1] Soete Laboratory, Ghent University, Ghent, Belgium
[2] Center for Molecular Modeling (CMM), Ghent University, Ghent, Belgium
[3] FlandersMake@UGent, Core Lab EEDT-MP, Ghent, Belgium

Abstract:
TEHL (Thermo ElastoHydroynamic Lubrication) is a specific lubrication regime where key machine elements, such as bearings and gears, ideally operate. In this regime, a thin lubricant film (generally < 1μm) entirely separates the surfaces in relative motion, in which very high hydrodynamic pressures prevail to support the load in the initial point or line contacts. Due to the thin film thickness, and depending on the slide-to-roll ratio, high shear rates occur, accompanied by significant temperature variations. It is well known that the high pressure rise in the TEHL contact, up to several GPa, is in company with a vast increase of the lubricant viscosity with several orders of magnitude. This is the result of the intensified interaction between lubricant molecules. Experimental measurements of viscosity at pressures above 1-2 GPa are very difficult and require specialized extreme-pressure rheometry. Alternatively, Molecular Dynamics (MD) simulations may offer a promising alternative to extract the thermomechanical properties of lubricants, particularly viscosity, which is one of the most crucial properties under TEHL operating conditions. In MD simulations, the accuracy is mainly determined by the accuracy of force fields used for describing the interatomic interactions in the system. In addition, among the two main variants of MD simulations, namely Equilibrium MD (EMD) and Non-Equilibrium MD (NEMD), when EMD simulations are used, the specific way of post-processing the EMD trajectories has a severe impact on the reliability and the accuracy of the calculated properties. Moreover, the available methods to post-process EMD simulations to extract viscosity contain several empirical and heuristic approaches which are not based on physical grounds. In this study, we aim to address the issues and arbitrariness in the current state-of-the-art and develop a new post-processing methodology to obtain robust, reliable, and reproducible predictions of lubricant properties from EMD simulations under relevant TEHL operating conditions.

Keywords: TEHL, lubricant modelling, Molecular Dynamics simulations, viscosity.

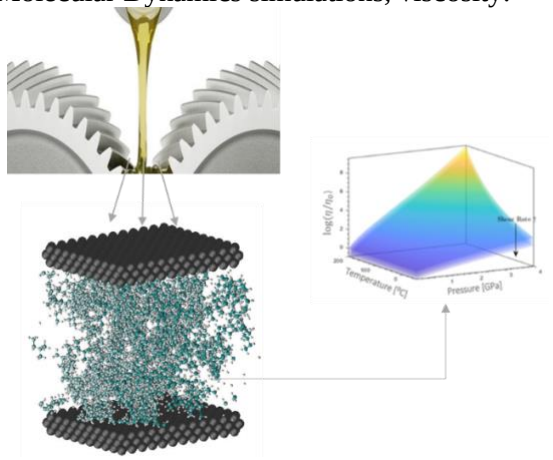


Figure 1: Figure illustrating the overall goal of our study that is the molecular level investigation of the lubricant properties under TEHL operating conditions.

References:

1. Maginn, E. J., Messerly, R. A., Carlson, D. J., Roe, D. R., & Elliott, J. R. (2019). Best Practices for Computing Transport Properties 1. Self-Diffusivity and Viscosity from Equilibrium Molecular Dynamics [Article v1.0]. *Living Journal of Computational Molecular Science*, *1*(1), 1–20. https://doi.org/10.33011/livecoms.1.1.6324
2. Zhang, Y., Otani, A., & Maginn, E. J. (2015). Reliable Viscosity Calculation from Equilibrium Molecular Dynamics Simulations: A Time Decomposition Method. *Journal of Chemical Theory and Computation*, *11*(8), 3537–3546. https://doi.org/10.1021/acs.jctc.5b00351

SICT 2023 Session III. B: Coatings for Energy and Environmental Applications

Plasma Etching of High Aspect Ratio Semiconductor Features: Challenges and Remedies

Florian Krüger, Evan Litch, Tugba Piskin and Mark J. Kushner
University of Michigan, Ann Arbor, MI 48109-2122 USA mjkush@umich.edu

Abstract:
The use of plasma processing for semiconductor fabrication is largely responsible for the industry's ability to maintain Moore's Law (doubling of microprocessor capability every 18-24 months) for several decades. With shrinking of semiconductor devices becoming more challenging, device architectures have transitioned from 2-dimensional layouts to 3-dimensional structures to increase device density (devices/area). These structures then require plasma etching processes that address high aspect ratio (HAR) features. For example, in 3D-NAND memory, vias must be etching through several hundred alternating layers of silicon-dioxide and silicon-nitride, having aspect ratios exceeding 100.

Plasma etching of HAR features as used in 3D-NAND and DTI (deep trench isolation) face several challenges, including twisting (features deviating from the vertical), partial etch, clogging of masks (deposition at the top of the feature that blocks the opening), pattern dependent defects, narrowing of features and ARDE (aspect ratio dependent etching) where etch rates slow with increasing AR. With the advent of 3D logic components (such as GAA – gate all around), HAR etching must have both anisotropic and isotropic capabilities, with selectivity between similar materials, such a Si and SiGe alloys.

In this talk, an overview will be provided of technology challenges in plasma etching HAR features for semiconductor fabrication. Results from computational investigations of possible remedies for these challenges will be discussed. These studies include modeling of conductor DTI etching in inductively coupled plasmas (ICPs) and dielectric etching in capacitively coupled plasmas (CCPs) using reactor scale (Hybrid Plasma Equipment Model - HPEM) and feature scale (Monte Carlo Feature Profile Model - MCFPM) simulation platforms.

Focus will be on the use of very-low-frequency biases with the intent of narrowing ion-angular distributions incident onto the wafer and voltage-waveform-tailoring (VWT) with the additional intent of crafting electron energy and angular distributions incident onto the wafer to minimize charging effects. (See Figure 1.) Other topics to be covered include the rise in use of pulsed plasmas for high volume manufacturing, and new equipment design challenges that follow, such as plasma instabilities dependent on gas mixture and antenna design. The use of machine-learning techniques to derive reaction mechanisms for profile simulation will also be discussed.

Work was supported by the US National Science Foundation, US Department of Energy Office of Fusion Energy Sciences, Samsung Electronics and Tokyo Electron America.

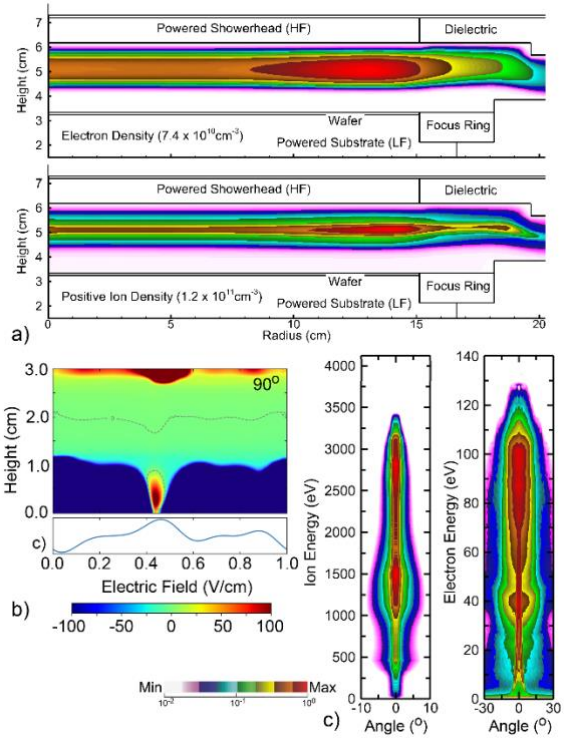


Figure 1 – Results of simulations using the HPEM for a CCP in $Ar/CF_4/O_2$ at 40 mTorr using VWT to produce electric field reversals (EFRs) to accelerate electrons into the wafer. a) Cycle averaged electron and total ion density. b) electric field above the wafer during the radio frequency cycle showing the momentary EFR. c) Ion and electron energy distributions incident onto the wafer [1].

Keywords: plasma etching, high aspect ratio features, modeling, reactor scale, feature evolution.

References:

1. F. Krüger, H. Lee, S. K. Nam and M. J. Kushner, *J. Vac. Sci. Technol. A* **41**, 013006 (2023).

Validation of non-equilibrium kinetics in CO_2-N_2 plasmas

T. Silva [1,*], C. Fromentin[1], T. C. Dias[1], E. Baratte[2], O. Guaitella[2] and V. Guerra [1]
[1] Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
[2]LPP, CNRS,Ecole Polytechnique, Sorbonne Universit e, Universitce Paris-Saclay, IP-Paris, 91128 Palaiseau, France

Abstract:
Plasmas have gained much attention in regard to CO_2 decomposition due to their potential to activate CO_2 at reduced energy cost and excite CO_2 vibrations that efficiently contribute to overcome the dissociation barrier. Combining plasma reactors with an efficient reduction of CO_2 would allow the conversion of electricity into chemical potential energy, leading to the decarbonization of energy sectors and the production of fuels in remote locations where renewable energy access is optimal. This has led to a growing field of research aimed at combining renewable electricity with plasmas to convert CO_2 emissions into synthetic fuels for energy storage pathways (see e.g. the schematic representation in [1]). This work presents a combination of modelling and experimental efforts aimed at studying the effect of N_2 addition on CO_2 dissociation and on the vibrational kinetics of CO_2 and CO under various non-equilibrium plasma conditions. A self-consistent kinetic model, previously validated for pure CO_2 and CO_2-O_2 discharges (see e.g. [2]), is further extended by adding the kinetics of N_2 [3]. The kinetic scheme is validated by comparing the model predictions with recent experimental data measured in a DC glow discharge operating in pure CO_2 and in CO_2-N_2 mixtures, at pressures in the range 0.6 - 4 Torr and a current of 50 mA. Both modelling and experimental results show a higher vibrational temperature of the different modes of CO_2 and CO and an increased dissociation fraction of CO_2, that can reach values as high as 70 %, when N_2 is added to the plasma. The model strongly indicates that the dilution of CO_2 and dissociation products, CO and O_2, reduces the importance of back reactions and contributes to the higher CO_2 dissociation fraction with increased N_2 content in the mixture, while the $N_2(B^3\Pi_g)$ electronically excited state further enhances the CO_2 dissociation (see figure 1).

Keywords: plasma, reforming, CO_2 decomposition, DC glow discharge. CO_2-N_2 mixtures, electronically excited states

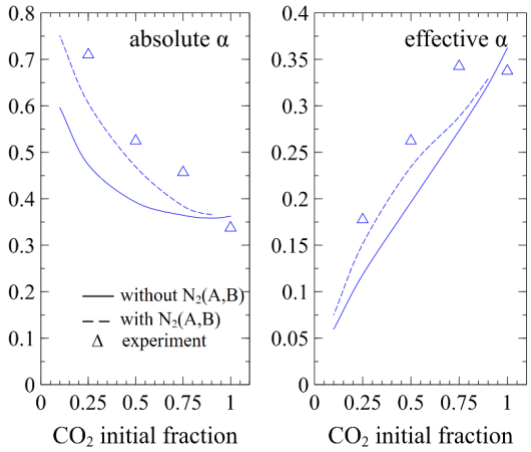


Figure 1: Figure illustrating the absolute and effective (accounting for CO2 initial fraction). dissociation fraction for different CO2/N2 mixtures for a discharge current of 50 mA and a pressure of 2 Torr. The effect of the electronically excited N_2 states is investigated.

References:

1. A. Goede, R. van de Sanden, CO_2-Neutral Fuels, Europhys. News. 47 (2016) 22–26.
2. A.F. Silva, A.S. Morillo-Candás, A. Tejero-del-Caz, L.L. Alves, O. Guaitella, V. Guerra, A reaction mechanism for vibrationally-cold low-pressure CO_2 plasmas, Plasma Sources Sci. Technol. 29 (2020) 125020.
3. C. Fromentin, T. Silva, T. C. Dias, E. Baratte, O. Guaitella and V. Guerra, Validation of non-equilibrium kinetics in CO_2-N2 plasmas, Submitted to Plasma Sources Sci. Technol. (2023)

Acknowledgments
This work was partially supported by the Portuguese FCT-Fundação para a Ciência e a Tecnologia, under projects UIDB/50010/2020, UIDP/50010/2020, PTDC/FIS-PLA/1616/2021, EXPL/FIS-PLA/0076/2021.

XPS analysis of ethylene-based encapsulants and damp heat aged fractured glass laminate surfaces

Gary Säckl[1,2,*], Gernot M. Wallner[1,3], Jiri Duchoslav[2], Martin Tiefenthaler[3], David Stifter[2]
[1] Christian Doppler Laboratory for Superimposed Mechanical-Environmental Ageing of Polymeric Hybrid Laminates (CDL-AgePol), Johannes Kepler University Linz, Altenberger Str. 69, 4040 Linz
[2] Center for Surface and Nanoanalytics (ZONA), Johannes Kepler University Linz, Altenberger Str. 69, 4040 Linz, Austria
[3] Institute of Polymeric Materials and Testing (IPMT), Johannes Kepler University Linz, Altenberger Str. 69, 4040 Linz, Austria

Abstract:
For long lifetimes of photovoltaic modules, the interaction of the various laminate plies is crucial. An essential component is the polymeric encapsulant[1,2,3]. In this study X-ray photoelectron spectroscopy (XPS) was used to characterize ethylene-vinyl acetate copolymer (EVA) with varying VA content. It was proven that XPS is a highly reliable method to quantify the VA content. The results were corroborated by Fourier-transform infrared spectroscopy (FTIR) and differential scanning calorimetry (DSC).
Further focus was given to the XPS analysis of damp heat aged glass laminates with three different encapsulants. Experiments were performed on EVA, polyolefin elastomer (POE) and thermoplastic polyolefin (TPO) double glass laminates. After delamination by compressive shear testing, the fractured surfaces were investigated by XPS and FTIR at the polymer side of the laminates. It was shown that EVA is more prone to degradation as the promising alternatives POE and TPO[1,3]. The differences were already discernible after 1000h and were even more pronounced with longer exposure times up to 10000h. Based on the obtained results, a possible degradation pathway was established for the encapsulant/glass interface and for the bulk of EVA, POE and TPO. Diffusion of Na ions from the glass substrate into the polymer matrix and the formation of Na-based salts at the interface were identified as primary mechanisms and degradation products.

Keywords: XPS, FTIR, DSC, photovoltaic modules, polymer degradation, interfacial interaction

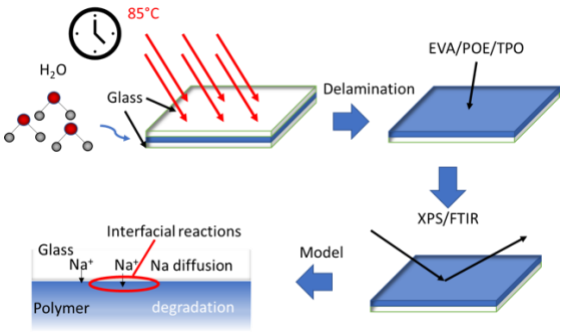


Figure 1: Schematic illustration of exposure, delamination and analysis of the fractured surfaces.

References:

1. Adothu, B.; Costa, F.R.; Mallick, S. (2021) Damp heat resilient thermoplastic polyolefin encapsulant for photovoltaic module encapsulation, *Solar Energy Materials and Solar Cells*, 224, 111024.
2. Wallner, G.M.; Adothu, B.; Pugstaller, R.; Costa, F.R.; Mallick, S. (2022) Comparison of Crosslinking Kinetics of UV-Transparent Ethylene-Vinyl Acetate Copolymer and Polyolefin Elastomer Encapsulants, *Polymers*, 14, 1441.
3. Oreski, G.; Omazic, A.; Eder, G.C.; Voronko, Y.; Neumaier, L.; Mühleisen, W.; Hirschl, C.; Ujvari, G.; Ebner, R.; Edler, M. (2020) Properties and degradation behaviour of polyolefin encapsulants for photovoltaic modules, *Prog. Photovolt. Res. Appl.*, 28, 1277–1288.

Hybrid polymer-liquid electrolytes for lithium-ion batteries: effect of porosity on the ionic and molecular mobility.

Martina Cattaruzza[1], Yuan Fang[2], István Furó[2], Göran Lindbergh[3], Fang Liu[4], Mats Johansson[1*]
[1]Division of Coating Technology, Department of Fibre and Polymer Technology, KTH Royal Institute of Technology, SE-100 44 Stockholm, Sweden
[2]Division of Applied Physical Chemistry, Department of Chemistry, KTH Royal Institute of Technology, SE-100 44 Stockholm, Sweden
[3]Division of Applied Electrochemistry, Department of Chemical Engineering, KTH Royal Institute of Technology, SE-100 44 Stockholm, Sweden
[4]Division of Materials and Manufacture, Department of Industrial and Materials Science, Chalmers

Abstract:
Lithium ions batteries (LIB) are the most prominent technology in the field of energy storage where liquid electrolytes are the most commonly used solution in the battery industries. Despite their attractive properties (such as high ionic conductivity and thermal stability at the ambient/sub ambient conditions), they have shown safety concerns due to their flammability which has led to the development of new electrolytes systems.
An emerging field are hybrid electrolytes (HEs) which are defined as electrolytes composed of at least two well-defined phases. One of the phases (or even both) conducts the ions and the other phase lend mechanical stability[2]. A promising example of HEs are solid-liquid electrolytes such as the structural battery electrolyte (SBE[2]) where two discrete co-existing phases are formed: one thermoset structural phase providing mechanical integrity and one percolating liquid ion-conducting phase. The phase separation is possible as a result of the variations in the solubility parameters of the monomers with respect to those of the formed polymers. The main feature of the polymer network is the microporous structure that gives structural integrity to the system thanks to the polymeric solid phase and, at the same time, conducts the ions through the percolating liquid phase. Although the SBE has shown remarkable properties results when tested in a negative half-cell lamina[3], it is not fully understood how the morphology and chemical composition affect the molecular transport in the system.
The present work describes an attempt to investigate ions transport in a series of hybrid solid-liquid electrolytes with different liquid contents using NMR-techniques. It is clearly shown that not only the tortuosity but also the ions conductance through the polymer phase plays a critical role in determining the electrochemical performances of these electrolytes (Figure 1).

Keywords: Hybrid electrolyte, lithium ion battery, polymer electrolyte, electrolyte, porosity, ion diffusion.

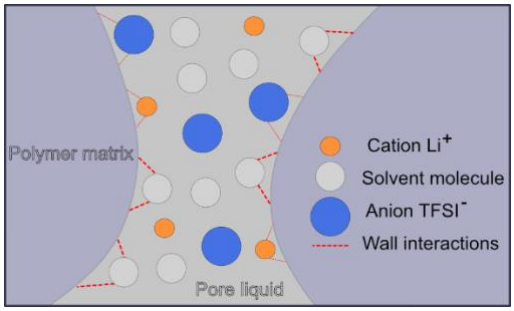


Figure 1: Figure illustrating the fundamental question that we are tempting to solve experimentally: How do the morphology and the chemical composition of hybrid electrolytes affect the molecular transport in the system.

References:

1. M. Keller, A. Varzi and S. Passerini (2018), Hybrid electrolytes for lithium metal batteries, *Journal of Power Sources*, 392, 206-225.
2. L. E. Asp et al. (2021), A Structural Battery and its Multifunctional Performance, *Advanced Energy and Sustainability Research*, 2, 2000093.
3. L. M. Schneider, N. Ihrner, D. Zenkert and M. Johansson (2019), Bicontinuous Electrolytes via Thermally Initiated Polymerization for Structural Lithium Ion Batteries, *ACS Applied Energy Materials*, 2, 4362-4369.

Synthesis and Characterization of Low VOC Unsaturated Polyester Coatings for Electrical Insulation Applications

K. Aksoy[1*], S.Gümüş[2], A. Aytaç[2,3]
[1] R&D Departmant, Betek Boya ve Kimya Sanayi A.Ş¸ Kocaeli, Turkey
[2] Department of Polymer Science and Technology, Kocaeli University, Kocaeli, Turkey
[3] Department of Chemical Engineering, Kocaeli University, Kocaeli, Turkey

Abstract:
While electric motors have become an integral part of daily life, developments in motor technology are constantly increasing the load on the insulation materials that use in the motor [1]. Electrical insulating varnishes are an important class of protective materials that contribute to the use of electricity in electrical and electronic equipment [2]. This work is aimed to develop an unsaturated polyester (UPE) varnish with low VOC content. The solvent-free varnish contains a reactive diluent (typically a monomer) to lower viscosity instead of solvent, and also has a catalyst to accelerate curing. The reactive diluent participates in the curing reaction [3]. In this study, UPE coatings for electrical insulation were produced using two different monomers, Sebacic Acid (SA) and Fumaric Acid (FA). Curing of UPE coatings was carried out using two reactive monomers, vinyl toluene (VT) and 1,4-butanediol dimethacrylate (BDDMA). Various physical tests (viscosity, density, solids content, flash point, etc.), and electrical measurements (volumetric and surface electrical resistance, etc.) were realized to determine the properties of the resins. Fourier Transform Infrared Spectrophotometer (FTIR) was used for chemical structure analysis. The thermal stability of the cured samples was determined by Thermogravimetric analyzer (TGA). In addition, since environmentally friendly and very low VOC products are targeted, VOC measurements were made with GC (Gas chromatography) measurements to determine this. As a result of the study, while the electrical volume resistance was measured as 1.58x10^15 Ω.cm in cross-linked coatings where FA was used; SA was measured as 6.96x10^11 Ω.cm. It has been observed that the VOC values of UPE coatings are between 2.10-3.60%.

Keywords: Unsaturated polyester coatings, Electrical insulation, Insulating varnish, Low VOC

Figure 1: A transformer in insulation varnish [4].

References:

1. Winkeler, M. (2002), Varnish and resin usage with various motor constructions, *Proceedings: Electrical Insulation Conference and Electrical Manufacturing and Coil Winding Conference* (Cat. No.99CH37035), Cincinnati, OH, USA.
2. Sassano, D. R. (1992), Electrical Insulating Varnishes: An Overview, *IEEE Electrical Insulation Magazine*, 8(6), 25- 32.
3. Balagam, B., Chapple, C., & Murray, T. (2018), UP Emulsion: A novel electrical insulating material, *2018 IEEE Electrical Insulation Conference (EIC)*, 581-584.
4. Coatings World. "Axalta's Voltatex Electrical Insulating Resins Used In Ventilators, Devices Producing N95 Face Masks". https://www.coatingsworld.com/contents/view_breaking-news/2020-04-22/axaltas-voltatex-electrical-insulating-resins-used-in-ventilators-devices-producing-n95-face-masks/?widget=listSection. Last accessed: 8 July, 2022.

Plasma Tech 2023 Session III. C: Plasma application in Energy and environment

Plasma-Assisted Nitrogen Fixation in the Presence of Water

M. Gromov [1*], I. Sremački[1], K. Leonova[2], N. Kamarinopoulou[3,4], E. Vervloessem[5], N. Britun[6], P. Dimitrakellis[3,4], Y. Gorbanev[5], C. Leys[1], D. G. Vlachos[3,4], N. De Geyter[1], A. Bogaerts[5], R. Morent[1], R. Snyders[2,7], A. Nikiforov[1]

[1] Research Unit Plasma Technology (RUPT), Dept of Applied Physics, Ghent Univ., Gent, Belgium

[2] Chimie des Interactions Plasma-Surface (ChIPS), CIRMAP, Mons University, 7000 Mons, Belgium

[3] Department of Chemical and Biomolecular Engineering, University of Delaware, Newark, Delaware 19716, USA

[4] Catalysis Center for Energy Innovation, University of Delaware, Newark, Delaware 19716, USA

[5] Research group PLASMANT, Department of Chemistry, Antwerp University, Universiteitsplein 1, 2610 Wilrijk, Belgium

[6] Center for Low-temperature Plasma Sciences, Nagoya University, Chikusa-ku, Nagoya, 464-8603 Japan

[7] Materia Nova Research Center, Parc Initialis, 7000 Mons, Belgium

Abstract:

The world's economy is now entering a new era of process electrification, aimed at the possibility of eliminating natural resource overuse and minimizing CO_2 footprint. In this context, non-equilibrium plasma is considered an appealing alternative tool in many applications, including nitrogen fixation for agricultural needs (N-containing fertilizers)[1,2].

Plasma-based nitrogen fixation has received a new wave of attention due to the possible integration with renewable (green) energy sources, as well as using N_2 from the abundant, ubiquitous air and H_2 from water, as shown in Figure 1. This technology can change the current paradigm of N-containing fertilizers synthesis, moving away from large-scale manufacturing towards decentralized on-site production, i.e., small-scale portable systems.

In this work, we focuss on the role of a plasma/liquid interface in both major pathways of nitrogen fixation: reduction ($N_2 \rightarrow NH_3$)[3,4] and oxidation ($N_2 \rightarrow HNO_x$)[5–7] of molecular nitrogen. We discuss the specifics of both processes and the main fundamental challenges associated with the energy-expensive process of dissociation of the chemically inert molecule N_2, evaluating the role of vibrationally excited nitrogen ground states and nitrogen fixation kinetics in the presence of water. Finally, we address the energy efficiency of systems with and without a plasma/liquid interface and indicate the main directions towards improving the process metrics and obtaining a maximal energy efficiency.

Keywords: nitrogen fixation, non-equilibrium plasma, ammonia, nitric acid, electrification of the chemical industry.

References:

1. K. H. R. Rouwenhorst, F. Jardali, A. Bogaerts and L. Lefferts, *Energy Enviromental Sci.*, 2021, **14**, 2520–2534.
2. A. Bogaerts and E. C. Neyts, *ACS Energy Lett.*, 2018, **3**, 1013–1027.
3. Y. Gorbanev, E. Vervloessem, A. Nikiforov and A. Bogaerts, *ACS Sustain. Chem. Eng.*, 2020, **8**, 2996–3004.
4. L. Hollevoet, E. Vervloessem, Y. Gorbanev, A. Nikiforov, N. De Geyter, A. Bogaerts and J. A. Martens, *ChemSusChem*, , DOI:10.1002/cssc.202102526.
5. M. Gromov, N. Kamarinopoulou, N. De Geyter, R. Morent, R. Snyders, D. Vlachos, P. Dimitrakellis and A. Nikiforov, *Green Chem.*, 2022, 13.
6. E. Vervloessem, Y. Gorbanev, A. Nikiforov, N. De Geyter and A. Bogaerts, *Green Chem.*, 2022, **24**, 916–929.
7. E. Vervloessem, M. Gromov, N. De Geyter, A. Bogaerts, Y. Gorbanev and A. Nikiforov, Nitrogen Fixation with Water Vapor by Nonequilibrium Plasma: Pathways for NH_3 Formation and Preventing NH_3 and HNO_2 Loss, *Submitt. Publ.*

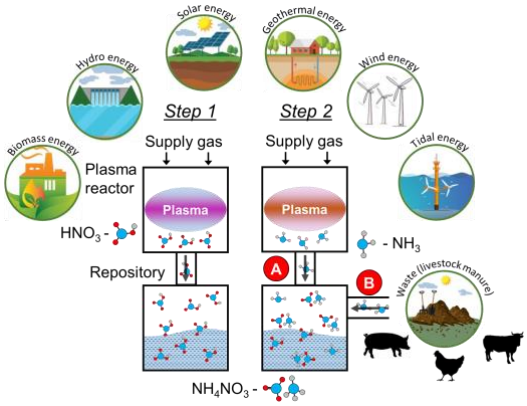


Figure 1: The concept of ammonium nitrate (NH_4NO_3) production using plasma technology. Step 1 – HNO_3 synthesis; Step 2 – Route A: NH_3 synthesis using atmospheric pressure plasma; Route B: using live-stock manure/wastewater from the farms as a source of NH_3.

CO_2 neutral concrete and sustainable fuels and chemicals produced in a novel plasma-based process

Paul Rößner *, Stephan Renninger, Maike Lambarth, Jan Stein, Samuel Kaufmann, Valentin Seithümmer, Jessica Hemmerling, Kai Peter Birke
Electrical Energy Storage Systems, Institute for Photovoltaics, University of Stuttgart, Germany

Abstract:
To keep the anthropogenic climate impact as low as possible, we must extract and utilize the resource carbon in cycles. Our innovative plasma process can decarbonize two sectors at once: Firstly, the mobility sector through synthetic fuels and, secondly, the construction sector through emission-free concrete production.

Ships and aircraft are responsible for 6% of global CO_2 emissions, and the trend is rising[1]. Besides the transport sector, the construction industry is one of the largest emitters of CO_2, with concrete as commonly used raw material. Concrete production is responsible for 8% of global CO_2 emissions, with around 3 billion tons of cement per year[1]. Concrete can only be produced in a very energy-intensive way, using around 3 GJ per m³ of concrete. This is because concrete uses calcium oxide (CaO) as a binder. To produce calcium oxide, lime ($CaCO_3$) must be burned at high temperatures. This produces emissions in two ways: Natural gas is burnt to generate the high temperatures needed for the process. In addition, CO_2 is released from lime during the burning process. Current production processes release 600 kg of CO2 per ton of cement, 60% of which is burnt out of lime ($CaCO_3$).

The novel plasma process presented here addresses both problems simultaneously: the high temperatures of the plasma process are used for lime burning, replacing fossil fuels which are usually used to supply process heat, and additionally, the released CO_2 can be converted using the same plasma reactor. The innovative plasma process produces carbon monoxide (CO) from the CO_2, which can be mixed with green hydrogen to yield synthesis gas (syngas). Synthesis gas is used to produce synthetic fuels and chemicals such as methanol.

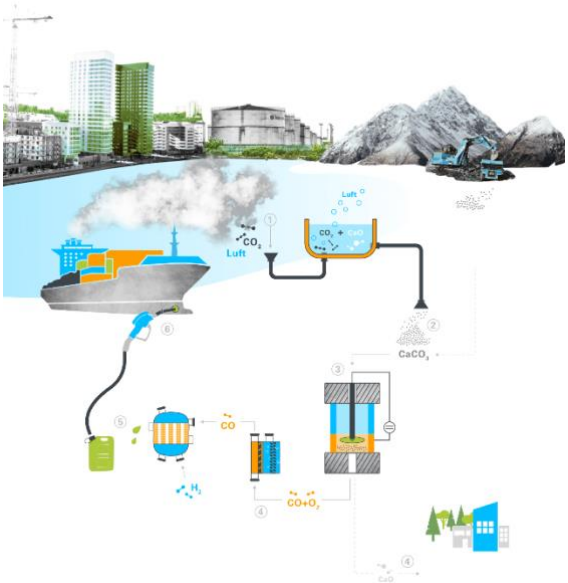
The process is designed to work in conjunction with a direct air capture (DAC) plant, which will be developed and characterized according to performance metrics such as the required energy input per captured unit of CO_2. Research and further development of energy efficient CO_2 capture from air is essential, as the reduction of CO_2 emissions from fossil fuels is slower than required for the 1.5°C goal. According to the Intergovernmental Panel on Climate Change (IPCC) the goals of the Paris agreement are only possible if CO_2 is removed from the atmosphere in substantial amounts[2]. Until now, the extraction and use of CO_2 have been separate processes. This is unfavorable because so far substrates have been used to absorb CO_2 from the air, which only release the gas for further use at very high temperatures, which must be provided additionally. Generating these temperatures is very energy intensive. This is where the innovative plasma reactor presented here can offer a novel pathway: it splits CO_2 directly electrically into CO and O_2. The resulting waste heat is sufficient to release further CO_2 from a substrate such as lime ($CaCO_3$) and to split this CO_2 directly in the plasma as well. The calcium oxide (CaO) produced by the waste heat of the plasma process is also an efficient CO_2 scavenger. The process can be applied either with focus on production of fuels and chemicals using CO_2 from the atmosphere or with focus on climate neutral lime production for the building industry.

The gliding arc discharge reactor developed at our institute can provide discharges at normal pressure in large volumes and splitting CO_2 with high efficiency [3-5]. The efficiency is decisive for the energy balance and the large volume of the plasma is a prerequisite for a scalable process. The next process step is the separation of the oxygen, which is produced during CO_2 splitting to exclude subsequent back reactions and facilitate downstream processes like Fischer-Tropsch.

A core research question is the interaction between plasma, the CO_2 as process gas and the solid lime and how the interfaces influence the reactor performance. Furthermore, the mode of operation, reactor geometry, gas flow and efficient supply of $CaCO_3$ are investigated. The goal is a nominal power of 1000 W in the plasma and a plant efficiency of η=50%. Previously, we were already able to achieve an efficiency of η=40%[5]. The CO_2 is efficiently converted and processed; subsequently, the product gases are measured. The solids produced are also

investigated for their usability as cement. Continuous operation of both processes, in which the lime is circulated several times, will demonstrate the stable operation of the plant.

Keywords: reaction engineering, CO2



conversion, glow discharge, plasma catalysis, sustainability, plasma processes.

Figure 1: Process scheme of a novel plasma-based process to produce climate neutral concrete.

References:

1. Change, I. C. (2014). Mitigation of climate change. 1454.
2. IPCC: Climate Change 2021 - The Physical Science Basis, Pat., 2021.
3. Renninger, S., Lambarth, M., & Birke, K. P. (2020). Journal of CO2 Utilization, 42, 101322.
4. Renninger, Rößner, Stein, Lambarth, Birke, (2021) Processes, 9, 2063.
5. Renninger, Stein, Lambarth, Birke, (2022), Journal of CO2 Utilization.

Influence of Enthalpy Inhomogeneity on the CO_2 Splitting Performance in a High-Power ICP

H. Burghaus [1,*], C. F. Kaiser [1], S. Fasoulas [1], G. Herdrich [1]
[1] Institute of Space Systems, University of Stuttgart, Stuttgart, Germany

Abstract:
The rapidly progressing climate change with already inevitable consequences for all life on Earth requires consistent action. One necessary step is to heavily reduce anthropogenic greenhouse gas emission [1]. Plasma-based conversion of carbon dioxide into valuable chemicals or fuels is a promising pathway to make captured CO_2 reusable for industrial processes [2]. It is shown that non-equilibrium plasma, utilizing vibrational ladder climbing, is capable of splitting the carbon dioxide molecule with high energy efficiency [3]. Moreover, recent analysis of high-temperature plasma shows that by super-ideal quenching, energy efficiencies of about 70 percent are possible [4].
At the Institute of Space Systems (IRS), the inductively coupled plasma source IPG4, powering the plasma wind tunnel PWK3, is used to study the CO_2 conversion in high-temperature plasmas [5]. In this work, a parameter study of the specific energy input (SEI) is performed by varying the input power between 135 and 160 kW, as well as the mass flow rate between 2.2 and 4.0 g/s. Influences of the SEI on the overall power deposition and generator efficiencies are investigated based on experiments with a cavity calorimeter, developed in-house [6]. Moreover, a heat flux-Pitot double probe is used to determine radial profiles of local heat flux, total pressure and mass-specific enthalpy values at x = 140 mm distance from the generator exit (Figure 1).
A comparison of the volume-integrated cavity calorimeter measurements with the local double probe results shows a strong inhomogeneity, i.e. radial dependence, of the mass-specific enthalpy and, as a consequence, power deposition. The aim of this study is to quantify the influence of this observed inhomogeneity on the overall carbon dioxide splitting performance in the plasma jet.

Keywords: CO_2 conversion, calorimetry, CO_2 splitting, inductively coupled plasma, plasma diagnostics, high-enthalpy, plasma wind tunnel, technology transfer.

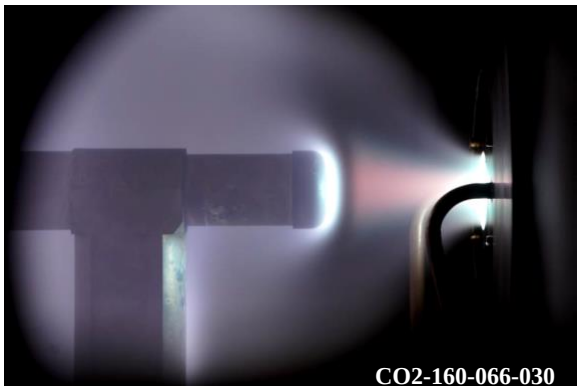


Figure 1: Photo of the heat flux-Pitot double probe on the plasma jet centerline at x = 140 mm distance from the generator exit. IPG4 is operated at 160 kW with a CO_2 mass flow rate of 2.2 g/s.

References:

1. IPCC, 2014, Summary for Policymakers, In: Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
2. R. Snoeckx, A. Bogaerts, Chemical Society Reviews 46.19 (2017) 5805-5863.
3. A. Fridman, Plasma chemistry, Cambridge university press, (2008).
4. A. van de Steeg, P. Viegas, A. Silva, T. Butterworth, A van Bavel, J. Smits, P. Diomede, M. van de Sanden, G. van Rooij, ACS Energy Letters, 6(8) (2021) 2876-2881.
5. H. Burghaus, C.F. Kaiser, A.S. Pagan, S. Fasoulas, G. Herdrich, Aerothermodynamic Characterization of an Inductively Generated CO2 Plasma by Laser Absorption Spectroscopy, In: AIAA SCITECH 2022 Forum, San Diego, USA & online (2022) p.1617.
6. G. Herdrich, Operational behavior of inductively heated plasma source IPG3 for entry simulation, Journal of Thermophysics and Heat Transfer 16.3 (2002), pp. 440–449.

Techno economic potential of plasma based CO_2 splitting in power to liquid plants

Samuel Kaufmann*, Stephan Renninger, Maike Lambarth, Moritz Raab, Jan Stein, Paul Rößner, Kai Peter Birke
Electrical Energy Storage Systems, Institute for Photovoltaics, University of Stuttgart, Germany

Abstract:
Mitigating climate change requires the development of technologies that combine energy and transport sectors. One of them is the production of sustainable fuels from electricity and carbon dioxide. As one option of splitting CO_2 plasma based processes promising a high potential due to their flexibility, scalability and theoretically high efficiencies.
Including plasma technologies into power to liquid plants for industrial use provide the research questions: How much does it cost to produce plasma-induced, pollution-free sustainable fuels? How big does a plant get to be profitable? Will we be able to synthetically produce diesel for €2/litre and how cheap does renewable electricity have to be for this?
A techno-economic analysis including a sensitivity analysis for the joint project PlasmaFuel process was carried out around different scenarios in order to be able to answer these and other valid questions.
The use of renewable energies to operate the traffic and transport sector plays an important role due to the high energy requirements and the large part of global CO_2 emissions (20%)[1].
The generation of electricity-based marine diesel is an important area of development for several reasons. On the one hand, electrification in shipping is not feasible. The reasons for this are the high costs and excessive masses of the battery units based on low energy densities and the charging infrastructure. On the other hand, conventional ship fuel releases sulfur emissions when burned. In order to reduce these emissions, the shipping industry is striving to further develop exhaust gas cleaning systems and to use alternative fuels.
In the present work different plasma technologies and plasma processes are modelled in power to liquid plants for production of synthetically sulfurfree marine diesel and techno economical analysed.
Crucial element of the techno economic assessment is the power to liquid process of the joint project PlasmaFuel. In this project, plasma-based CO_2 splitting through dielectric barrier discharge into carbon monoxide (CO) and oxygen (O_2) was carried out. Through subsequent oxygen separation, the CO is synthesized together with electrolysis-H2 in a Fischer-Tropsch reactor to form marine diesel. The energy required for this is to be supplied by excess wind power.
The PlasmaFuel process is modelled in ASPEN plus and techno economic analyzed via TEPET, a tool of the DLR-Stuttgart. For further variations of the process a MATLAB Simulink model was created to combine simulation and TEA in one model. The extensively studied CO_2 splitting with dielectric barrier discharge in comparison to novel processes for plasma based generation of syngas, for example from plasma based concrete production are examined in the model.
The results of the process simulation and the techno-economic analysis are divided into the three scenarios 2018, 2030 and 2045. The scenarios differ in the use of different boundary conditions and thus represent different degrees of technology. The evaluation results in process efficiencies and net production costs. The net production costs, which represent the price of the produced fuel, consist of capital and operating costs arising from the simulation results of the model.
In the subsequent sensitivity analysis results of parameter variations are considered. Both technical and economic parameters are varied.
In further model variations, the process of a PlasmaFuel follow-up project that will start soon is compared with the predecessor process. In this follow-up project a novel gliding arc discharge reactor developed at our institute is used. This reactor can provide discharges at normal pressure in large volumes and splitting CO_2 with high efficiency [2-4].
The model created allows statements to be made about the industrial use of various processes and conclusions can be drawn about the most important control variables in terms of process optimization.

Keywords: techno economic analysis, reaction engineering, CO2 conversion, dielectric barrier discharge, glow discharge, plasma catalysis, sustainability, plasma processes.

References:

1. PBL, Trends in global CO2 and total greenhouse gas emissions, 2020
2. Renninger, S., Lambarth, M., & Birke, K. P. (2020). Journal of CO2 Utilization, 42, 101322.
3. Renninger, Rößner, Stein, Lambarth, Birke, (2021) Processes, 9, 2063.
4. Renninger, Stein, Lambarth, Birke, (2022), Journal of CO2 Utilization.

Utilizing the Power of Thermal Plasma Technology for the Electrification of the Chemical Industry

S. Mirpour*, D.C.M. van den Bekerom, Yves Creyghton, Hans Linden
TNO, Geleen, the Netherlands

Abstract:
Brightsite knowledge center endeavors to cultivate a sustainable and carbon-neutral ecosystem within the Chemelot site in the Netherlands and the wider chemical industry worldwide. This consortium is a collaboration between Maastricht University, TNO, Sitech, and Brightlands Chemelot Campus, and encompasses six different program lines. The first program line focuses on reducing emissions through electrification, with the goal of developing thermal plasma technology for the CO_2-free production of hydrogen and hydrocarbons from residual methane or natural gas.
At Brightsite, we have identified and explored three generations of plasma technology for the valorization of methane. Maastricht University has developed a low-pressure microwave setup, which utilizes a 3 kW plasma source to process methane gas. This setup has the potential to produce high selectivity direct methane-to-ethylene production, a valuable product. TNO, in partnership with other organizations, is working to downscale the Hüls process [1], which uses a thermal arc to crack methane and produce acetylene and hydrogen. A 10 and 50 kW arc reactor will be used in this process, with the feedstock gas consisting mainly of hydrogen and methane mixtures. The gas mixture will be quenched in two steps using gas and water injection, leading to the formation of various products such as acetylene, ethylene, soot, and hydrogen. The research plan will also study the impact of temperature and residence time on hydrocarbon yield and selectivity.
In a separate application, our team is exploring the addition of nitrogen to the methane-hydrogen mixture in order to produce HCN, which is a sought-after feedstock in the chemical industry for the production of acrylonitrile Furthermore, we are investigating the potential to utilize these sources for the thermolysis of waste plastics, with the aim of upgrading them into valuable olefins. This presentation will provide a comprehensive overview of the latest developments and research outcomes in these reactors.
The next step in the development chain is the construction of a pilot plant, which will utilize a combination of the Hüls arc process and liquid-phase hydrogenation to produce hydrogen and ethylene from acetylene. The ultimate goal of the consortium, in conjunction with other partners, is to electrify most processes and installations at Chemelot by 2050, with plasma technology being used in several process steps to eliminate CO_2 emissions.

Keywords: Electrification, Thermal plasma, Methane cracking, Waste plastics, Decarbonization

Figure 1: The 10 kW arc source developed for the thermal cracking of inut gases and plastics

References:

1. Pässler, P., et al. "Acetylene. In Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH Verlag GmbH." (2008).

Plasmas reactors enabling the fossil-to-electric transition of industrial processes

Carsten Winnewisser[1*], Soha Salem[1], Gerd Hintz[1], Ekkehard Mann[1], Vasilis Ramopoulos[2]
[1] TRUMPF Hüttinger GmbH + Co. KG, Freiburg, Germany
[2] TRUMPF Hüttinger GmbH + Co. KG, Stutensee, Germany

Abstract:
Progressing climate change and the Russian invasion of Ukraine is pushing the world into global energy crisis. In response to this, the awareness of urgency to secure energy supplies through an accelerated deployment of renewable energy sources has risen worldwide.
Especially Europe is forced to accelerate it´s energy transformation towards renewable energies and subsequentially Europe need´s to electrify it´s industry.
The fossil-to-electric (F2E) transformation potential of Europe´s industrial sectors is estimated to accumulate to approx. 800TWh/a, (Figure 1) [1].
This talk will discuss different electrification options it´s related power electronic supply requirements. Here, a focus will be set on high power plasma torches for esp. retrofitting existing gas- and oil-burners in different industries, like for instance in the metal, cement, or glass industry.
Depending on the specific industrial process (material, required temperature range, flow-rates, pressures, …) which shall be electrified different plasma types can be utilized (Figure 2). Each plasma type requires dedicated power generators to ignite and maintain the plasma. This talk will discuss two application examples and the related boundary conditions.

Keywords: energy transition, fossil-to-electric (F2E) transition, decarbonization of industrial processes, energy demand, power-to-heat, P2X, plasma burner torches, plasma densities, plasma temperatures, flow rates, efficiency, power electronics, power generators

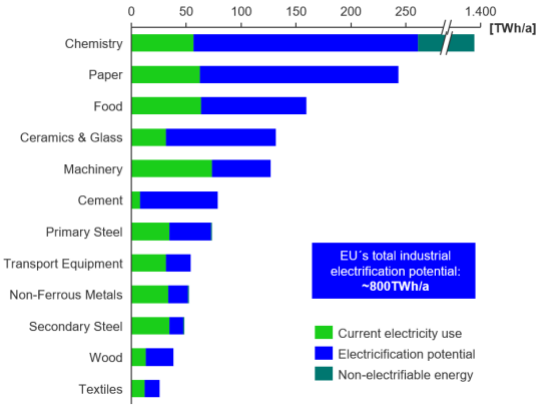


Figure 1: Europe´s industrial sectors´ electrification potential; transcripted by the curtesy of S. Madeddu [1].

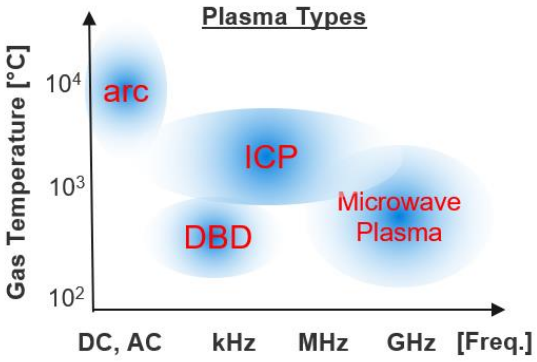


Figure 2: Different plasma types like DC-/AC-arc, MF- or RF- inductively coupled plasmas (ICP), dielectric barrier discharge (DBD) or for instance microwave plasma can be utilized.

References:

1. Silvia Madeddu Falko Ueckerdt, Michaja Pehl, Jürgen Peterseim, Michael Lord, Karthik Ajith Kumar, Christoph Krüger and Gunnar Luderer (2020) The CO_2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat), *Environ. Res. Lett. 15 (2020) 124004*

SICT 2023 / PlasmaTech 2023 / Tribology 2023 Joint Conferences Posters

Sensor-plasma coupling resistance: model and measurements in the Earth ionosphere

E. Seran [1*], S. Hess [2], M. Godefroy [1]
[1] LATMOS/ UVSQ/Sorbonne University, Paris, France
[2] ONERA, Toulouse

Abstract:
Measurements of the electric potentials, currents and ion thermal plasma in the ionosphere are determined by the plasma density, its temperature and ion composition, the ratio between thermal plasma velocity and the satellite velocity with respect to plasma, as well as on the intensity of the photoelectron emission from the surface materials on the day-side orbits. These measurements can be perturbed by a plasma sheath formed around the satellite and onboard sensors. Such a sheath is formed around a body to neutralize the electric charging of its surface in contact with the plasma. In the ionosphere, the sheath thickness is expected to be few centimeters and populated with slightly different plasma with respect to the ambient unperturbed plasma. Thus, a characterization of the sheath electrical properties can be essential for the interpretation of the onboard observations. In our paper we analyze a set of the plasma and electric field measurements performed in the ionosphere at the altitude of 700 km onboard the CNES DEMETER micro-satellite. The considered observations were collected during specific orbits when the plasma and electric field instruments were operated in the calibration mode and provided quick plasma measurements together with the wave form electric field records. The electric currents injected from the electric field sensor to plasma during the calibration sequences allow an estimation of the sensor-plasma coupling resistance.The collected data set is used to justify a recently developed analytical model to calculate the sensor-plasma coupling resistance from the measured ion thermal plasma parameters.

Keywords: Earth ionosphere, thermal plasma, photoelectrons, electric potentials and currents, plasma sheath, sensor-plasma coupling reistance.

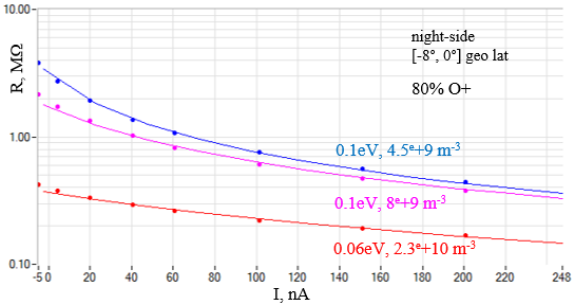


Figure 1: Coupling resistance deduced from the electric field measurements on the night-side ionosphere (dots) together with the modeled resistance calculated using the measured ion plasma parameters (lines).

References:

1. Berthelier, J.J., M. Godefroy, F. Leblanc, M. Malingre, M. Menvielle, D. Lagoutte, J.Y. Brochot, F. Colin, F. Elie, C. Legendre, P. Zamora, D. Benoist, Y. Chapuis, J. Artru, R. Pfaff, (2006), ICE, the electric field experiment on DEMETER, Planetary and Space Science, 54, 456–471, doi:10.1016/j.pss.2005.10.016.
2. Jorba-Ferro, O., (2018), Etude de l'influence de la propreté électrostatique du satellite sur les mesures du champ électrique basse fréquence de TARANIS, PhD Thèses, Université de Toulouse.
3. Seran, E. (2003), Reconstruction of the ion plasma parameters from the current measurements: mathematical tool, *Annales Geophysicae*, 21, 1159–1166.
4. Seran, E., J.-J. Berthelier, F.Z. Saouri, J.-P. Lebreton, (2005) The spherical segmented Langmuir probe in a flowing thermal plasma: numerical model of the current collection, *Annales Geophysicae*, 23, 1723- 1733.

Hybrid plasma source with wireless power transmission system

Ju-Ho Kim [1,*], Jun-young Park [1], Chin-Wook Chung [1]
[1] Department of Electrical Engineering, Hanyang University, Seoul, Republic of Korea
[*] electrickjh@gmail.com

Abstract:
Recently, several studies have reported that the efficient plasma generation and uniformity control are possible in an inductively coupled plasma [2–4, 6] and a capacitively coupled plasma [5] with a passive resonant antenna using wireless power transmission. In this study, hybrid plasma source with a wireless power transmission system is developed. In the system, the power transmission part consists of a power source, a matching network, a transmit antenna coil. The power receiving part consists of a resonant antenna coil, an electrode, and an impedance control unit. The distance between the antenna coils is about 5.5 cm. In case of non-resonance, the plasma is not generated even if the RF power is increased from 10 W to 100 W. However, it was observed that plasma is generated when resonance occurs, and the plasm density and ion flux change about 10 times or more with changing impedance controller. This is discussed along with the relevant physical mechanisms.

Keywords: Inductively coupled plasma, Capacitively coupled plasma, wireless power transfer, magnetic resonance, Plasma density and Ion flux

References:

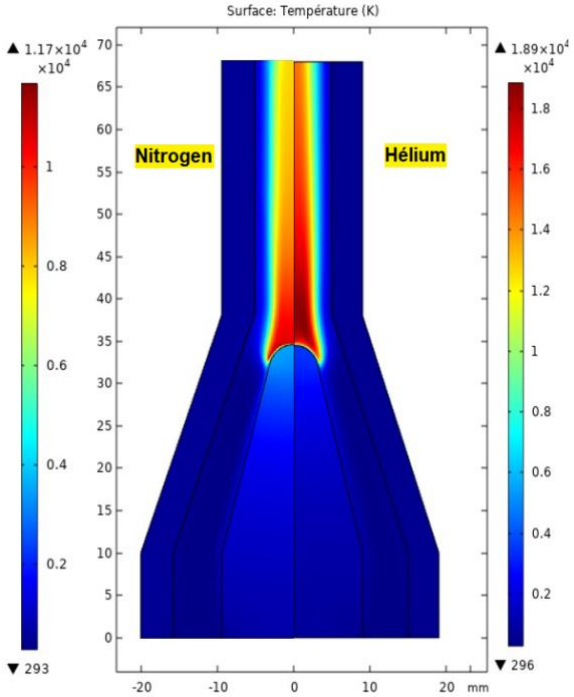
1. M. A. Lieberman and A. J. Lichtenberg (2005) Principles of plasma discharges and materials processing, John Wiley & Sons
2. H. J. Lee, H. C. Lee, Y. C. Kim and C. W. Chung (2013) “Control of plasma density distribution via wireless power transfer in an inductively coupled plasma”, *Plasma Sources Sci. Technol.* **22** 032002
3. J. H. Kim, Y. H. Hong and C. W. Chung (2019) “High efficient plasma generation in an inductively coupled plasma using a passive resonant antenna”, *Plasma Sources Sci. Technol.* **28** 105018
4. T. W. Kim, M. Y. Lee, Y. H. Hong, M. H. Lee, J. H. Kim, and C. W. Chung (2021) “Local electron and ion density control using passive resonant coils in inductively coupled plasma”, *Plasma Sources Sci. Technol.* **30** 025002
5. J. H. Kim and C. W. Chung, (2021) “Development of high-efficiency capacitive discharge using magnetic resonance wireless power transfer systems”, *Plasma Sources Sci. Technol.* **30** 055017
6. J. H. Kim and C. W. Chung, (2022) “Plasma and electrical characteristics depending on an antenna position in an inductively coupled plasma with a passive resonant antenna”, *Plasma Sources Sci. Technol.* **31** 015002

Non-transferred plasma torch modeling : methods and studies of the plasma properties with COMSOL

A. Truilhé [1] , Y. Cressault [1], F.Valensi [1], B.Chinè [2]
[1] LAPLACE, Paul Sabatier University, Toulouse, France
[2] School of Materials Science and Engineering, Costa Rica Institute of Technology, Cartago, Costa Rica

Abstract:
Used for welding, cutting, deposition by projection, for the treatement of waste, or in analysis for ICP torches, for the synthesis of high purity silica or for the manufacture of nanometric powders or nanoparticules, plasma torches are fundamental in processing of materials and in energy industry. Non-transferred plasma torches operate in DC and are composed by three main elements : a cathode where the electron are generated, an anode which serves as a nozzle and a plasma gas injection system. The arc is thus formed between the cathode and the anode, ionizing the plasma gas which will be blown and guided through the nozzle [1]. The establishment of a model to simulate the creation and maintenance of a thermal plasma at atmospheric preasure is an important issue, particularly in this field where the setting up of experiments proves to be very complex due to the large temperature values (several tens of thousands of Kelvin), but also the large voltage or current values necessary in order to achieve the breakdown of the arc. Indeed, the experimental manipulations remain feasable and very important, but the numerical model, once validated, allows us to have access to many parameters, in different regimes, to play quickly with the geometry or even to penetrate into the heart of the plasma without disturbing it, which takes much longer with experimental methods. In this work, we describe the plasma with the local thermodynamic equilibrium (LTE) hypothesis, so the electrons and heavy particles temperatures are approximatly equal, and we can implement the magneto-hydrodynamics (MHD) equations using the Plasma's Equilibrium Discharge interface of Comsol Multiphysics 5.5. The steady state equations of conservation of fluid mechanics, heat transfer and electromagnetics are developed using the multiphysics couplings options available in the software [2]. Thereby, compressible laminar flows (Ma<0.3) are simulated by modifying some parameters in order to evaluate their impact on the temperature field : the geometry (rounded and pointed cathode tip), the swirl parameter (low/high value), the current density (-0.5×10^7 and -2×10^7 A/m²), the velocity of the particles at the inlet (1 and 20 m/s), the radiative losses Q_{rad} (using Comsol data or the NEC from the LAPLACE), the transport coefficients (viscosity, electrical and thermal conductivites, thermodynamic properties from COMSOL or from the LAPLACE), the nature of the gas (Air, N_2, Ar, He) (Figure1).

Figure 1: Temperature field inside the torche depending on the plasma gas (N_2 / He).



Fixed parameters : v_{inlet} = 4 m/s ; J = -10^7 A/m² ; Q_{rad} and transport properties from COMSOL datas ; rounded cathod ; P = 1 atm ; swirl parameter k = 81 E-3 m²/s.

References:

1. Gadonna K, *Microwave plasma torch at atmospheric pressure: heat transfer,* Doctoral thesis from Paris Sud University - Paris XI, 2012.
2. Chinè B, *A Plasma Torch Model*, School of Materials Science and Engineering Costa Rica Institute of Technology, Cartago, Costa Rica, Comsol Conference 2017, October 18-20 2017, Rotterdam, Netherlands.

Determination of Vibrational and Rotational Temperatures of a Non-Equilibrium Nitrogen Atmospheric Pressure Plasma Torch dedicated for Surface Treatment by Optical Emission Spectroscopy and Diatomic Molecular Spectra Simulation.

V.E.Solofondrakotroka [1,2,*], Y.Cressault [1] , M.Masquère [1], R.Rakotosaona [2], V.Ramarozatovo [2], R.Ramanantsoa [3]

[1] LAPLACE, University Toulouse III Paul Sabatier, Toulouse, France

[2] ESPA, University of Antananarivo, Antananarivo, Madagascar

[3] Department of Physics, University of Antananarivo, Antananarivo, Madagascar

Abstract:

Non equilibrium plasmas are widely used technologies for surface treatment. The nature and quality of the modification of the surface properties depend on the temperatures and the plasma-surface chemical reactions. Non equilibrium plasmas are characterized by a high electron temperature responsible for high reactivity and a low gas temperature allowing to treat temperature sensitive materials. These kinds of plasmas are described by several temperatures : translational temperatures (the electron and heavy particles temperatures) and internal temperatures (electronic excitation temperature for atoms, electronic excitation, vibrational and rotational temperatures for molecules). The reactivity of plasma is known in the literature to be highly affected by vibrational levels [1], [2] and the rotational distribution can be used for the deduction of the gas temperature [3]. References [1] and [2] have studied the interaction of vibrationally excited molecules with solid surfaces. These works confirm the importance of vibrational excitation in the chemical reactions. This work is interested in the determination of vibrational and rotational temperatures for a plasma torch dedicated for surface treatment, working at atmospheric pressure and delivering a quasi-sinusoidal discharge in the frequency range of 80 kHz to 200 kHz through a gas flow rate of 30 slm to 60 slm. To determine these two temperatures, studies have been developed according two ways : (1) Optical Emission Spectroscopy and Boltzmann plot preferred as a non-intrusive method for the diagnostic of the plume in non thermal equilibrium [3]. Figure 1 shows a sample of the spectrum emitted by the plasma torch in the wavelengths range [225-255 nm]; (2) radiative simulations of diatomic molecular spectra for NO gamma / beta / delta, CN violet and N2 First Positive (FPS) systems. These simulations are compared with experiments in order to validate the temperatures found. As examples, some experimental and simulated spectra will be presented, and temperatures found will be discussed for several frequencies and gas flow rates.

Keywords: atmospheric plasma, non-equilibrium, optical emission spectroscopy, rotational temperature, spectra simulation, vibrational temperature.

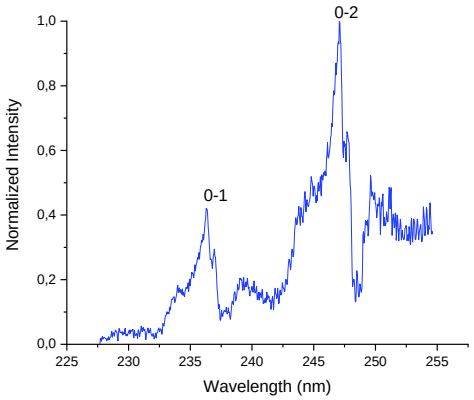


Figure 1: NO emissions from the plasma plume in the UV (0-1 and 0-2 bands of NO γ system). The light signal was acquired at 5 mm from the end of the nozzle, for 40 slm (N_2)and 80 kHz.

References:

1. Hou, H., Huang, Y., Gulding, S.J., Rettner, C.T., Auerbach, D.J., Wodtke, A.M. (1999) Enhanced Reactivity of Highly Vibrationally Excited Molecules on Metal Surfaces, *SCIENCE*, vol 284, 1647-1650.
2. Smith, R.R., Killelea, D.R., DelSesto, D.F., Utz, A.L. (2004), Preference for Vibrational over Translational Energy in a Gas-Surface Reaction, *SCIENCE*, vol 304, 992-994.
3. Bruggeman, P.J., Sadeghi, N., Schram, D.C., Linss, V. (2014), Gas temperature determination from rotational lines in non-equilibrium plasmas: a review, *Plasma Sources Sci. Technol*, 23 023001.

A 0D kinetic modelling of a DBD reactor in humid air

G. Pierotti [1,*], A. Popoli[1], A. Cristofolini [1]
[1] Department of Electrical, Electronic and Information Engineering "Guglielmo Marconi", University of Bologna, Bologna, Italy

Abstract:
Dielectric Barrier Discharge (DBD) reactors operating in humid air are widely used in many applications, including plasma medicine [1] and plasma agriculture [2]. Reactive species generated in a humid air plasma play a central role in these fields and, consequently, kinetic models of DBD devices is an essential tool to better understand and improve the operation of this kind of reactors. In this work, a 0D model is presented, aimed to simulate the chemical kinetics of a DBD sinusoidal reactor in humid air (considered as a tri-molecular gas composed by nitrogen, oxygen and water). The reaction set adopted is based on the one proposed by Sakiyama et al. [3]. The average power delivered to the DBD during one time period of the voltage source is assumed constant.
The occurence of microdischarges in a time period is evaluated assuming that discharges initiate whenever the electric field E_{gap} in the air gap reaches a given threshold value E_{in}, considered as a simulation parameter. E_{gap} is calculated as the difference between the external electric field E_{ext} (due to the imposed voltage at the electrodes) and the field E_c generated by the charge deposited on the dielectric barrier. When the discharge takes place, E_c is updated to make E_{gap} equal to another parameter of the simulation, i.e. the extinction field E_{end}. The behavior of E_{ext}, E_c and E_{gap} is reported in Fig. 1. ZDPlaskin [4] was utilized to model the DBD kinetics. A microdischarge is simulated introducing a triangular power peak as a source term.
This approach allows to account both for the input power and the frequency of the power supply.

Keywords: Kinetic modelling, global model, plasma kinetics, plasma modelling, dielectric barrier discharge

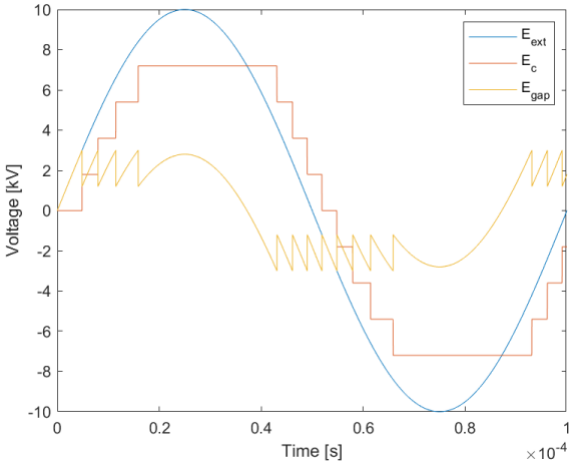


Figure 1: Figure illustrating the behaviour of the external electric field E_{ext} (due to the imposed voltage at the electrodes), the field generated by the charge deposited on the dielectric barrier E_c and the electric field in the air gap E_{gap}.

References:

1. Weltmann, K. D., Von Woedtke, T., Plasma Physics and Controlled Fusion (2016), **59**(1), 014031.
2. Ito, M., Oh, J. S., Ohta, T., Shiratani, M., Hori, M. Plasma Processes and Polymers (2018), **15**(2), 1700073.
3. Sakiyama, Y., Graves, D. B., Chang, H. W., Shimizu, T., Morfill, G. E., Journal of Physics D: Applied Physics (2012) , **45**(42), 425201.
4. Pancheshnyi, S., Eismann, B., Hagelaar, G., & Pitchford, L. Bulletin of the American physical society (2008). **53**.

Injection's core moulds reusing through the degraded coating's removal by laser technology.

R. Santos[1], I. Marcelino[2], T. Ferreira[2], L. Pereira[3], F. M. Costa[1], N. M. Ferreira[1]
[1] i3N & Physics Department, University of Aveiro, Aveiro, Portugal
[2] IPN – Instituto Pedro Nunes, Coimbra, Portugal
[3]MicroPlásticos S.A., Figueira da Foz, Portugal
*corresponding author e-mail: nmferreira@ua.pt

Abstract:
The injection moulds in the polymer industry must be in perfect condition to manufacture pieces without defects. Nevertheless, the thickness of the self-lubricating coating is expected to diminish with continuous manufacturing, where the functional moulds' surface, is decreased. Manufacturing pieces with defects, will fail the control quality tests. To prevent this and extend the mould's core lifetime, is required to maintain the mould's coating. For this process is necessary the complete removal of the degrading coating before the deposition of a new layer of a functional coating by PVD deposition. Laser technology has already been demonstrated to remove paints and oxides successfully. So, the present work reports the study to remove the CrN coating type of the injection mould, through fibre laser irradiation. The laser parameters such as scan speed, power, frequency, pulse width, and pitch were assess to promote the laser selectivity for the coating's removal, without degrading the mould's core (steel). Also, with laser irradiation is possible to prepare the mould's core surface, like its texture, to increase the adhesion of the new coating. The results prove that the laser technology can be used for the completely degraded coating's removal without damaging the mould's core.

Keywords: Fiber laser, functional coating removal, injection moulds, surface micromachining, PVD deposition, polymer industry.

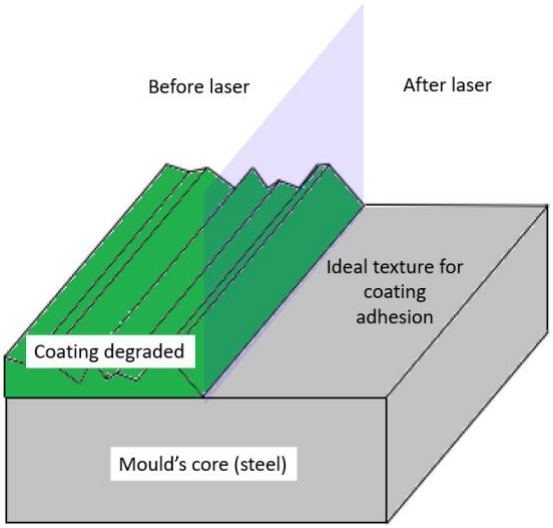


Figure 1: Figure illustrating the degraded coating removal selectivity through laser irradiation.

References:

1. D. E. Roberts, Pulsed laser coating removal by detachment and ejection, Applied Physics A 79 (2004) 1067-1070.
2. M. Shamsujjoha et al., Effects of laser ablation coating removal (LACR) on a steel substrate: Part 1: Surface profile, microstructure, hardness, and adhesion; Surface and Coating Technology; 281 (2015) 193-205.
3. https://cleanmould.web.ua.pt/wp

Development of a smart PDMS icephobic coating using encapsulated phase change materials

M. Shamhsiri, G.Momen, R.Jafari
Department of appelied sciences Name here, University of Quebec at Chicoutimi, Chicoutimi, Canada

Abstract:
The phase-change materials (PCMs) release a large amount of energy as latent heat upon freezing, which is a stimuli-response behavior for anti-icing applications. Such materials embedded within coatings can be applied to exposed infrastructures to protect them against icing. Here, we encapsulated a mixture of PCMs in a urea–formaldehyde (UF) shell by in situ polymerization and then incorporated the microcapsules into a polydimethylsiloxane (PDMS) coating. Microcapsules 5 to 15 µm in diameter having a shell thickness of about 200 nm were fabricated. Investigating the chemical composition of the fabricated microcapsules confirmed that PCM material was successfully encapsulated within the UF shell. Moreover, the differential scanning calorimetry (DSC) analysis showed that the PCM preserved its phase-change characteristics when encapsulated and embedded within the matrix. Increasing the abundance of microcapsules within the coating lowered the ice nucleation temperature, verified by DSC, and increased the freezing-delay time because of PCM latent heat release. We utilized a custom-made apparatus, called micro-push-off set-up that allowed us to measure ice adhesion at the exact moment that the water droplet was completely frozen. Therefore, it was observed that the presence of the PCM microcapsules reduced ice adhesion strength, through either possible mechanism of the formation of quasi-liquid layer (QLL) or thermal expansion differences. Furthermore, lower ice adhesion resulted in reduced ice accumulation on the PCM-containing coatings, verified by the static accumulation test (SAT).
IR thermography confirmed that this reduced ice accumulation in the PCM-containing samples occurred because of the higher surface temperature of these samples related to the latent heat released by the PCM. The lowest ice accumulation was observed for samples containing 20% PCM. In general, greater microcapsule content led to higher released latent heat, and therefore, reduced ice adhesion strength; however, for the sample containing 30% microcapsules, an increased ice adhesion is most likely related to a higher surface roughness favoring greater mechanical interlocking, matching the patterns observed with ice accumulation

Keywords: icephobity, phase change material, PDM, Ice adhesion,DSC,encapsulation .

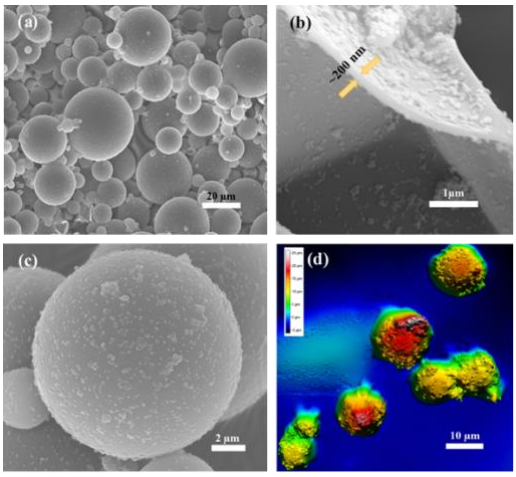


Figure 1: SEM images illustrating (a) spherical microcapsules, (b) poly urea–formaldehyde (PUF) shell thickness, (c) a PCM microcapsule surface, and (d) a topographical map of microcapsules obtained by profilometry.

References

1. A. Azimi Yancheshme, A. Allahdini, K. Maghsoudi, R. Jafari, and G. Momen, “Potential anti-icing applications of encapsulated phase change material–embedded coatings; a review,” J. Energy Storage, vol. 31, p. 101638, 2020, doi: 10.1016/j.est.2020.101638.
2. M. Shamshiri, R. Jafari, and G. Momen, “An intelligent icephobic coating based on encapsulated phase change materials (PCM),” Colloids Surfaces A Physicochem. Eng. Asp., vol. 655, p. 130157, 2022, doi: 10.1016/j.colsurfa.2022.13015.

Anodizing of AlSi10Mg alloy fabricated by LPBF

A. Togni [1,2,*], M. F. Bonilauri [1,2,3], A. Bruera [1,2], G. Bolelli [1,2,3], L. Lusvarghi [1,2,3]

[1] Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, Modena, Italy
[2] INSTM Research Unit, University of Modena and Reggio Emilia, Modena, Italy
[3] InterMech - MO.RE., University of Modena and Reggio Emilia, Modena, Italy
[*] Corresponding author. E-mail address: alessandro.togni@unimore.it

Abstract:
Anodizing is an electrochemical process widely used to protect aluminum and its alloys in wear and corrosion-prone applications. In cast Al-Si alloys, however, the presence of large Si precipitates causes local disruption of the anodic oxide layer, thus shortening the alloy service life. Unlike conventional casting, the high cooling rates of additive manufacturing (AM) processes promote the formation of a very fine microstructure, potentially suitable for the subsequent anodizing treatment [1−4]. In this work, we anodized and sealed AlSi10Mg samples fabricated by laser powder bed fusion (LPBF) and surface finished by sandblasting with glass microspheres, tumbling, and mechanical polishing. The microstructure, mechanical properties and corrosion resistance of the anodized and sealed samples were investigated as a function of surface finish. For all samples, scanning electron microscopy (SEM) micrographs revealed the formation of an oxide layer consisting of anodized Al cells decorated with partially oxidized Si particles and cavities (Figure 1). Anodic oxide layers with uniform thickness were found in the tumbled and polished samples due to the finer distribution of the Si network and the regular surface of the metallic matrix. As a result, the corrosion potential in 3.5 wt.% NaCl solution increased from about −500 mV for the untreated parts to −200 mV for the unsealed anodized ones. Sealing further enhanced the corrosion potential to +150 mV. On the other hand, the irregular surface of the sandblasted samples and the presence of residual glass microspheres embedded in the growing oxide layer resulted in lower corrosion resistance of the anodized sample, with high point-to-point variability. Finally, anodizing increased the hardness of the metallic matrix by about 100 $HV_{0.001}$ regardless of the surface finish.

Keywords: additive manufacturing, AlSi10Mg, anodizing, corrosion, hardness, laser powder bed fusion, microstructure, surface finish.

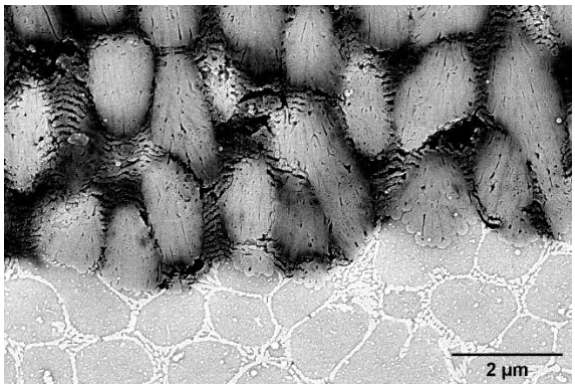


Figure 1: SEM micrograph showing the cross-sectional view of an anodized AlSi10Mg sample fabricated by LPBF.

Acknowledgments:
The authors acknowledge BEAMIT S.p.A. for providing the AlSi10Mg samples fabricated by LPBF and MOCHEM Industrie S.r.l. for carrying out the anodizing and sealing treatment.

References:

1. Revilla, R. I., Verkens, D., Couturiaux, G., Malet, L., Thijs, L., Godet, S., De Graeve, I. (2017), Galvanostatic Anodizing of Additive Manufactured Al-Si10-Mg Alloy, *J. Electrochem. Soc.*, 164, C1027−C1034.
2. Revilla, R. I., Terryn, H., De Graeve, I. (2018), Role of Si in the Anodizing Behavior of Al-Si Alloys: Additive Manufactured and Cast Al-Si10-Mg, *J. Electrochem. Soc.*, 165, C532−C541.
3. Rubben, T., Revilla, R. I., De Graeve, I. (2019), Effect of Heat Treatments on the Anodizing Behavior of Additive Manufactured AlSi10Mg, *J. Electrochem. Soc.*, 166, C42−C48.
4. Revilla, R. I., Rojas, Y., De Graeve, I. (2019), On the Impact of Si Content and Porosity Artifacts on the Anodizing Behavior of Additve Manufactured Al-Si Alloys, *J. Electrochem. Soc.*, 166, C530−C537.

Low-temperature gas and plasma nitriding on Inconel 718 produced by Laser-Powder Bed Fusion: effects on wear and corrosion resistance

M.F. Bonilauri[1,2,3,*], L. Bortolotti[1,2], G. Bolelli[1,2,3], R. Bolzonella[1,4], O. Messe[5], L. Lusvarghi[1,2,3]
[1] Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, Modena, Italy
[2] InterMech – MO.RE., University of Modena and Reggio Emilia, Modena, Italy
[3] INSTM, Research Unit: University of Modena and Reggio Emilia, Modena, Italy
[4] PetrolValves S.p.A, Viale Luigi Majno 17/A, 20122 Milano, Italy
[5] Oerlikon AM Europe GmbH, Kapellenstr. 12, Feldkirchen, 85622, Germany
* Corresponding author: mariafrancesca.bonilauri@unimore.it

Abstract:
Due to harsh working environments, parts in oil and gas plants must meet strict requirements in terms of corrosion resistance. Thus, they are usually made of either stainless steel or Ni-based superalloys. Among all components, metal seated ball valves are particularly critical, as they are additionally subjected to severe tribological contact conditions. Therefore, they are traditionally fabricated by forging and then coated with wear-resistant thermal-sprayed coatings. In recent years, additive manufacturing (AM) techniques have been increasingly adopted in the oil and gas industry, as they allow to shorten the production lead time. However, like a traditional part, AM components cannot meet the requirements for these applications without coatings or surface treatments. Among the latter, thermochemical treatments could enhance the corrosion and wear resistance of the parts [1,2] without significantly increasing the production time, as they could be performed in heat treatment furnaces.
In this work, we studied the effects of low-temperature gas nitriding and plasma nitriding on the hardness, wear resistance, and corrosion resistance of Inconel 718 parts obtained by Laser- Powder Bed Fusion (L-PBF). We performed micro-indentation tests, ball-on-disk tests using Al_2O_3 and 100Cr6 counterparts, potentiodynamic polarization tests, and corrodkote tests (ASTM B380). The results were compared to those obtained using a thermal-sprayed WC-10Co4Cr coating as a benchmark.
After both plasma and gas nitriding, the surface hardness increased from about 350 HV to 1000-1200 HV, leading to a reduction in the wear rate against both counterparts. The wear rate against 100Cr6 was comparable to that of the benchmark. By contrast, it was still two or three orders of magnitude higher than the benchmark against Al_2O_3. Due to the undesired formation of nitrides in the hardened layer, the corrosion resistance of the material deteriorated after nitriding. However, the corrosion current measured on the nitrided material was still two orders of magnitude lower than that of the reference WC-CoCr coating.

Keywords: nitriding, selective laser melting, corrosion, tribological properties.

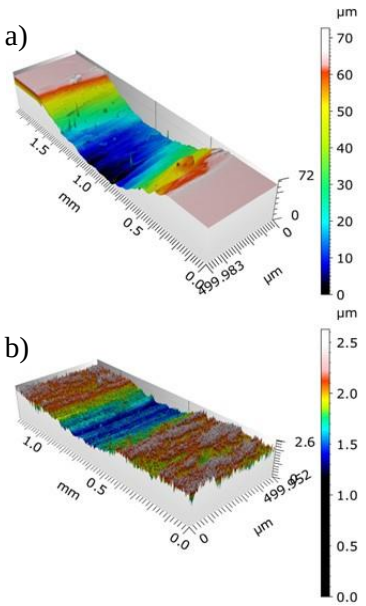


Figure 1: 3D reconstructions of the wear tracks on the surface of a) non nitrided sample, and b) gas-nitrided sample, after sliding against 100Cr6.

References:

1. G. C. Mondragón-Rodríguez *et al.*, Surface modification and tribological behavior of plasma nitrided Inconel 718 manufactured via direct melting laser sintering method, *Surf. Coat. Technol.*, 387 (2020), 125526, doi: 10.1016/j.surfcoat.2020.125526.
2. V. Singh and E. I. Meletis, Synthesis, characterization and properties of intensified plasma-assisted nitrided superalloy Inconel 718, *Surf. Coat. Technol.*, 201 (2006), 1093–1101, doi: 10.1016/j.surfcoat.2006.01.034.

A Low Friction and High Repetition Durability Sliding System based on Ionic Liquid Type Polymer Brushes Combined with a Molecularly Smooth Surface

T. Kamijo[1)*], H. Arafune[1)], T. Morinaga[1)] and T. Sato[2)]
[1] Department of Creative Engineering, National Institute of Technology, Tsuruoka College, Tsuruoka city, Japan,
[2] National Institute of Technology, Okinawa College, Nago city, Japan,

Abstract:
Ionic liquids (ILs) are organic salts consisting of anions and cations that exist as liquids at room temperature. The ILs bear many attractive properties such as negligible volatility, low flammability, and relatively high thermal durability. These properties can be varied in a controlled fashion through systematic changes in the molecular structure of their constituent ions. Recently, some studies have been reported which aim to use the ionic liquids as a new lubricant. However, at present, most of the low friction tribomaterials using ionic liquids are not reported.
In this study, we are developing a low friction sliding system using ionic liquid polymer brush. The sliding system is a lubrication system composed of the concentrated ionic liquid type polymer brush layer (ILPB) wet with an ionic liquid and a smooth glass ball (Maximum height roughness < 3 nm) obtained by gluing the smooth glass sheet to a glass ball with UV resin. The ILPB synthesized by the surface-initiated atom transfer radical polymerization (ATRP) of ionic liquid type monomer on a silicon substrate surface-modified with ATRP-initiating groups.
Combining ILPB and the smooth silica sheet has provided quite low friction coefficient values ($\leqq$ 0.01) at a sliding speed of 0.010 m/s under a normal load of 9.8 N at the same position to confirm the stability of its low frictional property. All through the 4000 friction cycles, the friction coefficient value of smooth glass ball/ILPB maintained a value of 0.003 (Figure 1) showing that the super lubricity of polymer brushes was maintained after a long time exposure and repeated usage. In contrast the glass ball (Maximum height roughness = 220 nm) /ILPB showed an immediate increase of the friction coefficient value within the first ten cycles, even under a much lower load (0.98 N). Molecular smoothness of the facing materials of polymer brushes was clarified as being essential to achieve super lubricity on a macroscopic tribology scale. In this meeting, we will also report on the results of a sliding system in which a porous anodized alumina (PAA, Figure 1) material was used for the polymer brush base material, resulting in even lower friction and higher repetitive durability.

Keywords: Ionic liquid, polymer brushes, tribology, low friction materials, porous alumina, texture

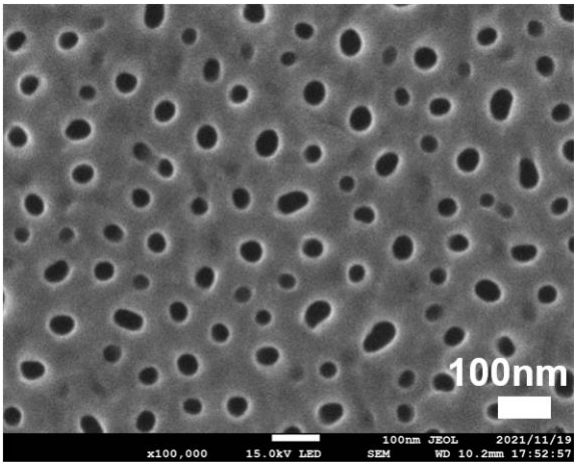


Figure 1: SEM image of PAA surface.

References:

1. Arafune, H., Kamijo, T., Morinaga, T., Honma, S., Sato, T., Tsujii, T. (2015) A robust rubrication system using an ionic liquid polymer brush *Adv. Mater. Int.* 1500187 (1-5).

Effects of Chemical Surface Modification on Diffusion Coefficients in Hierarchically Porous Media Through Multiscale Simulations

U. Tallarek [1,*], D. Hlushkou [1], N. Trebel [1], A. Höltzel [1]
[1] Department of Chemistry, Philipps-University Marburg, Marburg, Germany

Abstract:
We present a multiscale simulation approach to derive effective diffusion coefficients in hierarchically structured, macro/mesoporous materials employed as surface coating or supports for chromatographic separation and heterogeneous catalysis. Simulated diffusion coefficients account for the solute dynamics at the interface between the pore surface and saturation (wetting) liquid as well as for the actual morphology of the material. Molecular dynamics simulations characterize the interfacial dynamics through mesopore-level distributions of liquid and solute density and the diffusion coefficient parallel to the pore surface under explicit consideration of surface chemistry, solvent and solute properties, and composition of the liquid.
This information is incorporated into Brownian dynamics simulations of the effective diffusion coefficient in the mesopore space morphology as physically reconstructed by scanning transmission electron microscopy. Mass transfer between pore space hierarchies is simulated using an effective homogeneous medium representation for the mesoporous domain in the macropore space morphology as physically reconstructed by confocal laser scanning microscopy. The derived diffusion coefficients have immediate value as input parameters for transport in and through hierarchically structured surfaces and supports applied in environmental science and technology, for chemical separations and in catalysis. It strengthens the basis for predictive modeling and removes ambiguity regarding adsorption and transport mechanisms. The simulation approach is sensitive to subtle changes in interfacial dynamics (e.g., as induced by changes in the chemical surface modification) and flexible regarding the employed coating and support morphologies.

Keywords: chemical surface modification, interfacial dynamics, diffusion in porous media, hierarchical pore space morphologies, molecular dynamics simulations, Brownian dynamics, porous silica, glass.

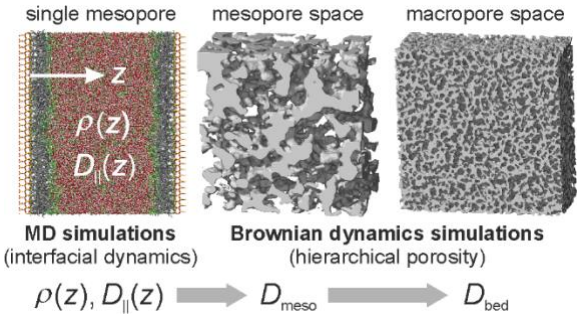


Figure 1: Multiscale approach to the simulation of effective mesopore and bed diffusion coefficients (D_{meso} and D_{bed}) in a hierarchicall porous material (coating or support) under consideration of the interfacial dynamics [1, 2]. The surface of the silica support is chemically modified with long alkyl chains (C_{18} or C_8). Molecular dynamics (MD) simulations address the interaction of solvent and solute molecules with this surface at the single-mesopore level (left). The information obtained for solvent and solute distribution and mobility, expressed by the density and surface-parallel diffusivity profiles $\rho(z)$ and $D_{||}(z)$, is subsequently embedded into Brownian dynamics (BD) simulations to obtain D_{meso} for the mesopore space (B). BD simulations of D_{bed} in the macropore space of the material (C) finally account for the interfacial dynamics from the MD simulations by considering solvent and solute exchange between pore space hierarchies as well as for diffusion in realistic pore space models derived by physical reconstruction.

References:

1. Tallarek, U., Hlushkou, D., Rybka, J., Höltzel, A. (2019) Multiscale simulation of diffusion in porous media: From interfacial dynamics to hierarchical porosity, *J. Phys. Chem. C* 123, 15099–15112.
2. Tallarek, U., Hlushkou, D., Höltzel, A. (2022) Solute sorption, diffusion, and advection in macro–mesoporous materials: Toward a realistic bottom-up simulation strategy, *J. Phys. Chem. C* 126, 2336–2348.

Effect of Chemial Surface Modification with Long Alkyl Chains on Surface Diffusion Properties: Chain Length vs. Ligand Density

N. Trebel [1,*], J. Rybka [1], A. Höltzel [1], U. Tallarek [1]
[1] Department of Chemistry, Philipps-University Marburg, Marburg, Germany

Abstract:
Fast surface diffusion of binary, aqueous-organic liquids near chemically modified hydrophobic silica surfaces describes a complex phenomenon that exists in a narrow ditch region where the silica-tethered alkyl chains meet the aqueous-organic binary liquid. The lateral mobility of solvent and solute molecules in the organic solvent-rich ditch can exceed their bulk diffusivity in the saturating binary liquid.
Through molecular dynamics simulations using an established silica-based mesopore model and aqueous-organic (water-acetonitrile) liquid phases as well as a suitable solute set, we study how chain length (C_{18} vs C_8) and ligand (C_8) density at the surface contribute to the lateral mobility gain from surface diffusion of solvent and soute mocules [1]. The simulations show that C_8 chains are better solvated and more often in an upright and stretched conformation than C_{18} chains, which leads to a higher maximum acetonitrile excess in the ditch region. High ligand density reinforces this effect. The acetonitrile-excess advantage of C_8 phases translates not necessarily into faster surface diffusion, because the shorter chains have lower alkyl chain mobility. Surface diffusion on a C_8 phase is generally slower than that on a C_{18} phase. The simulations have shown that the chemical surface modification contributes twofold to surface diffusion: passively through acetonitrile enrichment (interaction between alkyl chains and binary liquid) and actively through lubrication (interaction between alkyl chains and the solvent and solute molecules). Whereas a passive contribution to surface diffusion can be predicted to exist for any surface of the investigated surface modifications, the same cannot necessarily be said of the active contribution, for which a certain flexibility of the alkyl chains in the acetonitrile ditch is required.

Keywords: chemical surface modification, interfacial dynamics, surface diffusion, molecular dynamics simulations, silica models.

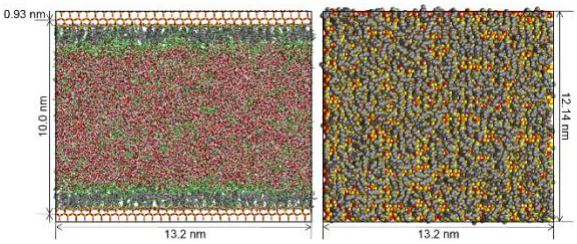


Figure 1: Snapshot of the silica surface chemically modified with long alkyl chains. The mesopore model features a C_8 (octadecylsilyl) phase equilibrated with 70/30 (v/v) water/acetonitrile (left panel) and a top view onto the silica surface bearing the high density-C_8 phase (right panel). Atoms and united-atom groups are colored as follows: Si, yellow; O (of silica and water molecules), red; H (of residual surface OH groups and water molecules), white; acetonitrile molecules, green; and CH_2 and CH_3 united-atom groups, gray.

References:

1. Rybka, J., Höltzel, A., Trebel, N., Tallarek, U. (2019) Stationary-phase contributions to surface diffusion in reversed-phase liquid chromatography: Chain length versus ligand density, *J. Phys. Chem. C*, 123, 21617–21628.

Obtaining of superhydrophobic surfaces by nanosecond laser ablation

Iuliana Urzica[1], Catalin Logofatu[1], Agota Simon[1,2], Cristian Udrea[1]*

[1]National Institute for Laser, Plasma and Radiation Physics, Magurele 077125, Ilfov, Romania
[2]Faculty of Physics of the University of Bucharest,Magurele, Romania

Abstract:
Many living beings in nature, including the lotus leaf, rice leaf, butter flying wing and water-strider legs are the inspiration for many innovations and continues to serve as an invaluable resource to solve technical challenges. Such unique surfaces possess several unique beneficial properties, i.e., extreme water repellency, self-healing, self-cleaning, anti-bacterial, anti-corrosion, enhanced heat transfer, drag reduction and improved corrosion resistance. Recently, superhydrophobic surfaces, for which the water contact angle is higher than 150° and sliding angle less than 10°, have received attention due to the many potential applications ranging from biological to industrial processes and usable/applicable even in daily life.
The main purpose of this scientific paper is to demonstrate that can be produced superhydrophobic structures on metallic surfaces with an innovative, flexible, and low-cost laboratory setup. The method which we use to design these structures is by laser ablation with a nanosecond pulsed Nd:YAG laser. These patterned superhydrophobic metallic surfaces help us to obtain a fingerprint device to be used on polymeric materials such as polydimethylsiloxane-PDMS and polyethylene terephthalate-PET. Because the polymeric structures have the same properties as those of metal patterns, they are used in a large number of remarkable applications: biology, food industry, marine, and textile industry. Therefore, in this experiment, we have developed an experimental and follow theoretical basis to obtain superhydrophobic surfaces.

Keywords: laser surface modifications, superhydrophobic surfaces, laser ablation, imprinting polymeric materials

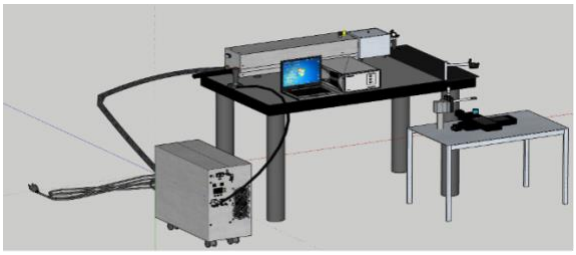


Figure 1: Experimental set-up

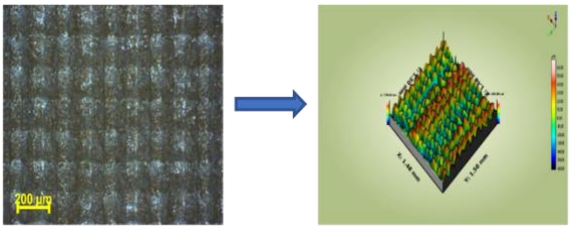


Figure 2: Al surface irradiated in the environment

References:

1. Yukui Cai 1 , Xichun Luo 1,*, Zhanqiang Liu 2,3 , Yi Qin 1, Wenlong Chang 1 and Yazhou Sun 4, Product and Process Fingerprint for Nanosecond Pulsed Laser Ablated Superhydrophobic Surface, Micromachines **2019**, 10, 177; doi:10.3390/mi10030177
2. Yang, C.J.; Mei, X.S.; Tian, Y.L.; Zhang, D.W.; Li, Y.; Liu, X.P. Modification of wettability property of titanium by laser texturing. Int. J. Adv. Manuf. Technol. **2016**, 87, 1–8.
3. Chi-Vinh Ngo, Doo-Man Chun, Fast wettability transition from hydrophilic to superhydrophobiclaser-textured stainless steel surfaces under low-temperatureannealing, Applied Surface Science,409 (**2017**) 232–240
4. Yukui Caia, Wenlong Changa, Xichun Luoa,Ana M.L. Sousab, King Hang Aaron Laub, Yi Qina ,Superhydrophobic structures on 316L stainless steel surfaces machined by nanosecond pulsed laser, Precision Engineering, 52 (**2018**) 266–275
5. Sun, C.; Zhao, X.W.; Han, Y.H.; Ze, Z. Control of water droplet motion by alteration of roughness gradient on silicon wafer by laser surface treatment. Thin Solid Films **2008**, 516, 4059–4063.

Improving adhesion of vulcanised rubber by atmospheric plasma surface treatment for the footwear industry

V.M. Serrano-Martínez*, C. Ruzafa-Silvestre, M.P. Carbonell-Blasco, E. Orgilés-Calpena.
Adhesives Department, Footwear Technology Centre (INESCOP), 03600 Elda, Spain
vmserrano@inescop.es

Abstract:
To ensure that the adhesive joints between the upper and the sole of the shoe are strong and durable, surface preparation is crucial. In this work, robotic atmospheric pressure plasma technology is researched as a more environmentally friendly surface treatment than chemical solvent treatments (i.e., halogenation) for styrene-butadiene rubber (SBR) vulcanised rubber to promote adhesion. In this work, different parameters, such as the application speed the nozzle distance of the atmospheric plasma system, have been optimised. In addition, the effects of plasma treatment on the surface of the rubber material have been evaluated using different experimental techniques such as Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS), field emission scanning electron microscopy (FESEM), contact angles (CA), surface free energy (SFE) and T-peel tests. The adhesion results show that the values obtained for the T-peel strength of the adhesive joints of the three polyurethane adhesives (solvent, water-based and hot melt) studied meet the requirements for footwear according to the standardised tests. Consequently, atmospheric plasma could replace solvents as a surface treatment for shoe soles by optimising and validating plasma operating conditions and rubber adhesion qualities. The main advantage of this technology is that it can fully automate the bonding process on the production line using robots.

Keywords: surface treatment, atmospheric plasma, footwear materials, plasma treatment surface, bonding process, sustainability.

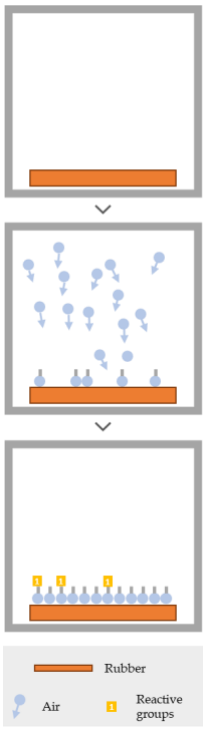


Figure 1: Surface activation process by plasma technology on vulcanized rubber.

References:

1. Carbonell-Blasco, M. P., Ruzafa-Silvestre, C., Mateu-Romero, B., Orgilés-Calpena, E., & Arán-Ais, F. (2022). Cleaner technologies to minimize the environmental footprint of the footwear bonding process. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science. https://doi.org/10.1177/09544062221140053
2. Ma, C., Wang, L., Nikiforov, A., Onyshchenko, Y., Cools, P., Ostrikov, K. (Ken), De Geyter, N., & Morent, R. (2021). Atmospheric-pressure plasma assisted engineering of polymer surfaces: from high hydrophobicity to superhydrophilicity. APPLIED SURFACE SCIENCE, 535. https://doi.org/10.1016/j.apsusc.2020.147032

Polymer Surface Characterization Improved by DCSBD Plasma Technique

M. Pajtášová [1], S. Ďurišová [1], D. Ondrušová [1], P. Skalková [1], R. Janík [1], S. Brigantová
[1] Department of Material Technologies and Environment, TnUAD of Trenčín, Faculty of Industrial Technologies, Púchov, Slovakia

Abstract:
Nowadays, synthetic rubbers plays an important role in the tire production industry. In many ways substitues natural rubber due to ist enhanced performance properties. However, according to its nature, there is a lack of required surface manufacturing properties e.g. mostly polymers are hard to adhere and non-wettable. Additionally, multiple physical treatements are performed to achieve desired characteristics. One of these treatment reflects atmospheric plasma source such as diffuse coplanar surface barrier discharge working in the artificial air. In recent years, the DCSBD source gained significance in treatment of glass, wood or polymers [1, 2]. The main andvantage of DCSBD system consist of fast treatment within seconds producing macroscopically homogenous plasma with relatively high electron density and input power [2, 3]. In this work, the SBR/BR/NR rubber blend filled with carbon black was subjected to the DCSBD plasma for 10 s and 30 s in order to improve surface properties. Morphology of modified rubber blend was studied via scanning electrone microscope and atomic force microscope with regards on surface roughness and fragmentation of surface relief. Also wetting characteristics and surface energy were studied via contact angle measurement using two testing liquids by sessile drop method. Furtermore, modified rubbers were characterized by IR spectroscopy. The submitted work has been supported by the Operational Program Integrated Infrastructure, co-financed by the European Regional Development Fund by the project: Advancement and support of R&D for "Centre for diagnostics and quality testing of materials" in the domains of the RIS3 SK specialization, Acronym: CEDITEK II., ITMS2014+ code 313011W442.

Keywords: DCSBD plasma, rubber blend, surface modification, wetting, activation, structure, morphology

References:

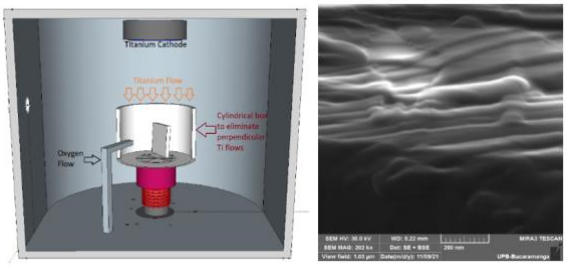
1. Janík, R., Kohutiar, M., Dubec, A., Eckert, M., Moricová, K., Pajtášová, M., Ondrušová, D., Krbata, M. (2022), DMA Analysis of Plasma Modified PVC Films and the Nature of Initiated Srface Changes. *Materials*, 15, 4658.
2. Štepánová, V., Kelar, J., Galmiz, O., Zemánek, M., Slavicek, P., Buček, A., Černák, M. (2017), Areal Homogeneity Verification of Plasma Generated by Diffuse Coplanar Surface Barrier Discharge in Ambient Air at Atmospheric Pressure. *Contrib. Plasma Phys.* 57, 182–189.
3. Čech, J., Hanusová, J., Sťahel, P.,Černák, M. (2015), Diffuse Coplanar Surface Barrier Discharge in Artificial Air: Statistical Behaviour of Microdischarges. *Open. Chem.* 15, 528–540.

Plasma activation for the growth of titanium and titanium dioxide thin films

Y F Barragan *[1], P A Tsygankov[1] ,FF Parada-Becerra[1],E A Orozco[1] , Y Q Pacheco [1] and C J Páez[1]
[1] Facultad de ciencias - Grupo de Física y Tecnología del Plasma y Corrosión-Fitek, Universidad Industrial de Santander,Bucaramanga-Colombia.

Abstract:
The use of plasma in producing thin films has proven to be effective in controlling the growth and structure of the forming crystallites. In this work, the effects of excitation of the plasma at different pressures of the medium on the flux and energy change of the atoms that reach the substrate during the growth of thin films of titanium and titanium dioxide are analyzed. Two methods of creating plasma are compared: microwave radiation (MR) and glow discharge at an applied voltage of -500 V . Molecular flux are calculated using Bohm's theory and plasma parameters are measured with a Langmuir probe. Titanium and titanium dioxide films are grown with different substrate voltages and flow angles of incidence (see Figure a), which are studied by scanning electron microscopy and X-ray diffraction (see Figure b). The results show that plasma activation at different pressures and with different methods of excitation significantly affects the growth and structure of titanium and titanium dioxide films.

Keywords:Langmuir probe diagnostic, plasma activation, CVD, PVD, the forming crystallites.



a) **b)**

Figure 1: Figure illustrating a) Experimental scheme to generate titanium dioxide films with an inclined columnar structure, b) Images obtained by SEM of thin film TiO_2.

References:

1. Kajzer, A., Grzeszczuk, O., Kajzer, W., Nowińska, K., Kaczmarek, M., Tarnowski, M., & Wierzchoń, T. (2017). Properties of Ti-6Al-7Nb titanium alloy nitrocarburized under glow discharge conditions. Acta of Bioengineering and Biomechanics, 19(1), 181-188.
2. Pacheco, Y. Q., Barragán, Y. F., Parada-Becerra, F. F., Tsygankov, P. A., & Orozco, E. A. (2019, November). Computational study of a glow discharge device. In *Journal of Physics: Conference Series* (Vol. 1386, No. 1, p. 012122). IOP Publishing.
3. Pamu, D., Krishna, M.G., Raju, K.C.J., & Bhatnagar, A.K. (2005). Ambient temperature growth of nanocrystalline titanium dioxide thin films. Solid State Communications, 135(1), 7-10. doi: 10.1016/j.ssc.2005.04.003
4. Mathur, S., & Kuhn, P. (2006). CVD of titanium oxide coatings: Comparative evaluation of thermal and plasma assisted processes. Surface and Coatings Technology, 201(3), 807-814. doi: 10.1016/j.surfcoat.2005.12.039
5. Kang, M., Kim, S.W., & Park, H.Y. (2018). Optical properties of TiO2 thin films with crystal structure. Journal of Physics and Chemistry of Solids, 123, 266-270. doi: 10.1016/j.jpcs.2018.08.009
6. Gazal, Y., Dublanche-Tixier, C., & Chazelas, C. (2016). Multi-structural TiO2 film synthesised by an atmospheric pressure plasma-enhanced chemical vapour deposition microwave torch. Thin Solid Films, 600, 43-52. doi: 10.1016/j.tsf.2016.01.011.

Acknowledgements
This work was carried out with the support of the Ministry of Science, Technology and Innovation of Colombia (Minciencias-Colciencias) through agreement No. 80740-535-2020 (project code 1102-852-69674) with the Universidad Industrial de Santander .

Computational study and diagnostics of glow discharge plasma

Y F Barragan *[1], Y Q Pacheco [1], P A Tsygankov[1] ,FF Parada-Becerra[1],E A Orozco[1] and C J Páez[1]
[1] Facultad de ciencias - Grupo de Física y Tecnología del Plasma y Corrosión-Fitek, Universidad Industrial de Santander,Bucaramanga-Colombia.

Abstract:
The last decade has seen an increase in technologies for plasma-assisted surface treatment, modification and diagnostic, such as the use of ion beams during the growth of thin films that influences microscopic properties and the sputtering process used in the cleaning of the substrates and the production of metal vapors, where most of these techniques are based on glow discharge. This work focuses on the numerical and experimental study of the main features of the glow discharge in a system composed of a cylindrical quartz chamber containing argon gas, whose length and radius are 20 cm and 2.5 cm, respectively (Figure 1). Said chamber is limited by two copper electrodes whose potential difference varies between 0 V to - 1 kV and the operating pressure range used is from 10 mTorr to 10 Torr as reported in the literature. This discharge is characterized by being independent of time, the generation of secondary electrons that allow the discharge to be self-sustaining, as well as the manifestation of fixed regions, among others. These properties were analyzed numerically using the COMSOL Multiphysics software since it facilitates the coupling of the electrostatic field to the transport equations of both the electrons and the heavy species of the gas. Subsequently, the physical system was built to experimentally determine the significant parameters of the argon plasma, such as the density of electrons and ions, the electronic temperature, and the spatial distribution of the potential; from electrical measurements acquired by a Langmuir probe diagnostic, which allowed theoretical and experimental quantities to be compared. The results presented in this article can be useful to establish a methodology in the design, construction, and characterization of new plasma-based technologies, oriented to the treatment and modification of surfaces.

Keywords:Langmuir probe diagnostic, argon plasma, thin films, Comsol Multiphysics, sputtering process, metal vapors.

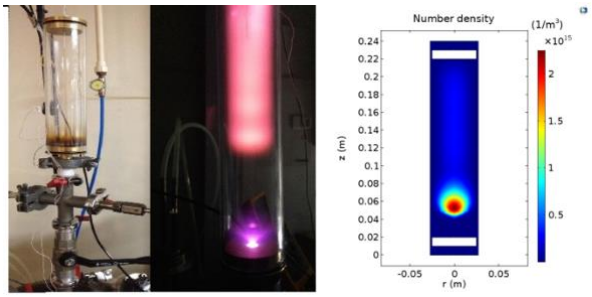


Figure 1: Figure illustrating the spatial distribution of the glowing discharge (argon plasma) obtained experimentally (left) and using COMSOL Multiphysics software to simulate said plasma (right).

Acknowledgements
This work was carried out with the support of the Ministry of Science, Technology and Innovation of Colombia (Minciencias-Colciencias) through agreement No. 80740-535-2020 (project code 1102-852-69674) with the Universidad Industrial de Santander .

References:

1. Pacheco, Y. Q., Barragán, Y. F., Parada-Becerra, F. F., Tsygankov, P. A., & Orozco, E. A. (2019, November). Computational study of a glow discharge device. In *Journal of Physics: Conference Series* (Vol. 1386, No. 1, p. 012122). IOP Publishing.
2. Dervaux, J., Cormier, P. A., Konstantinidis, S., Di Ciuccio, R., Coulembier, O., Dubois, P., & Snyders, R. (2015). Deposition of porous titanium oxide thin films as anode material for dye sensitized solar cells. *Vacuum*, *114*, 213-220.
3. Amini, A., Zakerhamidi, M. S., & Khorram, S. (2021). Changes of the TiO2 thin film electro-optical properties in the Ar and N2 glow discharge plasma due to effects of the electric field in plasma's sheath. *Physica B: Condensed Matter*, *612*, 412820.
4. Liu, H., Jiang, B., & Li, H. (2021). Mechanical properties of TiN films prepared in glow-arc transition region. *Surface Engineering*, *37*(2), 154-159.

Tribological Assessment of SLM Fabricated Biomedical Steel After Pulsed Plasma Processing

V. Efremenko[1,2,*], Yu. Chabak[1,2], I. Petryshynets[2], B. Efremenko[1], A. Lekatou[3], V. Zurnadzhy[1]
[1]Physics Department, Pryazovskyi State Technical University, Mariupol, Ukraine
[2]Institute of Materials Research of Slovak Academy of Science, Kosice, Slovakia
[3]Department of Materials Science and Engineering, University of Ioannina, Ioannina, Greece

Abstract:
The work is focused on the comparative evaluation of tribological and nanoindentation behaviors of 316 stainless steel fabricated by conventional rolling (316T) and selective laser melting (316L) process with further surface pulsed-plasma treatment. The specimens of the steel were used in as-received condition. An electrothermal axial plasma accelerator under a discharge voltage of 4.5 kV and pulse duration of 1 ms was employed for the pulsed-plasma treatment. The research was performed using optical microscopy, scanning electron microscopy, EDX, X-ray diffraction, nanoindentation measurements and tribological tests (according to the "Ball (Al_2O_3)-on-Disc" scheme, under 5 N normal load, in a simulated body fluid (SBF) having the ions concentration (mM/liter): Na^+=145.0, K^+=4.0, Mg^{2+}=1.0, Ca^{2+}=2.5, Cl^-=127.0, HCO^{3-} =24.0) [1].
It was found that SLM-fabricated 316L steel featured an inhomogeneous austenitic structure of a "fish-scale" pattern consisting of columnar and cellular dendrites. Also, SLM samples included Ti-based oxides, TiC carbides, silicate compounds, and pores. Due to the fine cellular structure and residual stresses, SLM-316L steel had nearly double hardness (at almost the same elastic modulus) as compared to the reference rolled 316T steel. The presence of porosity and coarse non-metallic inclusions in the structure resulted in an inferior dry-sliding wear resistance of as-received SLM-316L as compared to the rolled reference. Sliding in simulated body fluid has led to a notable drop in the friction force. Under these conditions, SLM-316L has performed a lower coefficient of friction (CoF) and three-fold higher wear resistance relatively to the plate-316T steel due to higher hardness and formation of oxide films on the surface.
Pulsed-plasma treatment has resulted in modification of the sub-surface layer to the depth of 22-26 μm through the melting (at a heating rate of up to $3.6 \cdot 10^6$ $K \cdot s^{-1}$) followed by crystallization at a cooling rate of up to $1.6 \cdot 10^6$ $K \cdot s^{-1}$ (Figure 1). The modified layer acquired a dense cellular structure with refined cells of 0.3-0.7 μm (in cross-section) diameter normally positioned to the surface. Plasma modification has greatly changed the structure of the rolled sample from a polygonal to a cellular pattern causing an increase in the hardness. With that, the pulsed plasma processing has not affected the hardness of the SLM samples. Moreover, the plasma modification has not influenced the elastic modulus of 316 steel.
The tribological testing has shown that the pulsed plasma modification moderately increased the dry-sliding wear resistance of both SLM-316L (due to the removal of porosity under surface remelting) and rolled 316T (due to hardness increasing). PPT has improved the SBF-wear resistance of plate-316T, however, it decreased the SBF-wear resistance of SLM-316L samples.

Keywords: steel 316L; selective laser melting processing; pulsed-plasma treatment; dry sliding wear; SBF sliding wear; nanoindentation.

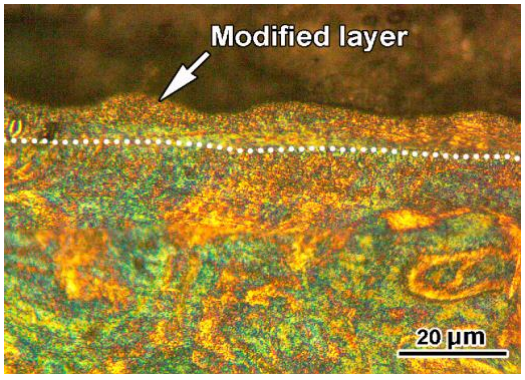


Figure 1: The subsurface layer of SLM sample of 316L after pulsed-plasma modification.

References:

1. Chabak, Y., Efremenko, B., Petryshynets, I., Efremenko, V., Lekatou, A.G., Zurnadzhy, V., Bogomol, I., Fedun, V., Kovaľ, K., Pastukhova, T. (2021) Structural and tribological assessment of biomedical 316 stainless steel subjected to pulsed-plasma surface modification: comparison of LPBF 3D printing and conventional fabrication. *Materials*. 14(24), 7671.

Development of amorphous carbon hard mask with the high etch selectivity by addition of nitrogen for high aspect ratio patterning

S. J. Park[1], K.-C. Shin, D[1]. Kim[1], S. Y. Baek[1], J. Kim[1], J. Park[1], S. Roh[1], S. Kyung[1] and C. Choi[1]

[1] Memory CVD Technology Team, Giheung Hwaseong Complex, Samsung Electronics.

Abstract:

As the feature size of semiconductor devices shrank to sub-100 nm scale, thin hard mask layers with performance beyond conventional polymer photoresists were required. For an etch-resistant hard mask, the material should satisfy requirements such as high etch selectivity, easy ash-off after the etch process, and transparency at visible range. Amorphous carbon layer (ACL) films are widely used as hard mask in semiconductor fabrication industry due to their good properties such as a high etch selectivity compared to silicon based materials (ex. Poly-Si, SiO2, Si3N4), optical transparency and easy stripability in oxygen plasma. Among the properties of ACL film, the dry etch selectivity is one of key factor to determine the critical dimension of the patterns on the wafer in patterning process and the high selectivity of ACL film has continuously been needed for the fabrication of high aspect ratio patterns. Thus it is essential to synthesize the ACL film with high dry etch selectivity without deteriorate any properties of current ACL for Vertical NAND (VNAND) devices [1].

ACL films were deposited using the commertial PE-CVD deposition system. 300 mm-sized Si Wafer was loaded through loadlock system and it was seated on the heater in chamber and then the temperature was kept at 550C during the deposition. Process gases for ACL films were C_3H_6 for carbon source and the inert gases such as Ar and He. N_2 gas was also added for process gas to promotion the selectivity of ACL films.

Figure 1 shows the extinction k variation with the change of N_2 flow rate. It is well known that the etch selectivity of ACL film had linear relations with extinction coefficient, k of film. Thus the selectivity of ACL film could be expected from its k value [2]. As shown in fig. 1, k increased with the N_2 flow rate. The reason for the increase of k with nitrogen could be due to the catalytic graphitization of nitrogen as expected. The carbon graphitization by nitrogen in ACL film was also confirmed by Raman Spectra of nitrogen doped ACL films. From these results, it was confirmed that the addition of nitrogen made a dense ACL film by the formation of carbon hexagonal cluster. And this dense ACL film showed the dyr etch selectivity increased by 10% from the test of etch test using CF_4 plasma. This ACL film with high selectivity was named by the nitrogen doped high selectivity ACL (NHS-ACL). The NHS-ACL was applied to channel-hole process in the VNAND device. Compared to HT-ACL, thickness range of NHS-ACL film was decreased by 50% and size distribution of patterned hole was much uniformed. From these results, NHS-ACL film was successively applied to VNAND fabrication

Keywords: etch hard mask, amorpnous carbon, ntrogen addition, dy etch selectivity, graphitization, VNAND memory device.

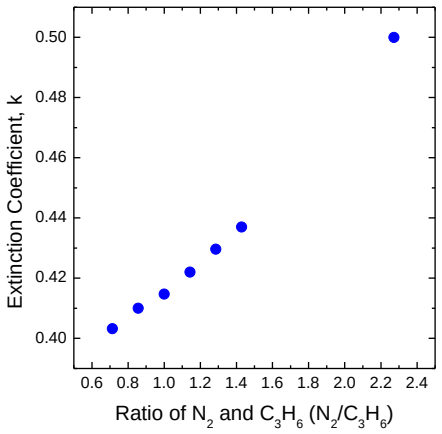


Figure 1: The Change of extinction coefficient, k with the change of the flow rate ratio of N_2 and C_3H_6.

References:

1. Park, S.J., Kim, D., Lee, S., Ha Y., Lim, M., Kim, K., (2018) Diamond-like amorphous carbon layer film by an inductively coupled plasma system for next generation etching hard mask. Thin Solid Films, 661, 21-24.
2. Padhi, D., Kim, B.H., Witty, (2009) D. Dry etch selectivity of a-C:H hardmasks for sub-65nm patterning applications. *J. Vac. Sci. Techol. B*, **27**, 1809-1812.

Microwave Cold Atmospheric Pressure Plasma for Surface Preparation in Aerospace Composite Bonding

K. Papangelis [1], A. Bennett [2], A. Prasad [2], Z. Huang [2], D. Ayre [2]
[1] ADTEC Europe LTD, London, UK
[2] Cranfield University, School of Aerospace, Transport and Manufacturing Cranfield, UK

Abstract:
The aerospace industry is seeking lighter and more fuel-efficient aircraft to reduce carbon emissions, and fibre-reinforced composite materials offer a solution to achieve this aim. Adhesive bonding has become a popular joining technique, eliminating the drawbacks of traditional methods and allowing for a stronger joint. Surface preparation modifies the surface morphology of the composite adherend, this has an impact on the interaction between the adhesive and the adherend. The use of adhesively bonded composite structures offers numerous benefits, but inadequate bonding processes have caused multiple failures in the past few decades, hindering their use in air- craft manufacturing. Therefore, mechanical fasteners are also used as redundancy. The strength and durability of a bonded joint depend on the adherend surface, which needs to be free from contaminants such as dust and grease. While cleaning the adherend can obtain a clean bond surface, employing surface preparation techniques that modify the surface energy, chemical composition, and roughness can significantly im- prove bond strength. The resulting improved wettability of the bond surface, results in a more intimate bond between the adhesive and the adherend hence creating a stronger joint.

Surface treatments play a crucial role in creating a stronger bond by increasing the roughness and surface energy of the composite adherend, but the varying effects of different surface preparation methods need to be characterised and ranked based on joint strength.

The work in this paper the effects of the most used sur- face treatment techniques on a Carbon Fibre Reinforced Polymer Composite (CFC) material.

For this study, the Microwave Atmospheric Pressure Plasma device PlasmaTact 50W from ADTEC Europe LTD was used. The preparation techniques that will be discussed are:

1. Solvent Cleaning
2. Sanding Treatment
3. Plasma Treatment

The degree of Bonding Improvement after each technique will be studied based on the following key indicators:

1. Contact Angle
2. Surface Energy
3. Surface Roughness
4. Lap Shear Failure Load

Keywords: Cold Plasma, Atmospheric Pressure Plasma, Surface Modification, Aerospace Composites, CFC, Microwave Plasma, Lap Shear Strength

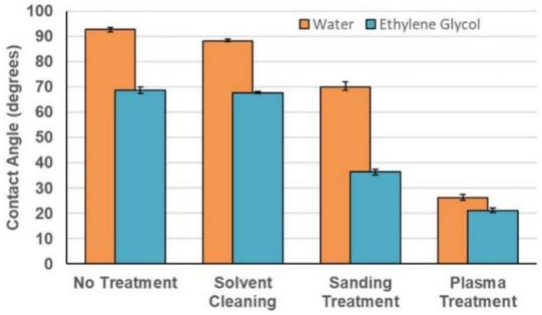


Figure 1: Figure illustrating the results from comparative testing of Contact Angle for different Surface Treatment Techniques.

References:

1. V. H. Martínez-Landeros, S. Y. Vargas-Islas, C. E. Cruz-González, S. Barrera, K. Mourtazov, and R. Ramírez-Bon, "Studies on the influence of surface treatment type, in the effectiveness of structural adhesive bonding, for carbon fiber reinforced composites," J Manuf Process, vol. 39, pp. 160–166, Mar. 2019
2. R. Slayton and G. Spinardi, "Radical innovation in scaling up: Boeing's Dreamliner and the challenge of sociotechnical transitions," Technovation, vol. 47, pp. 47–58, Jan. 2016
3. S. Omairey, N. Jayasree, and M. Kazilas, "Defects and uncertainties of adhesively bonded composite joints," SN Applied Sciences, vol. 3, no. 9. Springer Nature, Sep. 01, 2021

Low Temperature Atmospheric Pressure Plasma Treatment for Mould Inactivation on Building Materials

M. Domonkos [1,*], J. Jirešová[2], E. Lokajová[2], P. Tichá [1]
[1] Department of Physics, Faculty of Civil Engineering, Czech Technical University in Prague, Prague, Czech Republic
[2] Department of Physics and Measurements, University of Chemistry and Technology Prague, Prague, Czech Republic

Abstract:
Moulds are ubiquitous microorganisms capable of rapid growth in favourable environments. Building materials that are damp or water-damaged are highly susceptible to mould growth, which can have adverse effects on both occupants and buildings. The most crucial factors that influence mould colonisation are relative humidity, temperature, nutrients, the type of mould species, and the microstructure of the material. Recently, it has been demonstrated that a low temperature atmospheric pressure (LTAP) plasma can inactivate a wide range of microorganisms by generating reactive species that are lethal to cells.
In this study, samples of autoclaved building materials (such as autoclaved plasterboard, fiberboard and oriented strand board) were placed on an agar plate, and artificially inoculated with Aspergillus brasiliensis spores. They were incubated for 2 – 4 weeks. During various phases of mould growth, the samples were exposed to plasma generated by diffuse coplanar surface barrier discharge in ambient air. The surface area affected by the moulds was evaluated by image analysis (Figure 1), which is a fast and nondestructive method to detect moulds on the samples. Digital images taken at regular intervals during the incubation period were analysed using various methodologies depending on the type of mould and building material. The results indicate that LTAP plasma treatment during the germination phase inhibited mould growth, and plasma treatment during the hyphal phase resulted in a noticeable delay in mould growth.
LTAPP plasma treatment appears to be a promising and environmentally friendly method for the efficient control of fungal/mould pathogens that infect various materials. It offers several potential applications in a diverse range of industries, including food, agriculture, textile, electronics, and medicine (1, 2).

Keywords: mould growth, low temperature atmospheric pressure plasma, mould inactivation, building materials, image analysis

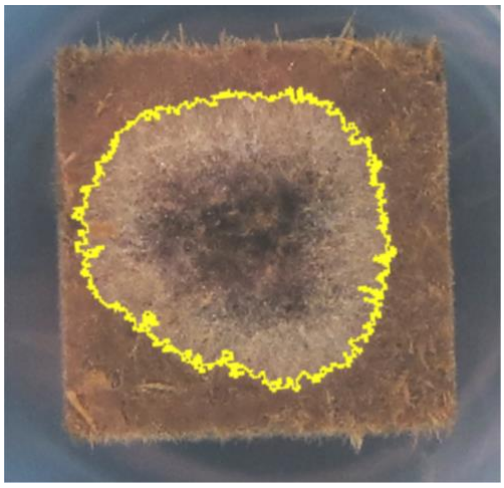


Figure 1: Representative image of mould-covered fibreboard (edges detected using image analysis).

References:

1. M. Domonkos and P. Ticha, "Low-Temperature Atmospheric Pressure Plasma Treatment in the Polymer and Textile Industry," *IEEE Trans. Plasma Sci.*, pp. 1–11, 2023.
2. M. Domonkos, P. Tichá, J. Trejbal, and P. Demo, "Applications of cold atmospheric pressure plasma technology in medicine, agriculture and food industry," *Appl. Sci.*, vol. 11, no. 11, p. 4809, 2021.

Cleaning injection moulds through laser technology

R. Santos[1], I. Marcelino[2], T. Ferreira[2], L. Pereira[3], F. M. Costa[1], N. M. Ferreira[1]
[1] i3N & Physics Department, University of Aveiro, Aveiro, Portugal
[2] IPN – Instituto Pedro Nunes, Coimbra, Portugal
[3]MicroPlásticos S.A., Figueira da Foz, Portugal
*corresponding author e-mail: nmferreira@ua.pt

Abstract:
The automotive industry has enormous quality control tests for the pieces manufactured. With the continuous injection process is expected the residues agglomeration on the mould's surface, compromising the pieces' dimensions, which will fail on the dimensional control tests. To prevent this the mould's surface must be regularly cleaned. Laser technology is already used in other industries for mould cleaning, for example, the use of CO_2 laser type to clean injection mould's from the glass and elastomers industries. The major challenge for the laser mould's cleaning is when the residues and the mould's surface absorb similar laser irradiation. However, with the laser parameters optimization, it's possible to increase the selectivity of the laser radiation towards the residue ablation, where the laser will promote the removal of the residues without damaging the mould's surface. The present work, study the implementation of a fiber laser to clean the injection moulds. The influence of the coating type on the residues' removal by laser radiation was also characterized in this study. Different coatings interact differently with the residues and with laser irradiation, so is necessary to optimize the laser parameters for each coating type. The removal of residues on different coatings as Diamon like carbon DLC and Chromium nitride (CrN), were studies.

Keywords: Fiber laser, mould cleaning; injection moulds, Diamon like carbon; Chromium nitride

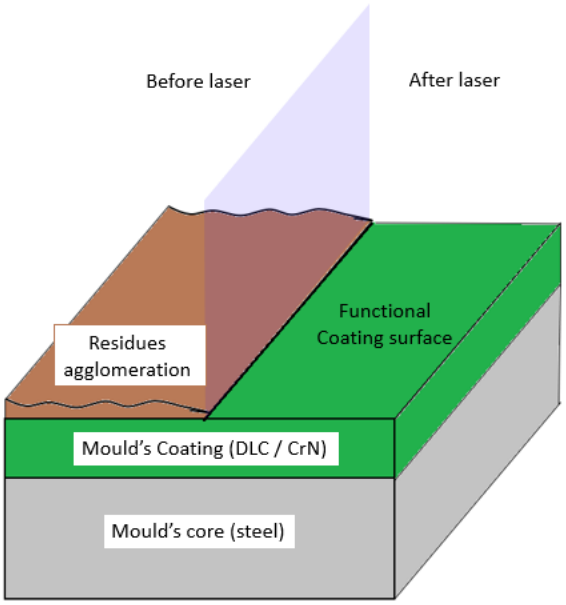


Figure 1: Figure illustrating the residue removal selectivity through laser irradiation, from an injection mould.

References:

1. https://www.p-laser.com/glass-mould-cleaning
2. https://cleanmould.web.ua.pt/wp
3. D. Höche, J. Kaspar, P. Schaaf, Laser Surface Engineering. Elsevier, 2015.
4. https://www.ctborracha.com/limpeza-

Modeling of the focusing system of an ion beam with the plasma lens

Y Q Pacheco [1*], Y F Barragan[1],F F Prada[1],P A Tsygankov [1]
[1] Escuela de fiscia,University industrial of Santander, Bucarmanga, Colombia.

Abstract:
The flow of ions in a specific direction is called an "ion beam" The following characteristics are used to describe the parameters of an ion beam: direction of travel (average velocity vector), the current density of the beam, the energy of the ions, and the distribution function of ions concerning energy, perveance of the beam, and the degree of beam ion charge compensation [1]. The ion beam has wide applications in the industry; Ion engines, systems to activate media and surfaces, pulverizing surfaces to obtain thin films, form nanometer-scale surface structures, and surface diagnostic systems [2,3]. Of all the possible applications, we focus on a beam focused on a small point. The system is called FIB (focusing ion beam). As the beam is a directed movement of charged particles, the path of the ions in the beam can be controlled with an external electric or magnetic field or their combination [4-6]. Up to now, electrostatic or magnetic lenses have mainly been used to focus the beam. It is evident that the focus of the ion beam in these lenses is limited by the maximum value of perveance (space charge) and is affected by the Coulomb repulsion of charged particles at high densities [6]. In this work, the performance of plasma lenses by analytical and computational methods, using the computational model that matches the analytical results guarantees, finding optimal values for the focusing of ion beams, with energy in the range of 400 eV-1000 eV, with focal lengths of 10cm, it is possible to focus an ion beam by applying the potential less than 1000V(Fig.1). The work developed allows the use of this computational model for future research.

Keywords: ion beam, plasma lenses, focus.

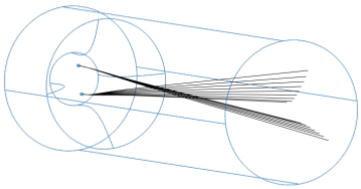


Figure 1: Model of the trajectory of some ions, subjected under a virtual electrode that focuses it.

References:

1. Morozov, A. I. (1966). Motion of charged particles in electromagnetic fields. Review of Plasma Physics, 2, 206-210.
2. Forrester, A. T. (1988). Large ion beams: fundamentals of generation and propagation.
3. Tamm, I. E. (1979). Fundamentals of the Theory of Electricity.
4. Morozov, A. I., Artyushkov, E. V., Solov'ev, L. S., & Shubin, A. P. (1967). Some properties of the flow of a conducting gas in a magnetic field. *Low-Temperature Plasma [in Russian], Mir*.
5. Protsenko, I., Goncharov, A., Gorshkov, V., Gubarev, S., Litovko, I., & Brown, I. (2002, July). Focusing properties of a permanent magnet plasma lens. In *20th International Symposium on Discharges and Electrical Insulation in Vacuum* (pp. 287-290). IEEE.
6. VV Zhukov, AI Morozov, and G Ya Shchepkin. Experimental study of plasma focusing of ion beams. Technical report,

Solar furnace synthesis of persistent luminescent strontium aluminate ceramic with improved luminescent properties

V. Vitola [1*], I. Bite [1]
[1] Institute of Solid State Physics, University of Latvia

Abstract:
We present persistent luminescent material SrAl2O4: Eu, Dy ceramic synthesis by PROMES-CNRS solar facilities, where a very high flux solar furnaces, capable of producing very high temperatures (over 3000°C) locally were used to create plasma on the surface of a before-prepared material pellet. Two kinds of samples of persistent strontium aluminate phosphor are compared – ones synthesised in the solar furnace and ones via conventional solid state synthesis. The optical and structural properties and phase composition of the obtained samples have been compared. The behaviour of afterglow, thermally stimulated luminescence, excitation and emission spectra are presented.with potential optical applications. It is shown that this method of synthesis yields improved optical properties if compared to the conventionally synthesized material – prolonged afterglow, more intensive emission.

Keywords: solar furnace, plasma-assisted synthesis, persistent luminescence

Figure 1: Plasma on the surface of the pellet undergoing the synthesis process

Crystallographic quality and surface morphology of V_2O_3 thin films deposited on annealed sapphire surfaces

Unnar. B. Arnalds and K. Ignatova
Science Institute, University of Iceland, Reykjavik, Iceland

Abstract:
Vanadium sesquioxide (V_2O_3) is a transition metal oxide that undergoes a structural phase transition at ~150 K from a low temperature isulating phase to a high temperature metallic phase. The temperature at which the transition occurs and its magnitude depend strongly on the fabrication conditions, including the sputtering power, oxygen partial pressure, substrate temperature as well as the choice of substrate. Through careful tuning of these parameters and substrate selection highly crystalline and atomically flat films can be obtained with a strong metal insulator transition [1, 2]. Several recent works have investigated the use of V_2O_3 in hybrid heterostructures, including with magnetic layers. In these cases the transition occuring in the material changes the properties of the magnetic material, e.g. creating a coercivity enhancement or inducing an exchange bias [4].

An interesting aspect of V_2O_3 film growth on c-plane sapphire is the formation of a fully strained interface layer with in-plane lattice parameters matching the substrate and extending up to 4 nm into the film. Above this, the film relaxes and the V_2O_3 settles into lattice parameters corresponding more closely to bulk values [3]. These results illustrate how the substrate selection affects the formation of the film and its structural, and therefore metal-insulator transition, properties.

To investigate the role of the substrate on the crystallographic nature of the films we performed a structural investigation of V_2O_3 films deposited at 600°C using reactive dc-magnetron sputtering on sapphire substrates with different surface orientations and annealed at different temperatures in air before deposition. The results reveal that the substrate surface treatment through annealing affects the crystallographic properties of the films strongly creating yet another means of controlling the structural phase transition in the metal and its effect on overlying materials in hybrid heterostructures.

Keywords: V_2O_3, x-ray diffraction, crystallography, phase transitions, thermal annealing, thin films, atomic force microscopy, interface quality.

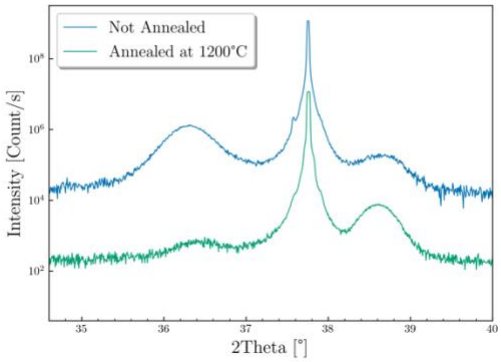


Figure 1: Comparison of x-ray diffraction data recorded for ~47 nm thick V_2O_3 films deposited at 600°C on annealed and not-annealed a-plane sapphire substrates. A preference for a-plane orientation is observed for the film grown on the not-annealed substrate (peak at ~36.3°) while a preference for c-plane orientation (peak at ~38.7°) is observed for the annealed substrate.

References:

1. E.B. Thorsteinsson, S. Shayestehaminzadeh, A.S. Ingason, F. Magnus, and U.B. Arnalds. Controlling metal–insulator transitions in reactively sputtered vanadium sesquioxide thin films through structure and stoichiometry. *Scientific Reports* **11**, 6273 (2021).
2. E.B. Thorsteinsson, S. Shayestehaminzadeh, and U.B. Arnalds. Tuning metal-insulator transitions in epitaxial V_2O_3 thin films. *Applied Physics Letters* 112, 161902 (2018).
3. H. Hajihoseini, E.B. Thorsteinsson, V.V. Sigurjonsdottir, and U.B. Arnalds. Strained interface layer contributions to the structural and electronic properties of epitaxial V_2O_3 films. *Applied Physics Letters* **118**, 161602 (2021).
4. K. Ignatova, E.B. Thorsteinsson, N. Strandqvist, C. Vantaraki, V. Kapaklis, A. Devishvili, G.K. Pálsson, U.B. Arnalds. Reversible exchange bias in epitaxial V_2O_3/Ni hybrid magnetic heterostructures. *Journal of Physics: Condensed matter* **34**, 495001 (2022).

Bio-degradation of Mechanical and Structural Materials Subjected to Mine Water Affected Environments.

A.M. Sarmiento [1*], J.M. Dávila [1], F. Macías [2], F. Córdoba [3], J.C. Fortes[1], J.A. Grande[1]
[1] Department of Mining, Mechanical, Energy and Construction Engineering, University of Huelva, Huelva, Spain
[1] Department of Earth Science, University of Huelva, Huelva, Spain
[1] Department of Environmental Biology and Public Health, University of Huelva, Huelva, Spain

Abstract:
Iron sulfide mining generates a highly acidic and oxidizing leachate, with a high concentration of sulfates, dissolved metals and the presence of microorganisms, called acid mine drainage (AMD). In the Iberian Pyritic Belt (FPI, southwest Spain), this problem is aggravated by the more than 4,800 ha. occupied by mining waste and facilities scattered throughout the area without preventive or corrective measures for pollution. Among the usual materials used in mechanisms and structures, steel has been the most widely used due to its versatility and adaptation to all types of buildings and machinery, and less frequently stainless steel and aluminum. Metallic materials and structural concretes suffer degradation processes that are strongly accelerated in aggressive acid and saline environments with negative consequences for their integrity and durability.

The activity of extremophilic microorganisms (e.g. bacteria of the Acidithiobacillus ferrooxidans type) in AMD environments considerably increases the degradation rate of these materials. A major problem for mining companies exploiting polymetallic sulfides is the corrosion they suffer due to the very low pH of water, machinery, tools and installations, especially in the mineralurgical plants built with the different types of steels and aluminum required to meet the inherent needs of the project in the exploitation phases and in the mechanical treatment of the minerals. On the other hand, to control the AMD generated, concrete and steel structures are used as basic materials for the construction of acid water and leachate collection ponds. Likewise, for the lining and fortification of slopes, in both indoor and outdoor mining, the use of shotcrete, which is highly affected by contact with acidic waters, is increasingly common. Concrete is also present in the bedplates of fixed machinery, as well as in the buildings of the mining operations themselves.

The main objective of this work is to study the effect of acid mine water on the concrete/AMD and metal/AMD interfaces, to determine the oxidation rates and to evaluate the degradation potential of the microorganisms present in acid mine leachates. For this purpose, the chemical and mineralogical characteristics of the elements resulting from the alteration of mass concrete and carbon steel plates in a medium contaminated by DAM in the absence and presence of microorganisms have been studied.

It is observed that the corrosion rate increases in an acid medium but is much higher in a medium with high Fe(III) concentration. Studies using JEOL JSM-IT500HR Field Emission Scanning Electron Microscope coupled with Oxford X-Max 150 Energy Dispersive System (FESEM-EDS) show microorganisms with the appearance of fungal hyphae (Figure 1), also abundant in heavy metal contaminated media (Brett, et al., 2004; Ezzouhri et al., 2009; Böhmer et al., 2020), and they seem to grow occupying or creating cracks, thus aiding the disintegration of the concrete. These microorganisms are yet to be characterized, however it is known how some fungi secrete organic acids releasing potassium, calcium and magnesium ions from the mineral, simultaneously excavating the tunnel and releasing these elements for absorption. With respect to carbon steel, large craters produced by pitting corrosion are observed (Figure 2), only present in steel in contact with water with high Fe(III) concentrations. In addition, inside the holes present, colonies of bacteria of the genus bacillus are observed (Figure 2), very abundant in acid mine drainage such as acidithiobacillus ferrooxidans (Schrenk, et al., 1998).

It is therefore important to evaluate the power of extremophile microorganisms, very abundant in mining environments, on the degradation of these materials.

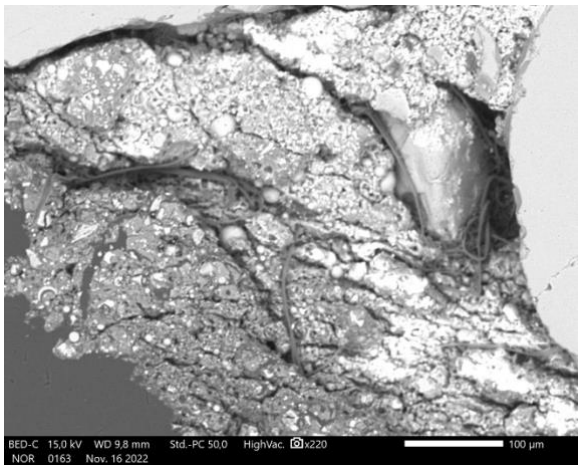


Figure 1: Field Emission Scanning Electron Microscope photo showing microorganisms between cracks in mass concrete affected by acid mine drainage.

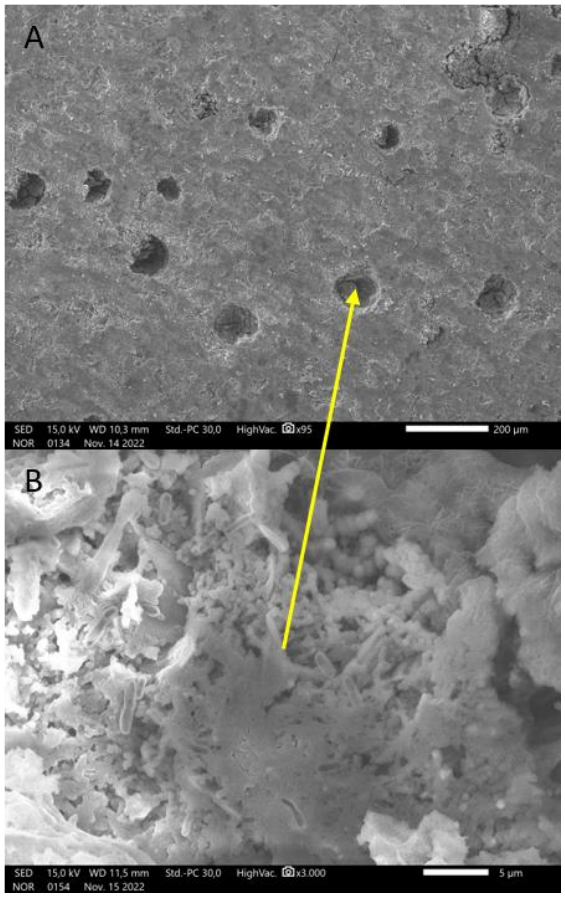


Figure 2: Field Emission Scanning Electron Microscope photo showing photo showing pitting corrosion on carbon steel affected by acid mine drainage, and bacterial community inside the holes.

Keywords: concrete degradation, steel corrosion, acid mine drainage, Scanning Electron Microscope, corrosion rate.

References:

1. Brett, J., Lutz, M., Dawson, S., Bond, P., Bandield, J. (2004) Metabolically Active Eukaryotic Communities in Extremely Acidic Mine Drainage, *Appl. Environ. Microbiol.*, 70, 6264-6271.
2. Ezzourhri, L., Castro, E., Moya, M., Espinola, F., Lairini, K. (2009) Heavy metal to erance of filamentous fungi isolated from polluted sites in Tangier, Morocco, *Afr. J. microbiol. Res.*, 3, 35-48.
3. Böhmer, M., Ozdín, D., Racko, M., Lichvar, M., Budis, J., Szemes, T. (2020) Identification of Bacterial and Fungal Communities in the Roots of Orchids and Surrounding Soil in Heavy Metal Contaminated Area of Mining Heaps, *Appl. Sci.*, 10, 2-18.
4. Schrenk, M., Edwards, K., Goodman, R., Hamers, R., Banfield, J. (1998) Distribution of Thiobacillus ferrooxidans and Leptospirillum ferrooxidans: Implications for Generation of Acid Mine Drainage, *Science*, 6, 1519-1522.

Extrem Reduction of Tensile Concrete Strength Subjected to Mine Water Affected Environments.

J.M. Dávila[1*], A.M. Sarmiento[1], M. santisteban[1], A.T. Luís[1], J.A. Grande[1]
[1]Department of Mining, Mechanical, Energy and Construction Engineering,University of Huelva, Huelva,Spain

Abstract:
Acid mine drainage problem is widespread throughout the world, fundamentally affecting pyrites and coal exploitations. In generating structures (such as pits or tailings) highly acid effluents are produced with high heavy metal and sulfate content.

Despite the fact that there is a large number of scientific publications that have addressed this problem, there are not many works that have analysed how this highly aggressive and polluting medium affects structural materials such as steel and concrete. Some precedents have studied the behavior of concrete in an acid environment, analysing how it affects the compressive strength of concrete (Davila et al, 2021; Pater et al, 2017), but there are no known studies on the tensile strength of this material.

Although it is clear that the main mechanical parameter of concrete is its compressive strength, it should not be forgotten that in some structural elements subjected to shear, pucncture or torsion, the tensile strength of the concrete is taken into account when determining the required reinforcement section. Therefore, we understand that it is important to study how this type of aggressive media affects tensile strength.

To carry out this research, several samples of mass concrete have been subjected to acid water extracted from the Aguas Agrias Stream, located in the Iberian Pyrite Belt. This water had an initial pH value of 2.8 and a sulphate content that reached 13301 mg/L, also knowing other physical-chemical parameters from previous studies. With these values, the aggressive environment corresponds to the maximum defined in the current regulations (Structural Code, 2021).

To determine the concrete tensile strength, the specimens were subjected to destructive tensile tests until failure was reached.

The samples were grouped into two series that were exposed for 3 months, the first one, and the second one until completing 6 months, reaching a reduction in tensile strength of 24% for this last period of time. This is due to the loss of the cement mass in the external zone of the concrete.

Keywords: concrete degradation, tensile strength, acid mine drainage, sulphates, gypsum.

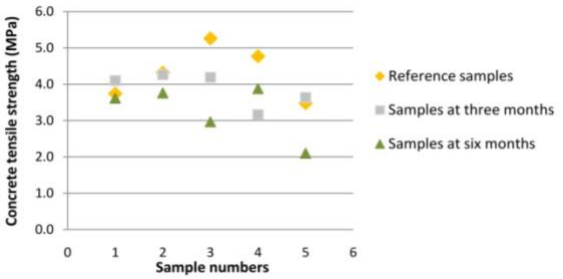


Figure 1: Concrete tensile strength results determined by destructive tests.

References:

1. Davila J.M., Sarmiento A.M., Fortes J.C., Santisteban M., Leiva M., Cordoba F., Cabello J.E., Grande J.A., (2021). Determination of the extreme reduction of concrete strength due to acid mine drainage by laboratory tests on specimens located in a real environment. Construction and Bulding Materials 269, 1-10, https://doi.org/10.1016/j.conbuildmat.2020.121817
2. Patel V., Shah N. 2017. Durability Study of M70 Grade Structural Concrete. Iranian Journal of Science and Technology, Transactions of Civil Engineering, 41, 241-248, https://doi.org/10.1007/s40996-016-0046-8
3. Código Estructural 2021. BOE núm. 190, de 10 de agosto de 2021. Ministerio de la Presidencia, Relaciones con las Cortes y Memoria Democrática. España.

Development of Transparent, Scratch Resistant, and Hydrophobic Coatings for Aerospace Transparencies

A. Kuban [1,2,3*], Y. Okumus [2,3], N. Erdogan [2,3], B. Baytekin [3,4], H. Y. Ersan [1]
[1] Chemical Engineering Department, Hacettepe University, Ankara, Turkey
[2] Functional Coatings & Transparencies Technology Center, Turkish Aerospace, Ankara, Turkey
[3] National Nanotechnology Research Center (UNAM), Bilkent University, Ankara, Turkey
[4] Chemistry Department, Bilkent University, Ankara, Turkey

Abstract:
Polycarbonate is a material widely utilized in aviation applications, particularly for windshields and canopies. However, it has low scratch resistance, which hampers the long-time use of the material. Here we show a coating method to increase the scratch resistance of polycarbonate used in aerospace applications. The method aims to retain the high optical transmittance of the material[1], which is an indispensable requirement of the applications.
Transparent organic-inorganic siloxane coatings stand out as a solution to improve the scratch resistance of polycarbonate. These coatings are a combination of organic and inorganic compounds that form a strong and durable film on the surface of the polycarbonate sheet[2]. The addition of nanoparticles can further increase the scratch resistance[3].
In this study, the coating solution was prepared with different ratios between tetraethoxysilane (TEOS) and 3-glycidoxypropyl trimethoxysilane (GPTMS), and coated on polycarbonate sheets with spin coating. Also, AminoPOSS particles were used as a filler that reinforced the coating and increased its scratch resistance. Furthermore, the ring-opening reaction between epoxy groups in the siloxane matrix and amino groups on POSS formed a three-dimensional crosslinked network that improves the hardness, toughness, and scratch resistance. The pencil hardness value of polycarbonate was increased from HB to 4H through the implementation of organic/inorganic siloxane coatings. Due to C12 functional groups of the AminoPOSS, the contact angle of the coatings increased from 65.7° to 117°. The samples were still transparent after coating, the optical transmittance loss of the coated samples were lower than 1% at 400nm – 700nm range.
The result of this study can be used to develop transparent and scratch-resistant coatings for the automotive, aerospace, and electronics industries.

Keywords: scratch-resistance, siloxane, transparent, hydrophobic, sol-gel coating, polycarbonate.

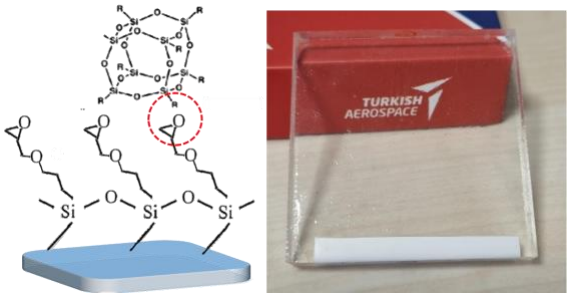


Figure 1: Representation of the epoxy–amine ring-opening reaction to obtain siloxane network (top) Transparent organic-inorganic siloxane coatings on polycarbonate sheet (bottom).

References:

1. Hwang, D. K., Moon, J. H., Shul, Y. G., Jung, K. T., Kim, D. H., & Lee, D. W. (2003). Scratch resistant and transparent UV-protective coating on polycarbonate. *Journal of Sol-Gel Science and Technology*, 26(1-3), 783-787.
2. Sanchez, C., Julián, B., Belleville, P., & Popall, M. (2005). Applications of hybrid organic–inorganic nanocomposites. *Journal of Materials Chemistry*, 15(35-36), 3559-3592.
3. Li, Y., Zhang, L., & Li, C. (2020). Highly transparent and scratch resistant polysiloxane coatings containing silica nanoparticles. Journal of colloid and interface science, 559, 273-281.

Acknowledgement:

This work was partially supported by Scientific and Technological Research Council of Turkey (TUBITAK) under contract numbers of 5189901 and 20AG001. The authors are thankful for the collaboration between Turkish Aerospace and Bilkent University – UNAM.

Effect of curring methods on the abrasive and corrosion wear resistance of organic coating systems

I. Stojanović , I. Juraga , M. Kurtela , M. Logar , I. Fatović
Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia

Abstract:
Nowadays, corrosive destruction of metal machine parts occurs easily, due to increased corrosiveness of the environment as a consequence of increased pollution of water, soil and air. Organic coatings are often used to protect the surface from harsh external factors. Except for the purpose of improving corrosion resistance of metal parts, coatings are used for aesthetic purposes, reduction of mechanical wear, such as due to abrasion and erosion, etc. In order for the coatings not to wear out too quickly, they must be durable. Coating systems based on epoxy and polyurethane are often used, because they create durable, high-quality surfaces that are resistant to wear and tear. With the aim of reducing negative impact on the environment and drying time, IR (infrared) technology can be used for drying the coatings. In order to simulate the effects of atmospheric corrosion on metal machine parts, testing chambers, such as humidity chamber (simulates an atmosphere of warm air saturated with moisture in the presence of condensed water) and salt spray chamber (simulates a marine atmosphere using dispersed droplets of NaCl solution) are used.
In this paper, solvent-borne 3-layer coating systems from different manufacturers, with and without Zinc in the primer, dried by catalytic IR technology and under atmospheric conditions were studied. Abrasion, hardness and adhesion tests were performed. Anticorrosion performance of the coatings was characterized using a humidity chamber. The results show that IR-dried coating systems display higher abrasion resistance. The accelerated corrosion test in humidity chamber showed better or equal properties of IR-dried coatings compared to atmospherically dried ones, while reducing drying time considerably.

Keywords: coating systems, abrasion, coating hardness, coating resistance, IR drying

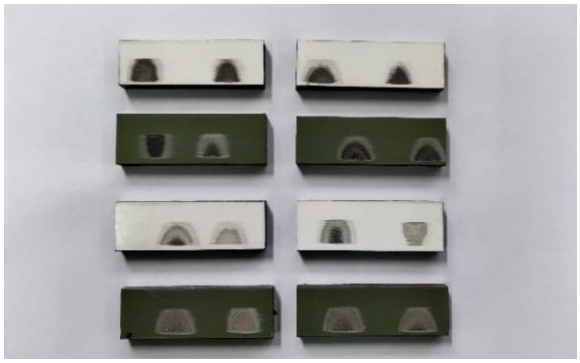


Figure 1: Samples after abrasion test

References:

1. Levy A.V. (1988). The Erosion-Corosion Behavior of Protec-tive Coatings. Surface and Coatings Technology 36 (1988), pp. 387 – 406.
2. Alqallaf J., Ali N., Amaral Teixeira J., Addali A. (2020). Solid Par-ticle Erosion Behaviour and Protective Coatings for Gas Turbine Compressor Blades-A Review. Processes 8, 984.
3. Wood R.J.K. (1999). The sand erosion performance of coating. Materials and Design 20, pp. 179 – 191, Elsevier.
4. Malaki M., Hashemzadeh Y., Fadaei Tehrania A. (2018). Abrasion resistance of acrylic polyurethane coatings reinforced by nano-silica. Progress in Organic Coatings 125, pp. 507–515, Elsvier.
5. Zhang S.W., Renyang He, Deguo W., Qiyun F. (2001). Abrasive erosion of polyurethane. Journal of Materials Science 36, pp. 5037 – 5043, Kluwer Academic Publishers.
6. Stojanović I., Cindrić I., Janković L., Šimunović V., Franjić H. (2022). Performance Assessment of Differently Dried Coating Systems for Potential Application in the Power Transformer Industry // Coatings, 12 (2022), 3; 1-17 doi:10.3390/coatings12030331
7. Cindrić I., Janković L., Stojanović I., Juraga I., Mezdić D., Franjić H. (2022). Abrasion and Erosion Properties of IR Dried Samples Zavarivanje, 64 (2022), 5/6; 173-179

Effect of Nano Particles on Mechanical and Thermal Properties of Polyurethane Based Transparent Coatings

Y.Okumuş [1,*], A. Kuban[1], S. Ağar[1], N. Erdoğan[1]
[1] Functional Coatings and Transparencies Technology Center, Turkish Aerospace Industries Inc., Ankara, Turkey

Abstract:
Polycarbonate is widely used in aerospace applications, especially canopies and windshields. However, due to the low scratch resistance of polycarbonate, coatings with improved scratch resistance and high optical permeability are needed to be applied to the surface 1.
The mechanical, electrical and thermal properties of polyurethane-based coatings, which are frequently used on polycarbonate surfaces, can be improved with the minimum loss of optical transmission by inorganic nanoparticles 2. The presence of functional groups on the surface of the reinforced nanoparticles improves the distribution in the matrix material and contributes to the scratch resistance by acting as crosslink points 3-4.
In this study, polyester based polyurethane dispersion (PUD) was used as resin and isocyanate was used as cross-linker. Untreated and surface modified boron nitride nanolayers and nano silica powders were dispersed in polyurethane dispersion at different rates and coating on polycarbonate surfaces by flow coating process. The effects on friction strength, thermal strength and optical transmittance were investigated.

Keywords: Polyurethane coatings, nano silica particles, friction strength

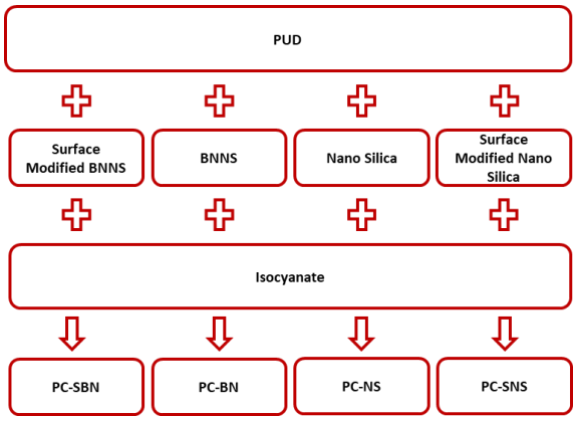


Figure 1: Schematic view of the study.

References:

1. Seubert, C., Nietering, K., Nichols, M., Wykoff, R., Bollin, S. (2012). An overview of the scratch resistance of automotive coatings: Exterior Clearcoats and Polycarbonate hardcoats. Coatings, 2, 221-234.
2. Sanchez, C., Julián, B., Belleville, P., & Popall, M. (2005). Applications of hybrid organic–inorganic nanocomposites. *Journal of Materials Chemistry*, 15(35-36), 3559-3592.
3. Malaki, M., Hashemzadeh, Y., Tehrani, A.F. (2018). Abrasion resistance of acrylic polyurethane coatings by nano-silica. Progress in Organic Coatings, 125, 507-515.
4. Li, J., Gan, L., Liu, Y., Mateti, S., Lei, W., Chen, Y., Yang, J. (2018). Boron nitride nanosheets reinforced waterborne polyurethane coatings for improving corrosion resistance and antifriction properties. European Polymer Journal, 104, 57-63.

Acknowledgement:
This work was partially supported by Scientific and Technological Research Council of Turkey (TUBITAK) under contract numbers of 5189901 and 20AG001. The authors are thank-ful for the collaboration between Turkish Aerospace and Bilkent University – UNAM.

Airborne Contamination Contribution to Nanoscale Friction of Graphene Surfaces

F. Ptak [1,2,*], C. M. Almeida [3] and R. Prioli [2]
[1] Department of Molecular Chemistry and Materials Science, Weizmann Institute of Science, Rehovot, Israel
[2] Departament of Physics, Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil
[3] Materials Metrology Division, INMETRO, Duque de Caxias, Brazil

Abstract:
Graphene have attracted much attention in recent years due to potential technological applications at the nanoscale, including their use as surface coating and solid lubricants at the nanoscale [1]. Due to its hydrophobic nature, when exposed in air, graphene surfaces are subject to airborne contamination, mainly by hydrocarbons [2]. In this work, nanoscale friction forces between an atomic force microscope tip and graphene were measured. Hydrocarbon contamination form different friction domains on the graphene surface without altering its topography. These are formed initially at the edges of the sample surface and at defects. As the tip slides through such domains, the friction is increased in relation to pristine graphene. By mapping the time evolution of friction, the contaminants adsorption rate was determined (Figure 1). Adorption begins at the monolayer and once its fully covered, it spreads to the subsequent layers. Different kinetics for mono and bilayer were observed, as the latter has a rate of contamination one order of magnitude slower than the first. Furthermore, contaminants alter the contact mechanics and elastic deformations of the graphene sheets induced by the tip are suppressed by the presence of adsorbates. Thus, the dependence of friction with the number of layers, mainly governed by out-of-plane elastic deformation, is affected by the presence of contaminants on the surfaces [3].

Keywords: graphene, nanoscale friction, airborne contamination, molecular adsorption, atomic force microscopy

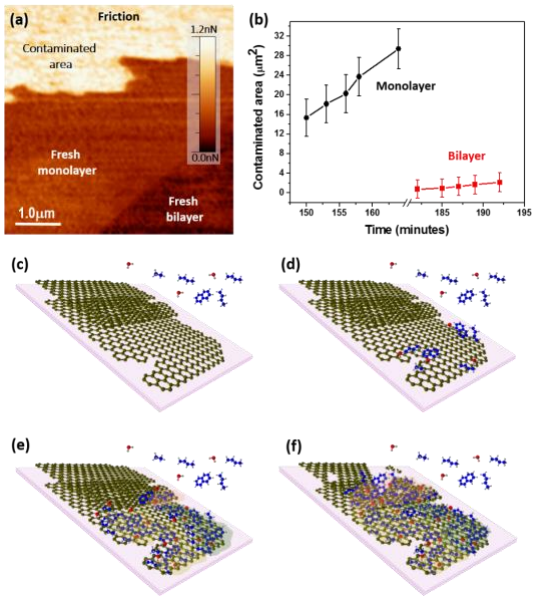


Figure 1: Time evolution of contaminated areas. (a) Friction image showing fresh and contaminated areas in monolayer and bilayer. (b) Total surface area covered by adsorbent molecules on a monolayer and a bilayer graphene as a function of time of air exposure. In (c-f) illustration of contamination taking over the graphene surface at different times of exposure.

References:

1. Berman, D., Erdemir, A., Anirudha, V. S., (2014), Graphene: a new emergent lubricant, *Materials Today*, 17, 31-42.
2. Li, Z. et al. (2013), Effect of airborne contaminants on the wettability of supported graphene and graphite, *Nat. Mater.*, 12, 925-931.
3. Ptak, F., Almeida, C. M., Prioli R. (2023) Observing the initial stages of molecular adsorption in graphene by nanoscale friction. *In preparation.*

Influence of steel and copper fibres in train brake friction materials on airborne wear particle emissions to the environment

Y. Tsybrii[1], I. Zglobicka[2], M. Kuciej[2], O. Nosko[1]
[1] Gdansk University of Technology, Gdansk, Poland
[2] Bialystok University of Technology Bialystok, Poland

Abstract:
Steel and copper fibres are common ingredients in brake friction materials, responsible for improving their mechanical, thermal and tribological properties. Due to the toxicity of copper, there is a global trend to replace copper fibres with copper-free ingredients in order to reduce emissions of copper contained in airborne wear particles. The influence of the steel and copper fibres amount in a train brake friction material in contact with steel on emission intensity and iron and copper content in emitted airborne wear particles was investigated using pin-on-disc tribometer. The friction pair was placed inside a clean chamber under controlled friction and environmental conditions. The addition of steel fibre to the friction material results in a more intensive emission of wear particles, comparing to similar amount of copper fibre. Another finding is that the wear of the steel disc sample is the main source of iron in the emitted 1–10 μm wear particles. The addition of steel and copper fibres into the friction materials leads to an increase of the pin and disc sample wear.

Keywords: train brake material, copper fibre, steel fibre, wear particle emission.

Acknowledgements:
The present work was supported by the National Science Centre, Poland [grant number 2017/27/B/ST8/01249].

References:

1. Oberdörster, G., Maynard, A., Donaldson, K., Castranova, V., et al. (2005), Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy, *Particle and Fibre Toxicology*, 2, 8. https://doi.org/10.1186/1743-8977-2-8
2. Shell, E.R. (2020), The role of air pollution, *Scientific American*, 322, 42–47.
3. Pope, C.A., Burnett, R.T., Thun, M.J., Calle E.E., et al. (2002), Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution, *Journal of the American Medical Association*, 287, 1132–1141.
4. Straffelini, G., Gialanella, S. (2021), Airborne particulate matter from brake systems: an assessment of the relevant tribological formation mechanisms, *Wear*, 478–479, 203883.
5. Leonardi, M., Menapace, C., Matejka, V., Gialanella, S., Straffelini, G. (2018), Pin-on-disc investigation on copper-free friction materials dry sliding against cast iron, *Tribology International*, 119, 73–81.

Cellulose Nanofiber Oleogels: A Target-Oriented Approach towards Environmental Preservation through Sustainable Lubrication

C. Roman [1], M.A. Delgado [1], S.D. Fernández-Silva [1], M. García-Pérez [1], M. García-Morales [1,*]
[1] Departamento de Ingeniería Química, Centro de Investigación en Tecnología de Productos y Procesos Químicos (Pro2TecS), Universidad de Huelva, Huelva, Spain

Abstract:
For the sake of minimizing the negative environmental impact provoked by traditional lubricating greases, oleogels based on elm pulp cellulose nanofibers suspended in castor oil were prepared and characterized. Small nanofiber concentrations, always lower than 2.8 wt.%, were considered. Bleached and unbleached samples of the same elm kraft pulp were used in order to analyze the effect of bleaching on the oleogels' thermo-rheological and tribological behavior. Moreover, with the aim to look into the influence of the nanofibrillation pretreatment, two samples of the same bleached pulp were subjected to either mechanical PFI refining or chemical TEMPO-mediated oxidation. Specific treatments of each pulp/nanofiber are summarized in Table 1. Unlike conventional lubricating greases, for which the so-called plateau modulus, G_N^0, undergoes a dramatic decay upon the grease's pour-point is surpassed [1], no evidence of such a phenomenon was identified up to 180 ºC in our oleogels. At a nanofiber concentration of 1.4 wt.%, the oleogel made up with the unbleached nanofibers was shown to perform better under large shear deformations. Thus, when subjected to a non-linear stress value of 100 Pa for 30 minutes, its complex shear modulus only decreased by 13.3 %, as compared to the dramatic decays found for the bleached-PFI and bleached-TEMPO oleogels, 41.4 % and 95.8 % , respectively (Figure 1). With regard to their tribological behavior, Stribeck curves were determined at normal loads within 10-40 N, at room temperature. The friction curves were remarkably affected by both nanofiber type/concentration and applied normal load. At the highest normal loads, improved lubrication performance on the mixed friction region, with the base oil as reference, was appreciated using the bleached nanocelluloses at the lowest concentration, i.e., 0.7 wt.%. In addition, the oleogel containing 0.7 wt.% of the most shear-sensitive nanofiber, i.e., bleached-TEMPO nanocellulose, yielded a noticeable reduction in the friction coefficient values as the sliding velocity was increased.

Keywords: cellulose, nanofiber, castor oil, sustainability, rheology, tribology, oleogel, grease, lubricant.

Table 1: Pulp and nanofibers treatments

Sample name	Pulp bleaching	Fibrillation pretreatment
Unbleached	Yes	PFI
Bleached-PFI	No	PFI
Bleached-TEMPO	Yes	TEMPO

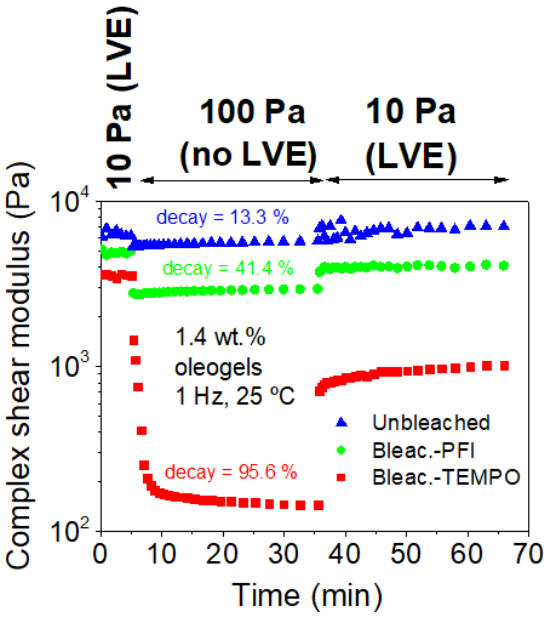


Figure 2: Time evolution of the 1.4 wt.% oleogels' complex shear modulus, |G*|, at 1 Hz and 25 ºC, when subjected to a stress program of 10-100-10 Pa.

References:

1. Delgado, M.A., Valencia, C., Sánchez, M.C., Franco, J.M., Gallegos, C. (2006) Thermorheological behaviour of a lithium lubricating grease, *Tribol. Lett.*, 23, 47-54.

Tribological Properties of Glycol-Based Deep-Eutectic Solvents

C. Del Toro, M.D. Avilés, M.D. Bermúdez and F.J. Carrión-Vilches
Universidad Politécnica de Cartagena. Grupo de Ciencia de Materiales e Ingeniería Metalúrgica.
C/Doctor Fleming sn. 30201 Cartagena Spain

Abstract:
New challenges in the 21st century focus on reducing greenhouse gases and fossil fuels consumption, adapting industrial processes, and mobility towards renewable energy sources, thereby minimizing the carbon dioxide footprint. Green Tribology, a crucial area within Tribology, plays a significant role in these new objectives in relation to new bio-lubricants, coatings, or materials, among others [1]. The developments of green tribology involve reducing the losses of energy due to friction by up to 18% and 40% in the next 8 and 15 years [2].
Demand has increased for more efficient lubricants with low environmental impact and toxicity. Ionic liquids (IL) have demonstrated great potential in lubrication, both as neat lubricants and as additives [3]. A recent advance in the search for new lubricants involves Deep Eutectic Solvents (DES), which share certain unique properties of IL [4].
Deep Eutectic Solvents (DES) consist of a mixture of organic compounds and can be considered a category of IL with growing importance [5]. DES are a liquid mixture of binary ion pairs with no neutral solvent [6]. DES have properties similar to those of IL but are cheaper to produce, less toxic, and often biodegradable and have physical properties which would make them useful as lubricants.
DES are obtained by mixing a hydrogen bond-acceptor salt (HBA) with hydrogen bond donor species (HBD).
Herein, we show the tribological properties of several glycol-based DES using cholin acetate as a hydrogen bond-acceptor salt (HBA), in comparison with neat glycols.
We found that friction coefficients and wear rates in a ceramic-steel contact improved when DES was used as the lubricant under a pin-on-disc configuration, as compared with neat glycols (see Figure 1).
Techniques such as contact angular analysis, Raman spectroscopy, or microscopy were used to evaluate the friction and wear mechanism present in the tribological contact.

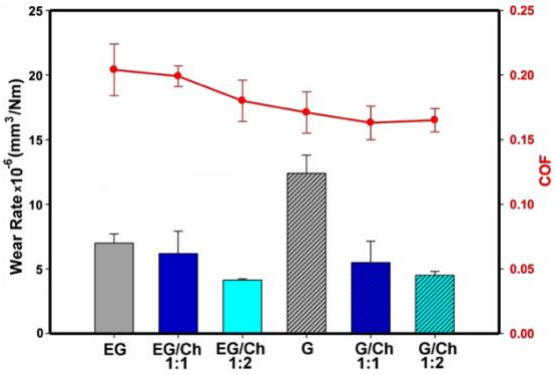


Figure 1. Wear Rate and COF of neat glycols Ethylene Glycol (EG) and Glycerol (G), and DES using Cholin Acetate (Ch) at χ=1:1 and 1:2.

Keywords: DES, green tribology, glycols, lubrication

References:

1. 2020 Report. Emerging Issues and Trends in Tribology and Lubrication Engineering. *Society of Tribologist and Lubrication Engineers May 7, 2020.*
2. K. Holmberg and A. Erdemir. Influence of Tribology on Global Energy Consumption, Costs, and Emissions. *Friction 5(2017)263–284.*
3. A. E. Somers, P. C. Howlett, D. R. MacFarlane and M. Forsyth. A Review of Ionic Liquid Lubricants. *Lubricants, 1(2013) 3–21.*
4. M.T. Donato, R. Colaco, L.C. Branco, B. Saramago. A review on alternative lubricants: Ionic liquids as additives and deep eutectic solvents. J Mol Liq *333(2021)116004.*
5. E.L. Smith, A.P. Abbott, K.S. Ryder. Deep Eutectic Solvents (DESs) and Their Applications. *Chem. Reviews 114(2014)11060.*
6. B. B. Hansen et al. Deep Eutectic Solvents: A Review of Fundamentals and Applications. *Chem. Reviews 121(2021)1232–1285.*

An approach on the potential application of a smart nanoclay-based biolubricant in electrified ball bearings

S.D. Fernández-Silva [1], M. García-Morales [1], C. Roman [1], T. Amann [2], F. Gatti [2], A. Kailer [2], M.A. Delgado [1,*]

[1] Departamento de Ingeniería Química, Centro de Investigación en Tecnología de Productos y Procesos Químicos (Pro2TecS), Universidad de Huelva, Huelva, Spain

[2] Fraunhofer Institute for Mechanics of Materials IWM, MicroTribology Center µTC, Freiburg, Germany

Abstract:

Lubricating oils play a vital role when a reduction in friction and wear is needed. In specific applications and under certain operating conditions, oils might not be sufficiently viscous, so their use might not be a suited option. Formulating lubricating oils with larger hydrocarbon molecules is not the most environmentally friendly option. The increasing use of lubricants worldwide and their uncontrolled disposal into the environment upon their utilization have motivated the replacement of the petroleum-derived feedstocks with more sustainable and non-toxic products such as vegetable oils [1]. However, vegetable oil-based lubricants still show serious technical limitations. Achieving in-situ control of friction is becoming a current challenge in the field of tribology. Even so, only few studies have explored the potential interest of the so-called "electro-viscous" effect in relation with the development of electro-sensitive lubricants [2].

On this basis, homogeneous and storage stable electro-rheological (ER) suspensions of the organomodified clay Montmorillonite Cloisite 15A in castor oil were prepared and analyzed. The main objective of the present research was to study the feasibility of using nanoclay-based ecofriendly lubricants in order to promote an electro-active control of the friction behavior in ball bearings under electric potential.

A NTN 51104 thrust ball bearing (20x35x10 mm), previously customized according to a electrified prototype described in the patent US 2010/0247012 [3], was used.

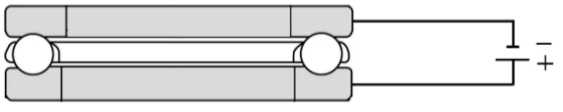


Figure 1: Schematic of an electrified ball bearing device.

Keywords: nanoclay, biolubricant, sustainability, electrorheology, electrotribology, ball bearing.

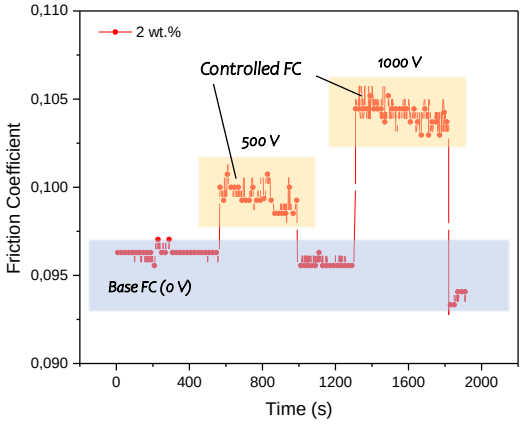


Figure 2: Electro-active control of the friction coefficient (FC) with voltage (0, 500 and 1000 V) for a Cloisite 15A nanoclay concentration of 2 wt.% in an electrified ball bearing apparatus coupled to a MCR501 rheometer (Anton Paar), at room temperature, 5 N and 500 rpm.

As shown in Figure 2, it was feasible to develop the electro-active control of the internal friction behavior in the lubricant film. The friction coefficient increased by 9.5 % when the tension was raised from 0 V to 1000 V. This outcome was attributed to the above mentioned electro-viscous effect under an electric field.

References:

1. J.A. Cecilia, D. Ballesteros, R.M. Alves, F. Murilo, C.L. Cavalcante Jr., E. Rodríguez-Castellón, An overview of the biolubricant production process: challenges and future perspectives, Processes 8 (2020) 257, https://doi.org/10.3390/pr8030257.
2. Peng, J. et al., "Hydrodynamic Characteristics of ER Journal Bearings with External Electric Field Imposed on the Contractive Part", J. Intell. Mater. Syst. Struct. 16, 2005, 493-499
3. R.P. Reitz, G.F. Plangetis, Bearing apparatus featuring electrorheological fluid lubrication. US 2010/0247012, (2010).

Woven fabric abrasion resistance conditioned by weave, weft density and raw material composition

I. Schwarz, S. Brnada, T. Bardov, A. Kalazic
University of Zagreb, Faculty of Textile Technology, Zagreb, Croatia

Abstract:
The woven fabric abrasion resistance is a property conditioned by its structural and constructional characteristics, raw materials and finishing processes. The surface of the fabric is defined by numerous parameters (such as weave, thickness, mass, thread density, yarn parameters and crimp), which directly affect the abrasion resistance properties. Fabric abrasion occurs during material use, as a result of the material rubbing against another surface. This phenomenon causes the degradation of the material in the form of the gradual removal of fibres from the yarn, which ultimately leads to a decrease in fabric strength, as well as aesthetic appearance and functionality.
In order to investigate the influence of weave, thread density and the proportion of individual components of the raw material composition on the fabric abrasion resistance property, fabric samples were produced in 2 different weaves (plain and twill) and with two different weft thread densities (21 and 24 threads/cm). The fabrics were woven with warp thread 50/50% Polyamide 6.6/Cotton, fineness 30.8 tex, and the weft threads, fineness 33.3 tex, with different proportions of individual components of the raw material composition 30/35/35% PA 6.6/Lenzing FR/M-Aramid and 22/38/40% PA 6.6/Lenzing FR/M-Aramid. The abrasion resistance was tested on a Martindale according to the standard HRN EN ISO 12947-2: 2017, at a nominal pressure of 12 kPa.
The influence of weave on fabric abrasion properties is conditioned by different loads in the abrasion process itself. In twill weaves (where larger thread floating are present) during the abrasion process, the threads migrate within the surface and thread-to-thread abrasion occurs (intro-yarn load). Furthermore, the higher the fabric density, the more compact the structure, which results in less thread migration and higher abrasion resistance. Concerning the raw material composition, increasing the proportion of aramid fibre on the fabric surface reduces its abrasion resistance (due to the lower abrasion resistance of aramid yarns). On the contrary, fabric woven in plain weave (due to maximum thread interlacing and minimal floating), has a more compact structure, and threads do not have much freedom for migration, therefore abrasion, i.e. the load of the surface of the abrasive fabric occurs on the sample fabric surface.

Keywords: abrasion resistance, weave, weft density, raw material composition.

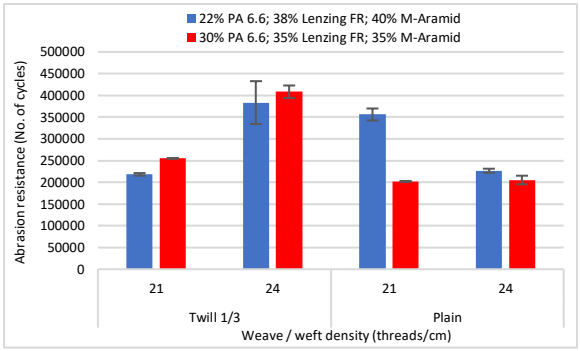


Figure 1: Woven fabric abrasion resistance conditioned by weave, weft density and raw material composition

Acknowledgements: This research has been supported by the European Union from the European Structural and Investment Funds, the Operational Programme Competitiveness and Cohesion, the European Regional Development Fund under the project KK.01.2.1.02.0064.

References:

1. Krstovic, K., Kovacevic, S., Schwarz, I., Brnada, S. (2022) Study of Aramid Yarns Sizing, Polymers, 14, 761. https://doi.org/10.3390/polym14040761
2. Jahan, I. (2017)Effect of fabric structure on the mechanical properties of woven fabrics, Advance Research in Textile Engineering 2, 2:1018-2
3. Kaloğlu, F., Önder, E., Özipek, B. (2003) Influence Of Varying Structural Parameters On Abrasion Characteristics of 50/50 Wool/Polyester Blended Fabrics, Textile Research Journal, 73, 11, 980-984
4. Kaynak, H.K., Topalbekiroğlu, M. (2008) Influence of Fabric Pattern on the Abrasion Resistance Property of Woven Fabrics, Fibres & Textiles in Eastern Europe, 16, 1 (66), 54-56

Triboelectric Activation of Wood Surfaces by means of Wood Disintegration Processes

LM. Leiter [1*], R. Wimmer [1]
[1] Institute of Wood Technology and Renewable Materials, University of Natural Resources and Life Sciences, Vienna, Austria

Abstract:
Wood is one of the most important natural resources that is renewable and widely industrially used. The disintegration of wood by sawing, cutting, chipping, shredding or defibration is one of the most important process steps in the wood industry. During all disintegration processes friction occurs between the processing tool and solid wood, or any other wood-based material. This friction is causing surfaces to become electrically charged. Charging of wood surfaces is a phenomenon that has received little attention so far, and related research in this field is almost entirely lacking. Wood is an electrically semi-conductive material. Its electrical conductivity is influenced by the wood moisture, the wood density, and the overall anatomical structure. In this research the extent of triboelectric activation of wood surfaces was investigated by using a wood brushing machine. The electrical surface field strengths were continuously detected using a self-designed experimental setup (Figure 1). To understand the conducted surface treatment effects, two wood species, i.e. beech and poplar, were measured: (1) after densification, (2) after steaming, (3) after heat treatment at 120° and 180°C, respectively, and (4) also on untreated control samples. Overall, it is shown that wooden surfaces can be electrically charged and that the introduced charges are significantly influenced by the applied settings. Preliminary data showed that densification of the samples did lead to an increased electric surface field strengths. Tailoring surface charges can be an asset for new technical applications, such as chemistry-free primer treatments prior to wood coating.

Keywords: electrical field strength, triboelectricity, wood machining, wood processing, wood surface

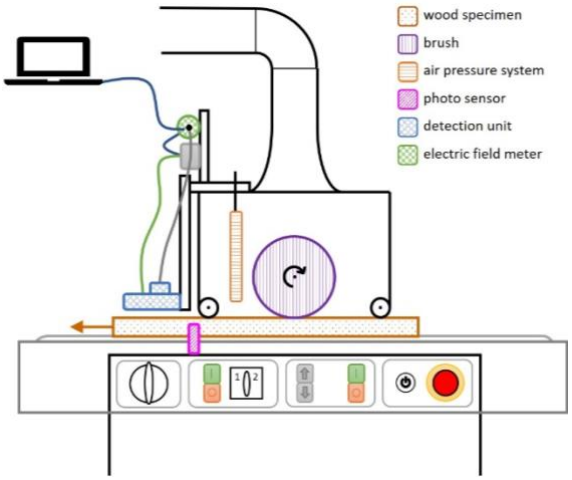


Figure 1: Experimental setup to continuously measure electrical surface field strength of wood samples due to surface brushing. The wood specimen (brown) was tribo-activated by using a brush (purple), rotating at 1400 rpm. Followed by an air pressure system (orange) to blow-off wood dust, and a photo sensor (pink) that included the triboelectric detection unit (blue) and an electrical surface field strength meter (green).

References:

1. Leiter, L.M., Myna, R., Frömel-Frybort, S., Liebner, F., Wimmer, R. (2022), Triboelectric surface field strength of wood after brushing, *Wood Sci Technol*, 56, 1401–1417.
2. Myna, R., Wimmer, R., Liebner, F., Leiter, L.M., Frömel-Frybort, S. (2021), Triboelectric charging of dust particles during hand-held circular sawing of wood and wood-based materials, *Wood Mater Sci Eng.*, 16(1): 64-73.
3. Zhang, L., Hou, J., Bi, X. (2013), Triboelectric charging behavior of wood particles during pellet handling processes, *J. Loss Prev. Proc. Ind.*, (26) 1328 – 1334.

Multilayer Chitosan/Lignin Nanocoating with Silver Nanoparticles for Antimicrobial Cotton

M. Radetić [1,*], D. Marković [2], J. Petkovska [3], N. Mladenovic [3], M. Radoičić [4], N. A. Vest [5], B. Palen [5], J. C. Grunlan [5,6,7], I. Jordanov [3]

[1] Textile Engineering Department, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

[2] Innovation Centre of the Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

[3] Department of Textile Engineering, Faculty of Technology and Metallurgy, Ss. Cyril and Methodius University, Skopje, Republic of North Macedonia

[4] "Vinča" Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia

[5] Department of Chemistry, Texas A&M University, College Station, USA

[6] Department of Materials Science and Engineering, Texas A&M University, College Station, USA

[7] Department of Mechanical Engineering, Texas A&M University, College Station, USA

Abstract:

The demand for antimicrobial textiles is rapidly growing particularly in medical sector. In an effort to develop a simple and efficient antimicrobial treatment for cotton, layer-by-layer deposition of chitosan and magnesium lignosulfonate, followed by in situ synthesis of silver (Ag) nanoparticles, was accomplished. Lignin is exploited as a natural reducing and stabilizing agent[1,2], producing Ag nanoparticles in amounts even larger than those obtained with sodium borohydride as a strong reducing agent. The influence of the number of bilayers (4 and 12) and initial concentration of $AgNO_3$ solution (10 and 20 mM) on antimicrobial activity of cotton fabric against Gram-negative bacteria *E. coli*, Gram-positive bacteria *S. aureus*, and *C. albicans*, yeast was examined. The presence of evenly scattered Ag nanoparticles all over the fiber surface is confirmed by FESEM analysis (Figure 1). The number of bilayers does not affect the size of nanoparticles (~56 nm), but an increase of bilayers results in greater Ag content. The samples treated with 20 mM $AgNO_3$ solution contain more Ag than those treated with 10 mM solution. The formation of metallic Ag nanoparticles is confirmed by XPS analysis.

Synthesized Ag nanoparticles provide excellent antibacterial activity against bacteria *S. aureus* (99.9 %), independent of the initial concentration of $AgNO_3$ and number of bilayers. Larger content of Ag nanoparticles i.e., higher initial concentration of $AgNO_3$ solution leads to considerably enhanced antibacterial activity against *E. coli*. A similar trend is evident with the *C. albicans* yeast, but the desired yeast reduction of 99 % was not obtained.

Keywords: layer-by-layer assembly, Ag nanoparticles, chitosan, lignosulfonate, cotton, antimicrobial activity.

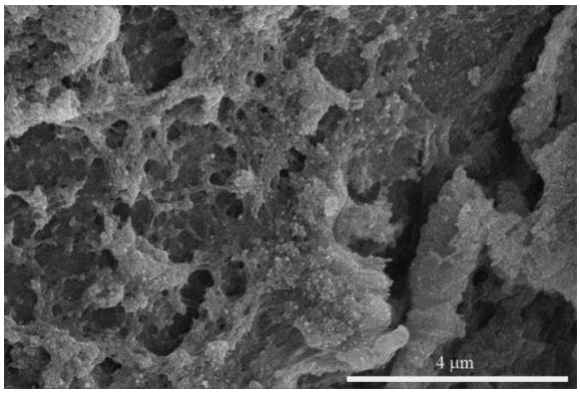


Figure 1: FESEM image of cotton fiber surface nanocoated with 12 chitosan/ligninsulfonate bilayers and Ag nanoparticles synthesized from 10 mM $AgNO_3$ solution.

Acknowledgement

The authors would like to thank the NATO Science for Peace and Security (SPS) program for their funding through the G5905 (MULProTex) project.

References:

1. Li, Y., Yang, D., Li, P., Li, Y. (2022) Lignin as a multifunctional-agent for the synthesis of Ag nanoparticles and its application in antibacterial coatings, *J. Mater. Res. Technol.*, 17, 3211-3220.
2. Shen, Z., Luo, Y., Wang, Q., Wang, X., Sun, R. (2014) High-value of lignin to synthesize Ag nanoparticles with detection capacity for Hg^{2+}, *ACS Appl. Mater. Interface.*, 6, 16147.

Carbon-based coatings on ureteral stents to prevent urinary infections

S. Cruz[1,2,*], D.Santo[1], P. Pereira[1,2], D. Calheiros[3,4], L. Rodrigues[3,4], T. Gonçalves[3,4], A. Cavaleiro[1,2], S. Carvalho[1,2]

[1] Laboratory of Tests, Wear and Materials, IPN, LED & MAT—Instituto Pedro Nunes, Rua Pedro Nunes, 3030-199 Coimbra, Portugal
[2] CEMMPRE Mechanical Engineering Department, University of Coimbra, 3030-788 Coimbra, Portugal
[3]CNC-Center for Neuroscience and Cell Biology, University of Coimbra, Rua Larga, 3004-504 Coimbra, Portugal
[4]FMUC-Faculty of Medicine, University of Coimbra, Rua Larga, 3004-504 Coimbra, Portugal
*sandracruz@ipn.pt

Abstract:
Ureteral stents are among the most often implanted medical devices used to treat benign and malignant urological disorders. Yet, the existing ureteral stents in clinical usage have certain drawbacks, including the pain and discomfort associated with their invasive administration and the increased risk of urinary tract infection[1]. Given the significant impact on patient quality of life and healthcare expenses, innovative strategies to enhance stent efficacy are urgently needed. Many attempts have been undertaken to coat stents with antibiotics, hydrogels, or biodegradable polymers to avoid stent-associated urinary tract infection and encrustation[2]. Sputter-deposited diamond-like carbon (DLC) coatings (Figure 1) have numerous important features, including low coefficient of friction, corrosion resistance, chemical inertness, and biological compatibility[3].
Silver (Ag) was chosen as a dopant to DLC due to its broad range of antibacterial action and low prevalence of bacterial resistance. Ag clusters were effectively integrated into an a:C matrix and coated on TPU substrates, exhibiting significant antibacterial activity governed by silver ionisation processes and a superior biocompatible profile. The working conditions of the coated stent may have an impact on its performance. We show how urine affects the deterioration and mechanical qualities of a coated stent in this research. This study was carried out over time, simulating physiological conditions.

Keywords: AgDLC thin films, Physical Vapor Deposition, Ureteral Stents, sputtering, doped-DLC/Ag films, antimicrobial, cytotoxicity.

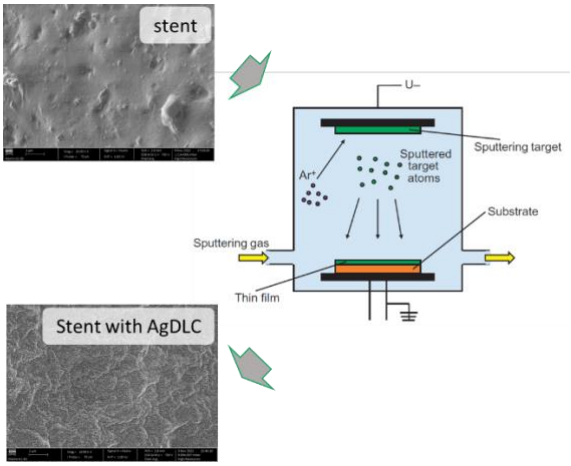


Figure 1: Illustration of the sputtering process used to modify the surface of the stents to give them antimicrobial properties.

References:

1. Kumon, H.; Hashimoto, H.; Nishimura, M.; Monden, K.; Ono, N. Catheter-Associated Urinary Tract Infections: Impact of Catheter Materials on Their Management. Int. J. Antimicrob. Agents 2001, 17 (4), 311–316.
2. Domingues, B.; Pacheco, M.; de la Cruz, J. E.; Carmagnola, I.; Teixeira-Santos, R. et al. Future Directions for Ureteral Stent Technology: From Bench to the Market. Adv. Ther. 2022, 5 (1), 2100158.
3. Carvalho, I.; Rodrigues, L.; Lima, M. J.; Carvalho, S.; Cruz, S. M. A. Overview on the Antimicrobial Activity and Biocompatibility of Sputtered Carbon-Based Coatings. Processes 2021, 9 (8).
4. Carvalho, I.; Dias, N.; Henriques, M.; Calderon V, S.; Ferreira, P.; Cavaleiro, A.; Carvalho, S. Antibacterial Effects of Bimetallic Clusters Incorporated in Amorphous Carbon for Stent Application. ACS Appl. Mater. Interfaces 2020, 12 (22), 24555–24563.

Inactivation of Spores and Mycelium of Aspergillus Brasiliensis by Non-Thermal Atmospheric Pressure Plasma

P. Tichá [1*], M. Domonkos [1], K. Zdeňková [2], P. Demo [1]
[1] Department of Physics, Faculty of Civil Engineering, Faculty of Civil Engineering, Czech Technical University in Prague, Prague, Czech Republic
[2] Department of Biochemistry and Microbiology, Faculty of Chemical Engineering, University of Chemistry and Technology, Prague, Czech Republic

Abstract:
Indoor mould growth is an increasingly common problem that has adverse effects on both occupants and building materials. The Aspergillus species consists of several hundred species found in different climates, causing diseases in humans including human asthma, ear and nose infections, and invasive pulmonary aspergillosis, especially in immunosuppressed individuals. Aspergillus brasiliensis is a member of Aspergillus section Nigri (i.e. black Aspergillus), the mould species that produce enormous amounts of melanin pigmented spores within short time periods and are present in the air and indoor environment. Melanin supports resistance to a range of environmental stressors (e.g. UV irradiation) and contributes to the survival of mould. The aim of this study was to present a new environmentally friendly method (non-thermal atmospheric pressure plasma treatment) for the inactivation of moulds which should lead to a reduction in the risk of airborne infections and the improvement of indoor environments contaminated with mould spores. Non-thermal plasma generated by a diffusion coplanar surface barrier discharge was used to treat culture medium surfaces inoculated with different concentrations of spores and with different stages of micromycete development. The surface coverage of the mould was assessed by image analysis. The experimental data were compared with the numerical simulations. The growth of Aspergillus sp. hyphae and mycelia exposed to non-thermal atmospheric pressure plasma was reduced or arrested compared to mycelial formation in untreated samples. Treatment with non-thermal plasma induced a colour change in colonies of A. brasiliensis, which changed from their original black colour to brown (Figure 1). This study demonstrated that non-thermal atmospheric pressure plasma is a more effective in inactivation of mould spores than inactivation of higher stages of micromycetes on malt extra agar.

Keywords: Moulds, mould spores, non-thermal atmospheric pressure plasma, spore concentration, inactivation.

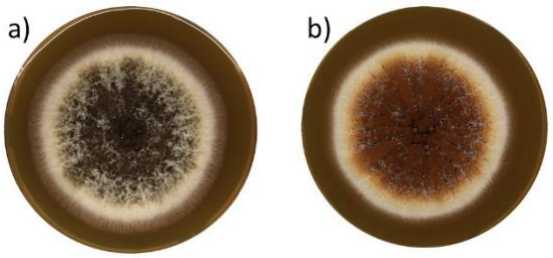


Figure 1: Effects of non-thermal atmospheric pressure plasma on colony colour of A. brasiliensis grown on malt extract agar. Representative images of Aspergillus brasiliensis taken on day 7 after inoculation: a) untreated sample, b) plasma treated sample (300 W, exposure time 10 min) showing colour changes.

References:

1. Ticha, P., Domonkos, M., Rácová, Z., Demo, P. (2023) Application of cold atmospheric plasma for mold inactivation, *Acta Polytechnica CTU Proceedings*, In Press.
2. Domonkos M, Tichá P, Trejbal J, Demo P. (2021) Applications of Cold Atmospheric Pressure Plasma Technology in Medicine, Agriculture and Food Industry. *Applied Sciences*, 11, 4809.

Optical limiting behavior of the DNA-based materials functionalized with natural dyes

Petronela GHEORGHE[1]*, Adina Mirela ANTON[2], Adrian PETRIS[1]
[1]National Institute for Laser, Plasma and Radiation Physics, 409 Atomistilor Street, 077125 Magurele, ROMANIA
[2]University POLITEHNICA Bucharest, Faculty of Applied Chemistry and Materials Science, 1-7 Polizu Str., 011061 Bucharest, ROMANIA
Correspondence: *petronela.doia@inflpr.ro

Abstract:
The optical limiting (OL) functionality is one of the most promising practical applications of the nonlinear absorption process. OL devices are of great importance due to the possibility of their use for the protection of human eye, light sensors, cameras and of other sensitive optical and opto-electronic devices against intense sources of laser radiation, which can irreversibly damage of such elements when a safety damage threshold is exceeded [1-5]. The continuous development of these type of devices is crucially dependent on the availability of suitable optical materials and structures. Lately, the natural dyes extracts are emerging as an important class of optical materials for this application and are intensely studied due to their interesting photosensitive properties. The synthetic polymers that have been used so far in optical limiters can be successfully replaced by these bio-polymers that have some advantages over artificial materials [6,7].
In this work are presented our recent results regarding the optical limiting capability of femtosecond laser pulses at 1550 nm wavelength of these novel bio-polymers functionalized with DNA by intensity scan experiments. The studied natural extracts have low costs, being extracted from raw materials thus making the components based on them un-expensive. A series of optical properties of these natural dyes are reported and discussed. A comparative analysis of the DNA presence and of natural dye extract concentration are also reported and discussed to assess the influence of DNA on the optical limiting properties.
These studies reveal an interesting potential of these bio-polymers functionalized with DNA for photonic applications, such as optical limiting and may serve as an eco-friendly alternative for hardly degradable and highly polluting synthetic polymers and dyes.

Keywords: optical limiting, bio-polymers, natural dye extract functionalization, DNA, nonlinear optical response

References:

1. K. C. Chin, A. Gohel, H. I. Elim, W. Z. Chen, W. Ji, G. L. Chong, et al (2006) , Modified carbon nanotubes as broadband optical limiting nanomaterials, J. Mater. Res., 21, 2758;
2. Z. B. Liu, Y. Wang, X. L. Zhang, Y. F. Xu, Y. S. Chen, J. Q. Tian, (2009), Nonlinear optical properties of graphene oxide in nanosecond and picosecond regimes", Appl. Phys. Lett., 94, 021902;
3. T. Xia, D. J Hagan, A. Dogariu, A. A. Said, E. W. Van Stryland (1997), Optimization of optical limiting devices based on excited-state absorption", Appl. Opt., 36 (18), 4110;
4. H. Lundén, E. Glimsdal, M. Lindgren, C. Lopesa, (2018), How to assess good candidate molecules for self-activated optical power limiting", Optical Engineering 57(3), 030802;
5. D. Dini, M. J. F. Calvete, M. Hanack (2016), Nonlinear Optical Materials for the Smart Filtering of Optical Radiation, Chem. Rev. 116, 13043;
6. A.M. Anton, I. Rau, F. Kajzar, A. M. Simion, C. Pirvu, N. Radu, C. Simion (2018), Natural materials with enhanced optical damage threshold, Optical Materials 86, 1;
7. A. Stathis, M. Stavrou, I. Papadakis, I. Obratzov, S. Couris (2020), Enhancing and Tuning the Nonlinear Optical Response and Wavelength-Agile Strong Optical Limiting Action of N-octylamine Modified Fluorographenes, Nanomaterials 10, 2319.

Acknowledgements: This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS - UEFISCDI, project number PN-III-PI-l .1-TE-2021-1546, within PNCDI III".

Integration of capacitive sensors and LEDs into HPL boards. -interactive surfaces-

F. Wirth[1], T. Volkmer[1]
[1] School of Architecture, Wood and Civil Engineering, Bern University of Applied Sciences, Biel, Switzerland

Abstract:
Capacitive sensing is a common technology in various fields where information about touches or distances are needed to control processes, or software. The integration of capacitive sensors into high pressure laminate (HPL) used for furniture, wall covering, or facades creates new possibilities for interactions. Furthermore, the integration reduces the number of components, complexity and therewith the prone to errors compared to external devices that are mounted behind the material and measuring through the material. To date, capacitive sensors are installed behind materials as external devices that measures through the covering material. HPL consists of impregnated paper stacked on top of one another. With the developed method, capacitive sensors are printed with silver nanoparticle ink on one paper layer in the stack close to the surface. The stack is then pressed with 150°C to form a solid board. To test the procedure, a circuit for controlling a height-adjustable table was developed. The circuit consists of three sensors that serve as buttons and six LEDs that are controlled and read by an external microcontroller. The resistance of straight conductor tracks was continuously measured during the pressing process, so that conclusions could be drawn about changes in resistance due to the pressing process. On the one hand, the results show that small electrical components such as LEDs or resistors can be easily integrated into the surface without causing a functional failure or impairing the surface. On the other hand, the measurements show a reduction in resistance of around 50% as a result of the pressing process. With the methodology presented, not only capacitive sensors but also other single-layer circuits with flat SMD components can be integrated into HPL boards and form an interactive surface.

Keywords: printed electronic, sensitive surface, High Pressure Laminate, capacitive sensor, smart furniture, silver nanoparticles, interactive surface

Figure 1: The figure shows the structure of an HPL with integrated sensors and LEDs. The position of the paper with the electronics printed on depends on the intended use, the height of the electronics and the intensity or color of the LED.

SETCOR
Conferences & Exhibitions