Surface Engineering - Applied Research and Industrial Applications
Room Town & Country D - Session IA2-1-MoA
Surface Modification of Components in Automotive, Aerospace and Manufacturing Applications I

Moderators: Satish Dixit, Plasma Technology Inc., USA, **Masaki Okude**, Mitsubishi Materials Corporation, Japan, **Jan-Ole Achenbach**, KCS Europe GmbH, Germany

2:20pm **IA2-1-MoA-3 Laser Surface Remelting Induced Reaction Sintering of Nickel and Titanium Powders***, **Milton Lima [miltonsflima@gmail.com]**,* Institute for Advanced Studies, Brazil*; Alana Brito,* Technological Institute of Aeronautics, Brazil*; Felipe Costa,* BRENG Co., Brazil*; Rafael Siqueira,* Technological Institute of Aeronautics, Brazil*; Sheila Carvalho,* Federal University of Espirito Santo, Brazil

There is currently an interest in the synthesis and applications of mnemonic structure materials for various applications, such as biomedical, aerospace, automotive, and robotics. Shape memory alloys (SMAs) are metallic materials that can return to their initial state after being subjected to deformation as a result of increased temperature, increased pressure, or other stress conditions. These materials have been used in thermoelastic actuators in space applications, such as antenna supports and solar panel deployments, and can impact the manufacture of polymorphic aircraft engines and fuselages. SMAs, such as Nitinol (equimolar alloy of Ni and Ti), are difficult to fabricate, and the powder metallurgy route, whether classical or using laser powder bed fusion (L-PBF), has been constantly improved to meet new application niches. This study proposes reactive sintering of samples with equiatomic compositions of Ni and Ti to form Nitinol using laser surface remelting. Elementary powders were inserted into a high-energy ball mill to fabricate mechanically alloyed Ni-Ti powders, which were subsequently pressed in the form of discs (20 mm diameter, 5 mm thickness). An experimental arrangement with a vacuum chamber and fiber laser beam manipulation was developed to induce sufficient heat for the reaction of elementary powders. Spiral scanning of the fiber laser beam produced surface remelting that ignited the pressed powder mixture. Macro- and microstructural analyses, the crystalline structure, and the composition of the sample surface remelted with a beam power ranging from 10 to 46 W were performed. In this power range, the sintering time was varied between 55 and 295 s when the laser power was varied from 46 W to 10 W. Although the presence of intermetallic phases was approximately the same, the microstructure in the laser-surface-remelted region was more homogeneous than that in the sintered volume. At the end of sintering, tablets were obtained with an apparent density of 61%–67% and a large number of intermetallic phases, such as $NiTi_2$, Ni_3Ti, and Ni_4Ti_3, together with unreacted elemental powders (Ni and Ti). The samples prepared in air also presented these phases in addition to TiO_2 and NiTi. The air-processed samples presented an equimolar Nitinol phase, as observed by X-ray diffractometry. According to mass spectrometry analyses of secondary ions, the presence of air oxidized the surface of the grains, which reacted at shorter distances and generated the Nitinol phase.

2:40pm **IA2-1-MoA-4 A Comparative Study on the Formation of Micro-Arc Oxidation Coatings on AZ31 and AC84 Magnesium Alloys***, **Chi-Hua Chiu [qiuqihua90@gmail.com]**, Shih-Yen Huang, Yueh-Lien Lee, Yu-Ren Chu,* National Taiwan University, Taiwan

Magnesium-aluminum-calcium (Mg−Al−Ca) alloys have attracted significant attention due to their excellent strength-to-weight ratio, good castability, and potential for flame retardancy, owing to the presence of calcium and aluminum. However, the applications of these alloys are limited by their poor corrosion resistance. Micro-arc oxidation (MAO) is one of the most common techniques for corrosion protection of magnesium alloys; however, the formation mechanism of MAO coatings is extremely complex and influenced by numerous process parameters, including the substrate effect. In this study, the mechanism of MAO coating formation on the AZ31 and dual-phase AC84 (Mg−8Al−4Ca) alloys was comparatively examined. The preliminary results reveal that, during MAO treatment at a constant anodizing voltage of 150V, unreacted Al_2Ca secondary phases were observed in the micro-arc oxidation coatings of AC84 magnesium alloys, causing non-uniform surface structures and thicknesses, which led to poor corrosion resistance compared to the MAO coating formed on AZ31.Conversely, AC84 exhibited better corrosion resistance than AZ31 when the voltage was increased to 250V. Further increasing the voltage to 300V resulted in the involvement of secondary phases in the reaction, leading to more uniform microstructures and chemical compositions of the coatings on both alloys. These findings suggest that the anodizing voltage plays a crucial role in the reaction behavior of secondary phases and the properties of the MAO coatings.

3:00pm **IA2-1-MoA-5 HIPIMS – Fascinating Technology to Make Next Steps in Tool, Decorative and Functional Applications***, **Philipp Immich [pimmich@hauzer.nl]**, Ivan Kolev, Andreas Fuchs, Daniel Barnholt, Julia Janowitz, Louis Tegelaers, Huub Vercoulen, Chinmay Trivedi, Geert-Jan Fransen,* IHI Hauzer Techno Coating B.V., Netherlands*; Holger Hoche, Thomas Ulrich,* TU Darmstadt, Germany*; Peter Polcik,* Plansee Composite Materials GmbH, Australia

The PVD (Physical Vapor Deposition) market is rapidly expanding into new application fields. To achieve these new applications, various PVD coating techniques are employed, with HIPIMS (High Power Impulse Magnetron Sputtering) being one of the most fascinating since its discovery. Over the past 25 years, numerous advancements have been made in latest Generation 3 - HIPIMS power supply technology, including modifications in bipolar mode, pulse shape, pulse length, pulse trains, and higher frequencies. Synchronization of cathodes and HIPIMS-based bias has also led to innovative PVD coating solutions.

Beyond the well-known performance improvements in HIPIMS-coated cutting tools, HIPIMS has demonstrated its potential for various other applications. We will showcase the ability to create different colors using HIPIMS technology and highlight its advantages for decorative applications on 3D products. For components, HIPIMS is an excellent tool for enhancing the wear and corrosion resistance of existing material systems. We will also present the latest coating development for cutting tools. Our presentation will illustrate how combining HIPIMS with new material systems can further expand and enhance potential application areas.

Decorative, tool and tribological markets are driven by production costs, making coating volume and size crucial factors. To meet these demands, we have scaled up our HIPIMS developments to deposit coatings on our largest industrial platforms, e.g. the Flexicoat 1500 to address market needs.

We will also provide an outlook on future developments and what can be expected next in the PVD market.

3:20pm **IA2-1-MoA-6 Inorganic Sputtered Coatings to Reduce Snow Friction for Cross-Country Skiing***, **Pauline Lefebvre [pauline.lefebvre@grenoble-inp.fr]**,* SIMAP, Grenoble-INP, CNRS, France*; Fabian Wolfsperger,* WSL Institute for Snow and Avalanche Research SLF, Switzerland*; Jean Herody,* FFS, France*; Matthias Jaggi,* WSL Institute for Snow and Avalanche Research SLF, Switzerland*; Arnaud Mantoux,* SIMaP, CNRS, University Grenoble Alpes, France*; Nicolas Coulmy,* FFS, France*; Pascal Hagenmuller,* Centre d'Etudes de la Neige, CNRM, Météo-France*; Elisabeth Blanquet,* SIMAP, Grenoble-INP, CNRS, France

In cross-country skiing, reducing the friction coefficient between the skis and snow is essential for sportive performance [1]. Fluorinated waxes, i.e. containing perfluoroalkyl (PFA) are known for their hydrophobic properties and were remarkably efficient in wet snow conditions. However, the International Ski and Snowboard Federation (FIS) has banned fluorinated wax since winter 2023/2024 -for health and environmental reasons [2]. Since then, no alternative with equivalent performance has been found. This project aims to develop hard and hydrophobic coatings based on titanium nitride (TiN), aluminum nitride (AlN) and alumina (Al_2O_3) materials directly deposited on ski bases and UHMW polyethylene. The role of coating surface properties and structure in friction is investigated

Thin films were deposited using DC and RF magnetron sputtering. The surface (contact angle, roughness, chemical composition), mechanical and thermal properties of the coatings were investigated. Friction coefficient of coated samples was evaluated on snow with a linear tribometer (speed: 0.1 m/s, displacement: 130 mm, contact pressure: 50 kPa). The tribo-system is therefore a 10cm-long coated ski sliding on controlled man-made snow in a cold-room at 0°C and dry air. Snow with different liquid water content were used for the tests.

Results are encouraging as deposition on ski base is feasible at ambient temperature with adhesive and dense coatings. Coating thicknesses were evaluated by scanning electronic microscopy between 50 and 200 nm depending on process parameters. Chemical analysis with XPS indicates nitride films contain a relative high amount of carbon and oxygen. Coatings, selected for their hydrophobicity and structural properties, were investigated in gliding tests. AlN and Al_2O_3-based coatings presented very high friction coefficient (0.2-0.3). TiN-based coating had the lower friction coefficient with a value of 0.11 on very wet snow, whereas a ski waxed with PFA friction coefficient was measured at 0.072.

To sum up, deposition of sputtered coatings was realized with success and may be a promising technique for preparing competition skis. For winter sport application, titanium nitride seems to be the most promising: it is indeed known for better mechanical properties [3] and lower thermal conductivity [4] which will be further investigated.

References:

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[2] Freberg, B. I. et al, Environ Sc & Techno, 44, 7723–7728 (2010).

[3] Glocker, D. A. et al, Bristol, UK: Inst of Phys (1995).

[4] Moraes V. et al, J Appl Phys, 119, 225304 (2016).

4:00pm **IA2-1-MoA-8 Influence of Corrosion on Wear and Brake Particle Emissions of Alumina-Coated and Uncoated Cast Iron Brake Discs***, **Ran Cai [cai12r@uwindsor.ca]**, Xueyuan Nie,* University of Windsor, Canada*; Yezhe Lyu Lyu, Jens Wahlström,* Lund University, Sweden

Hard coatings can be applied to cast iron brake discs to enhance wear and corrosion resistance and reduce brake particle emissions. This study investigated the influence of corrosion on brake particle emissions from cast iron discs through comparison of plasma electrolytic aluminized (PEA)-coated and uncoated surfaces. Six discs were subjected to corrosion in raining-snowy conditions for 24, 48, and 72 hours before undergoing tribological testing using a pin-on-disc tribotester combined with an airborne particle emission measurement system. The counterpart pins were machined from a commercially available low-steel (LS) brake pad. Data of particle concentration, size distribution, and total wear (disc and pad) were collected, while wear tracks, friction transfer layers and worn pad surfaces were analyzed using scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX). The results showed that the degree of corrosion of the uncoated disc increased with time, while the coated discs didn't show any corrosion sign. The corrosion products on the uncoated discs can be cleaned during the early stage of the tribotests where the particle emission was much higher than the later stage. The PEA coating effectively mitigated the effects of corrosion, resulting in significantly lower wear and brake particle emissions compared to uncoated discs. These findings demonstrate the potential of PEA coatings to reduce wear and emissions under winter conditions, offering benefits for environmental sustainability and public health.

4:20pm **IA2-1-MoA-9 The Effect of Mg Addition on the Corrosion Resistance of Two-Step Galvanizing Zn-5Al Coating***, **Huan-Chang Liang [hcliang@niu.edu.tw]**,* Department of Mechanical and Electro-Mechanical Engineering, National I-Lan University, Taiwan*; Yen-Kai Chen, Chaur-Jeng Wang,* Department of Mechanical Engineering, National Taiwan University of Science and Technology, Taiwan

The atmospheric corrosive substances like Cl^- ions or SO_3^{2-} ions make it easier for soluble zinc salts to form. Consequently, the introduction of more magnesium into the Zn-Al alloy bath enhances the formation of basic zinc salts that are susceptible to environmental corrosion. Zinc-aluminum carbonate hydroxide and aluminum-magnesium carbonate hydroxide are particularly notable corrosion products because of their stable and compact characteristics. Local acidity influences the rate of transformation of zinc hydroxide from zinc oxide, while the formation of $Mg(OH)_2$ mitigates the surface reduction of the galvanizing coating.

Although the Zn-5Al-2Mg coating is effectively produced using the continuous galvanizing process, the maximum coating thickness achieved is 20 µm. Numerous studies present their experimental findings about batch galvanizing zinc alloys. The coating structure is nonuniform, with an enrichment of iron content resulting from the elevated operating temperature, which inhibits the formation of a dense and continuous layer of corrosion products. Consequently, two-step batch galvanizing is utilized to provide a zinc alloy coating of adequate thickness. The initial process involves immersing samples in pure zinc, followed by immersion in zinc alloy. The coating's microstructure consists of an outer layer formed from zinc alloy and internal layers including an iron-aluminum intermetallic compound combined with a eutectic phase.

This study aims to examine the microstructure of two-step batch galvanizing Zn-5Al and Zn-5Al-2Mg coatings on low-carbon steel. The samples are produced by batch galvanizing pure zinc for 10 minutes, followed by batch galvanizing zinc alloy for 2.5 minutes. The corrosion resistance performance of both samples is evaluated by interfacial polarization and impedance matching. The microstructure of two-step galvanizing Zn-5Al and Zn-5Al-Mg consists of four distinct layered structures: a binary (Zn-Al) or ternary (Zn-Al-Mg) eutectic phase layer, a branch-like $FeAl_3$ phase layer, a dense $FeAl_3$ phase layer, and an internal eutectic phase layer. As the zinc content in the coating layer increases, there is a corresponding decrease in the charge transfer impedance (R_{ct}). This behavior is ascribed to the area fraction of the $FeAl_3$ phase in conjunction with the eutectic phase. The addition of magnesium into the zinc alloy bath enhances the R_{ct} of the entire coating layer. The advantageous effect arises from the disparity in corrosion potential between magnesium and zinc. Magnesium functions as a sacrificial anode for the Zn-rich phase, hence enhancing the effectiveness of cathodic protection.

4:40pm **IA2-1-MoA-10 Erosion Resistant PVD Conatings on CFRP Substrates***, **Pablo Abarca [pablo.abarca-martinez@unilim.fr]**, Thibault Maerten,* Oerlikon Balzers France*; Cedric Jaoul, Pascal Tristant,* University of Limoges, France*; Sebastien Guimond,* Oerlikon Surface Solution AG, Liechtenstein*; Marjorie Cavarroc,* Safran Tech, France*; Simon Belveze,* Oerlikon Balzers France

Environmental challenges and European regulations push aircraft manufacturers to increase the efficiency of engines and to reduce the weight of the whole aircraft. Carbon-fiber reinforced polymers (CFRP) rose as a solution on the CFM LEAP engine to reduce the weight of the engine as the compressor fan blades, the outlet guide vane (OGV) and other elements are made of CFRP. Nevertheless, this material is vulnerable to the erosive conditions that the aircraft encounters during service. Right now, some of these elements are coated with polyurethane to reduce the erosion and increase the lifetime of the elements, but this material is targeted by REACh regulations and its substitution is a challenge for manufacturers.

To address this problem, some research has been done to coat CFRP substrates via PVD techniques with erosion resistant coatings like TiN in combination with metallic coatings like titanium, aluminum and chromium. These studies used mainly magnetron sputtering technique with laboratory scale coaters. This study presents an original approach that combines magnetron sputtering and arc evaporation on an industrial scale Oerlikon Surface Solutions coater. Arc evaporation without filter has the reputation of coating at high temperatures (> 400°C), but it will be shown that it is possible to coat CFRP components via this process.

Trying to modify arc evaporation processes to reduce the substrate temperature during the coating can result in a dramatical loss on deposition rate and mechanical properties of the layer. In this talk we will share a strategy to mitigate the loss of mechanical properties (H > 26GPa) while keeping an acceptable deposition rate (>1µm/h) and substrate temperature below 180 °C, which is a critical temperature for CFRP. An extensive set of parameters is tested and their influence on deposition rate, substrate temperature and mechanical properties of the coating is reported.

The resulting arc evaporated coating is compared to a magnetron sputtered version of the same material done in the same machine. Finally, we will share some erosion test results done on this coating/CFRP system.

5:00pm **IA2-1-MoA-11 PVD Coatings for High Temperature Applications in Turbines***, **Markus Esselbach [markus.esselbach@oerlikon.com]**,* Oerlikon Balzer, Liechtenstein

Materials utilized in turbine applications at high temperatures frequently need a surface protection against corrosion or oxidation. Especially suited for such applications are oxide coatings due to their ability to suppress oxygen diffusion. Spray technology is the most prominent method for these applications because it combines high deposition rates with the possibility to form high quality oxide coatings. However, during the last decade PVD technology was developed for coatings of larger thickness and for oxide coatings synthesized by cathodic arc evaporation (CAE). In a specific process approach, a hybrid process combining cathodic arc evaporation with plasma enhanced CVD (PECVD) (PVD+) has been developed for much higher deposition rates and with the possibility to synthesize high quality oxide coatings. PVD+ has been implemented in production systems. The utilization of this process approach resulted in sophisticated coating material developments. First applications for PVD oxide coatings are demonstrated for superalloy and SiC substrates.

Surface Engineering - Applied Research and Industrial Applications
Room Palm 1-2 - Session IA1-TuM

Advances in Application Driven Research and Hybrid Systems, Processes and Coatings

Moderators: Ladislav Bardos, Uppsala University, Sweden, **Hana Barankova**, Uppsala University, Sweden

8:00am **IA1-TuM-1 Advancing Correlative Microscopy: In-Situ Integration of AFM-SEM-EDS for Multi-Modal Analysis***, **Kerim T. Arat [karat@qdusa.com]**, William K. Neils, Stefano Spagna,* Quantum Design Inc., USA

There is a growing interest in in-situ correlation microscopy, which brings the complementary strengths of different imaging modalities without the inherent complications of sample transfer. These approaches ensure high confidence in correlation accuracy and eliminate the risk of sample contamination and alteration during the sample transfer.

We have developed a correlative microscopy platform based on AFM-SEM [1]. These techniques can map the surface in high resolution, and the trunnion stage, with up to 80° tilt capability, allows monitoring of tip quality and tip-sample interaction [2]. However, these methods fall short in identifying the elemental composition of the sample.

To address this issue, we have extended the capabilities of the correlative platform with an energy-dispersive X-ray spectrometer (EDS). The spectrometer is based on a state-of-the-art silicon drift detector [3], which provides high energy resolution. Its graphene window offers improved transmission performance, especially at the lower energy range, allowing elemental detection down to carbon. The elemental identification algorithm uses a background subtraction method to remove non-characteristic signals and compares the resulting spectra to reference datasets based on the NIST database for standardless quantification [4]. Both hardware and software integration allow the correlation of elemental information with the other imaging modalities that the tool can provide (see the supplementary document), where one can superimpose topography and elemental information.

Integration of the X-ray detector adds a comprehensive analysis capability to AFM-SEM techniques applicable to a diverse range of fields such as materials science, semiconductors and biosciences. With this option, researchers can obtain an in-situ correlation of high-resolution, localized elemental information with high-resolution lateral and vertical topographical information.

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8:20am **IA1-TuM-2 Non-stick Hydrophobic and Superhydrophilic Metallic Coatings: Their PVD Fabrications and Applications***, **Jinn P. Chu [jpchu@mail.ntust.edu.tw]**,* National Taiwan University of Science and Technology, Taiwan*; Sea-Fue Wang,* National Taipei University of Technology, Taiwan

The presentation will begin with an introduction to a non-stick, low-friction hydrophobic metallic glass coating and its applications. This amorphous coating, fabricated using PVD techniques, has been successfully applied in various fields, including medical devices. For the superhydrophilic coating, a 316 stainless steel layer is sputtered onto the substrate, resulting in a water contact angle of approximately 10 degrees on the coated surface. This coating also demonstrates antifouling and underwater superoleophobic properties, which are advantageous for use in separation membranes for oil/water emulsions. Furthermore, it has proven highly effective in enhancing electrochemical responses in electrodes used as electrochemical sensors.

8:40am **IA1-TuM-3 Energy Bandgap Engineering for Gate-All-Around Poly-Ge Charge Trapping Flash Memory by Using Stacking Tunneling Layer***, **Kuei-Shu Chang-Liao [lkschang@ess.nthu.edu.tw]**,* National Tsing Hua University, Taiwan*; Dun-Bao Ruan,* Fuzhou University, China*; Chu-Chun Su,* National Tsing Hua University, Taiwan

A high-performance junction-less charge-trapping flash memory device based ongate-all-around structure with a poly-Ge channel was successfully fabricated in this work.By leveraging the high carrier mobility of Ge, the use of a low-temperature poly-Ge channel enhances the operational speed of the flash memory device.However, under stringent thermal budget limitation, the reliability of the Poly-Ge flash device may degrade without enoughthermal processing.This degradation is likely attributed to the narrow energy bandgap of Ge material and Ge out-diffusion phenomena.By integrating post plasma processand stacked tunneling layer engineering, the memory device incorporating an aluminum oxynitride (AlON) tunneling layer demonstrates significant improvements, including high programming/erasing speeds, excellent endurance cycles,and long data retention time.These enhancements can be primarily attributed to the superior thermal stability and interface quality of AlON, which may mitigate interface defects and improves robustness during thermal cycles. Besides, compared to traditional silicon nitridecharge-trapping layers, AlON exhibits shallower trap energy levels. This property enables faster charge injection/ejection during programming/erasing operations without compromising data retention or endurance performance.

9:00am **IA1-TuM-4 PVD Coatings for the Hydrogen economy - Applications, Testing and Production***, **Herbert Gabriel [h.gabriel@pvtvacuum.de]**,* PVT Plasma und Vakuum Technik GmbH, Germany **INVITED**

Green hydrogen could be the fuel of the future. Generated by electroysers powered by photovoltaics and used in fuel cells could be part of the solution to the human mankind’s problems with the climate change.

The harsh environments in electrolysers and fuel cells require components to be coated for corrosion resistance, electrical conductivity and other related properties..

Most of the components are made of stainless steel or titanium, but still need for their performance and long lifetimes up to 100.000 hours coatings with high performance properties.

Depending on the application, whether PEMWE, PEMFC, AEM, SOFCs, SOECs or others, thin coatings made of materials such as C, Ti, Cr, Nb, Au, Pt, Ir, MCO, Al2O3....... are deposited in the nanometer to a couple of micron range.

Preferred coating processes are magnetron sputtering, respectively HiPIMS, high power impulse magnetron sputtering to deposit highly adherent and dense coatings.

Most components of fuel cells and electrolycers to be coated are thin 2-dimensional structures in high quantity. For this reason high productive so-called in-line systems with vertical orientation are the preferred coating systems for double-sided deposition.

Apart from a number of other QC – tests, adhesion, corrosion and ICR (interface contact resistance) prior and after corrosion testing are essential properties to continually be tested and monitored.

9:40am **IA1-TuM-6 Improving Doping Concentration for Shallow N^+/P Substrate Germanium Pn Junction with Plasma-Immersion Ion Implantation Process***, **Bo-Syun Syu [brian20000713@gmail.com]**,* National Tsing Hua University, Taiwan*; Dun-Bao Ruan,* Fuzhou University, China*; Kuei-Shu Chang-Liao, Po-Chun Wu,* National Tsing Hua University, Taiwan

In recent years, due to the development of device technology nodes, therequirements for the mobility of channel materials have become increasingly demanding. Considering the compatibility with existing process equipment, the most suitable and high-mobility material is germanium (Ge) based channel material. However, unlike traditional silicon, Ge has a smaller band-gap, lower solubility for dopant impurities, a lower melting point, and other issues, making it very prone to phenomena such as Fermi-level pinning, small on/off junction current ratio, high reverse junction current, and poor reliability. Therefore, exploring an effective ion implantationmethod, which may achieve shallow high-density dopingPN junction, is particularly important. This work successfully utilizes plasma immersion ion implantation technology to fabricate high-performance shallow N^+/P junctions. It is believed that this work can provide an important technical path exploration for theapplication of Ge-based devices.

10:00am **IA1-TuM-7 Molecular Layer Deposition – Versatile Tool for High Performance CNT-Polymer Composites***, Roie Yerushalmi* ***[roie.yerushalmi@mail.huji.ac.il]****,* Edmond J Safra Campus, Givat Ram, Israel

Composite materials, particularly those reinforced with carbon nanotubes (CNTs), are gaining significant attention due to their remarkable strength-to-weight ratio compared to traditional materials. Additionally, these composites exhibit exceptional thermal and electrical properties. However, a primary challenge hindering the widespread application of CNT-reinforced composites arises from the very properties that make them desirable—the CNT Csp^2-Csp^2 network. To enhance the compatibility of CNTs with polymer matrices, modifications to the surface properties of CNTs are necessary. Unfortunately, these modifications often compromise the integrity of the CNT network, creating a significant barrier to progress.To address this challenge, we have developed an innovative vapor-phase approach that utilizes combined Atomic & Molecular Layer Deposition (M/ALD). This method allows for molecular-level precision in tailoring CNT interfaces while minimizing negative impacts on the CNT network. By integrating surface engineering with M/ALD vapor-phase chemistry, we achieve a balanced interaction between non-covalent and covalent bonds with the polymer matrix in a single streamlined process.

This approach facilitates the fine-tuning of physical properties, enabling the design of high-performance CNT-reinforced polymer composites. The combined M/ALD methodology is broadly applicable for engineering the CNT-polymer interphase, providing precise control over surface interactions. Ultimately, this paves the way for the systematic development of high CNT loading composites and other nano-reinforced systems, exhibiting enhanced strength, toughness, and a range of additional desirable properties typical of nanomaterials composites.

Surface Engineering - Applied Research and Industrial Applications

Room Town & Country D - Session IA2-2-TuM

Surface Modification of Components in Automotive, Aerospace and Manufacturing Applications II

Moderators: Satish Dixit, Plasma Technology Inc., USA, **Jan-Ole Achenbach**, KCS Europe GmbH, Germany, **Masaki Okude**, Mitsubishi Materials Corporation, Japan

8:00am **IA2-2-TuM-1 2D Material-Based Coatings for Superlubricity in Dry Sliding and Rolling Contacts***, Diana Berman* ***[diana.berman@unt.edu]****,* University of North Texas, USA **INVITED**

Friction and wear-related failures are critical challenges for modern mechanical systems, affecting applications from microelectromechanical devices to automotive assemblies and biomedical implants. The pressing need to reduce these tribological failures has intensified efforts to design advanced coatings and lubrication solutions tailored to withstand extreme operating conditions. This presentation emphasizes our progress in the precise design of 2D material-based coatings, particularly those using graphene, molybdenum disulfide, and MXene, to achieve superlubricity—an ultra-low friction regime that greatly enhances component lifespan and efficiency.

By establishing a fundamental understanding of material interactions at sliding interfaces, we are able to develop coatings that not only improve performance but also contribute to the reliability and sustainability of tribological systems. These engineered coatings are evaluated for their tribological properties under a range of conditions, demonstrating that superlubricity can be achieved at the macroscale, under high contact pressure and shear conditions. We also propose experimental pathways to realize superlubricity in rolling-sliding contact conditions using solid-lubricant coatings, which could open new opportunities for industrial applications requiring highly durable, low-friction surfaces. Overall, this work lays the groundwork for next-generation tribologically optimized coatings, offering promising solutions for critical sectors reliant on advanced friction and wear management.

8:40am **IA2-2-TuM-3 Exploring Controlled Plastic Deformation as a Preferable Pre-Treatment for Enhanced Tribo-Mechanical Properties of Fundamental Industrial Materials: Design of Wear Resistant Surfaces/sub-Surfaces***, Daniel Toboła* ***[daniel.tobola@kit.lukasiewicz.gov.pl]****, Puneet Chandran,* Łukasiewicz Research Network – Krakow Institute of Technology, Poland*; Łukasz Maj, Jerzy Morgiel,* Institute of Metallurgy and Materials Science of Polish Academy of Sciences, Poland

The need for superior physical, mechanical and tribological properties in modern industrial applications has driven manufacturers to develop advanced materials or provide tailor-made/innovative solutions for utilizing existing high performance materials. Aerospace and automotive industries are known to employ innovative materials like modern steels, titanium alloys, advanced ceramics etc., to meet the exponentially growing demand for 'sustainable' materials, taking into account industrial and economic viability. However, an exclusive solution addressing the increased adaptability of these materials is always inadequate owing to the excellent mix of inherent physical and mechanical properties. Although industry favors a 'one solution' to all materials/problems approach, it is practically impossible to implement it in real time. In this study, we aim to strategically propose solutions to enhance the tribo-mechanical properties of well-known, critical industrial materials like titanium, ceramics (alumina/Si) and advanced steels (Vancron/Vanadis) - through the synergistic effects of cold working and thermo-chemical processing.

The substrates of all the materials were subjected to simple finishing processes like grinding, turning/milling followed by controlled burnishing and shot peening/micro-blasting. Low temperature gas/plasma nitriding formed the last stage of pre-processing. Detailed tribological studies were carried out on all the samples. The nanoscale characterization of the pre-processed samples and the wear track via SEM/TEM revealed the formation of a thin 'tribo zone' with improved tribo-mechanical properties. The nature of tribo zone formed in each material, based on the type of cold working along with thermo chemical treatment will be outlined for all the materials and presented in the conference.

Acknowledgments

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9:00am **IA2-2-TuM-4 Liquid Feedstock Thermal Spraying for Advanced Functional Coatings***, Shrikant Joshi* ***[shrikant.joshi@hv.se]****,* University West, Sweden **INVITED**

Thermal spraying with liquid feedstock offers an exciting opportunity to obtain coatings with characteristics vastly different from those produced using conventional spray-grade powders. The two extensively investigated variants of this technique are Suspension Plasma Spraying (SPS), which utilizes a suspension of fine powders in an appropriate medium, and Solution Precursor Plasma Spraying (SPPS), which involves use of a suitable solution precursor that can form the desired particles *in situ*. The advent of axial injection high power plasma spray systems in recent times has also eliminated concerns regarding low deposition rates/efficiencies associated with liquid feedstock. The 10-100 µm size particles that constitute conventional spray powders lead to individual splats that are nearly two orders of magnitude larger compared to those resulting from the fine (approximately 100 nm - 2 µm in size) particles present in suspensions in SPS or formed *in situ* in SPPS. The distinct characteristics of the resulting coatings are directly attributable to the above very dissimilar 'building blocks' responsible for their formation. This talk will discuss the advancements in suspension and solution precursor thermal spraying associated with axial plasma spraying, with specific emphasis on thermal barrier coating (TBC) and environmental barrier coating (EBC) applications. Prospects of liquid feedstock thermal spraying for addressing some other niche applicationswill be discussed through some illustrative examples. A further extension of deploying solutions and suspensions that involves use of hybrid powder-liquid feedstock combinations for thermal spraying will also presented. This approach can be used to elegantly deposit coatings with unusual microstructures to develop a wide array of composite coatings. The possibilities unplugged by such hybrid feedstock processing will also be illustrated through case studies.

9:40am **IA2-2-TuM-6 Research on HVOF Sprayed WCCoCr Coatings in Terms of Their Use on Sliding Rings of Mechanical Seals**, ***Aleksander Iwaniak [aleksander.iwaniak@polsl.pl]***, Silesian University of Technology, Poland; *Łukasz Norymberczyk,* ANGA Uszczelnienia Mechaniczne Sp. z o.o., Poland; *Grzegorz Więcław,* Certech Sp. z o.o., Poland

In many technical devices, where rotating elements occur and at the same time there is a need to transfer power, mechanical seals are used. This applies to practically every industrial sector, including: machinery, mining, automotive and aviation. Classic examples of such devices are pumps and compressors. The main purpose of using mechanical seals is to ensure the tightness and impermeability of the system. The critical elements of mechanical seals are sliding rings. Practical in all constructions used in industrial conditions, at least one of these rings is usually made of solid ceramic. Due to high requirements for durability, mainly resistance to wear through friction and high resistance to corrosive factors, the rings are most often made of tungsten carbide or silicon carbide.

The paper presents the results of tests on slip rings made of metal, whose working (friction) surfaces were coated with a HVOF thermal spraying technology using WCCoCr powder. This solution, in which a metallic ring core was used, provides very good mechanical properties, mainly impact strength. Thermally sprayed carbide coating on the working surface makes the slip rings highly resistant to wear due to friction. It is comparable to rings made of solid ceramics.

The work presents the results of durability tests of the working surfaces of rings manufactured using the HVOF technique. Specialized research methodology is discussed, including tests in static and dynamic conditions on a stand imitating the actual conditions of the device. The friction systems of rings made of different materials were tested. The condition of the surface layer of the rings after the tests was analyzed using 3D profilometry, SEM, EDS. The tests showed that the analyzed solution is characterized by high durability and has application potential. It should also be noted that this solution fits into the trends of sustainable development and closed circulation - worn slip rings can be regenerated.

Financial support by The National Centre for Research and Development (NCBiR) in Warsaw, Poland - Project No INNOTECHK2/IN2/2/181798/NCBR/13 is gratefully acknowledge.

10:00am **IA2-2-TuM-7 Advanced Coatings for Critical Semiconductor Manufacturing Components**, ***Julien Keraudy [julien.keraudy@oerlikon.com]***, Oerlikon Surface Solutions AG, Liechtenstein; *Matthew Kirk,* Oerlikon Surface Solutions AG, USA; *Venkateswarlu Kuchi,* Oerlikon Surface Solutions AG, Liechtenstein; *John Coniff,* Oerlikon Surface Solutions AG, USA; *Klaus Boebel, Florian Rovere,* Oerlikon Surface Solutions AG, Liechtenstein

The semiconductor industry is experiencing unprecedented growth, driven by the increasing demand for advanced technologies such as artificial intelligence, electric vehicles, and high-performance computing. This boom has led to a projected market value of $1 trillion by 2030. To meet this demand, semiconductor manufacturers are under pressure to enhance production efficiency and reduce the cost of ownership. High throughput in semiconductor manufacturing is essential to achieve these goals, as it directly impacts production capacity and operational costs. The semiconductor industry relies heavily on specialized equipment to produce microchips and other semi-conductor devices. These machines, tasked with operating in highly demanding environments, require durable, precise, and dependable mechanical components to function optimally and with high reliability. High-quality coatings applied over inexpensive substrates offer a promising approach to meet the stringent demands of next-generation semiconductor manufacturing. These coatings can replace expensive monolithic materials without compromising performance, significantly reducing metallic contamination and improving the cost of ownership (CoO). This paper explores the development and application of advanced coatings by PVD or PECVD deposition methods for critical semiconductor manufacturing components. These advanced coatings enhance the longevity and efficiency of semiconductor manufacturing components, including but not limited to wafer stages, E-Chucks, and chamber liners by offering as an example superior wear resistance, reduce friction and improve lubricity, lower particulate generation under aggressive corrosive environment.

Surface Engineering - Applied Research and Industrial Applications
Room Palm 1-2 - Session IA3-TuA

Innovative Surface Engineering for Advanced Cutting and Forming Tool Applications

Moderators: Alessandro Bertè, Lafer SpA, Italy, **Markus Esselbach**, Oerlikon Balzer, Liechtenstein

1:40pm **IA3-TuA-1 Natural Rock Star: PVD-Functionalizing of Nature-Derived Materials for Cutting Applications**, *Wolfgang Tillmann, **Dominic Graf [dominic.graf@tu-dortmund.de]**, Nelson Filipe Lopes Dias,* TU Dortmund University, Germany*; Bernd Breidenstein, Berend Denkena, Benjamin Bergmann, Hilke Petersen,* Leibniz Universität Hannover, Germany

The manufacturing process of traditional cutting materials such as cemented carbide involves significant energy consumption and costly raw materials that are often linked to environmental harm during extraction. To address these concerns, there is a growing demand for developing sustainable cutting materials. In this context, natural materials are both environmentally friendly and abundant. Natural rocks, in particular, are promising due to their hardness, which typically ranges from 8 to 16 GPa depending on the rock type. The suitability of these natural materials for machining can be enhanced via functionalization of the surface properties by applying a protective thin film using physical vapor deposition (PVD) technology.

Preliminary studies show the suitability of various rock types as cutting material. Cutting inserts are crafted from these natural rocks and subsequently ground. A TiN thin film is deposited onto the various natural rock inserts using a magnetron sputtering process. The resulting TiN thin films crystallize in a cubic structure on all rock types. The obtained hardness values are comparable to TiN thin films grown on tool steel. In contrast to a polished surface, a ground surface of the natural rocks promotes good adhesion of the TiN thin films. To assess the cutting performance and wear characteristics of PVD-coated natural rocks, turning tests are conducted using the aluminum alloy Al7075. The TiN thin film significantly enhances wear resistance, thus extending the service life of the cutting inserts. Additionally, it is observed that the distinct material properties of the natural rocks significantly affect the wear behavior. Rock types with a more homogeneous structure demonstrate improved wear resistance over extended cutting lengths.

To analyze the effect of the substrate on the TiN thin film adhesion three different glass substrates were chosen as surrogates for natural rocks. Glasses are particularly suitable as surrogates because of their similar SiO2 content. The investigations reveal a strong influence of the stress state on the adhesion, as TiN on window glass shows weaker adhesion due to high compressive residual stresses. The possible adaptation of thin film design strategies developed for glass onto natural rock surfaces is evaluated. The utilization of a PVD-coated natural rock emerges as a promising concept for broadening the spectrum of cutting materials and promoting sustainability in their manufacturing. A tailored adjustment of the grinding process for cutting inserts with an adapted thin film design is anticipated to further elevate the cutting performance of natural rock inserts.

2:00pm **IA3-TuA-2 Effect of Si Alloying on CrN Coatings Deposited by S3p Technology for Plastic Processing Applications**, ***Alessandro Togni [alessandro.togni@oerlikon.com]**, Denis Kurapov, Thomas Vermland,* Oerlikon Surface Solutions AG, Liechtenstein

In the plastic processing industry, molds and tooling components are frequently exposed to chemically aggressive environments, particularly when handling plastics containing halogenated and phosphorus-based flame retardants. While CrN coatings generally offer good corrosion resistance, their wear resistance may fall short when processing plastic formulations containing highly abrasive additives such as glass fibers or hard polymers like polycarbonate. In addition, achieving an ultra-smooth surface finish is essential for producing mirror-polished plastic components, requiring deposition techniques that enhance surface quality while ensuring precise control over coating thickness to meet stringent dimensional tolerances.

To address these challenges, we developed Si-alloyed CrN coatings using Oerlikon Balzers' Scalable Pulsed Power Plasma (S3p) technology. Si-doped Cr targets with varying Si concentrations were employed to systematically investigate the effect of Si content on the microstructure and mechanical properties of the coatings.

Our findings revealed that all coatings exhibited a cubic CrN phase and a columnar growth morphology. Increasing the Si content progressively refined the grain structure and induced higher compressive residual stress levels, thus improving mechanical performance. Notably, the hardness of the coatings increased by up to 50% at approximately 5 at.% Si while maintaining a consistent elastic modulus, resulting in a higher H/E ratio—a key indicator of wear resistance. These results highlight the potential of Si-alloyed CrN coatings as a promising solution for extending the lifespan of molds and tooling components in demanding plastic processing environments.

2:20pm **IA3-TuA-3 Tailoring PVD Coatings by Electro-Magnetic Fields Generated by Coil Systems for Cathodic Arc Evaporation**, ***Dominic Stangier [dominic.stangier@oerlikon.com]**,* Oerlikon Balzers Coating Germany GmbH, Germany

Cathodic arc evaporated (CAE) coatings are dominating the field of wear resistant PVD thin films for tools due to their excellent adhesion, high deposition rates and outstanding performance as well as service life in industrial scale applications. An established approach to control the movement of the arc spot on the cathode surface during the deposition process is the use of static magnetic fields, which are generated by a defined arrangement of permanent magnets placed close to the cathode material. However, this solution is strongly limited in its setting options and does not consider any dynamic effects such as an increasing magnetic field strength caused by changes of the erosion profile of the cathode material or adjusted evaporator currents. To overcome these challenges and limitations of CAE processes electro-magnetic fields generated by coil systems (CS) are a promising approach to precisely control and adjust the magnetic field design and strength and therefore enable the possibility of tailored and improved properties of PVD coatings. Due to this reason, a coil system consisting of an inner and outer independently controllable coil, which additionally allows switching of the polarity was used for an industrial scale arc source (APA evaporator) as well as in combination with permanent magnets. It was found, that besides the higher material utilization compared to permanent magnetic setups for cathodic arc materials, the adjustment of the magnetic field by APA CS enables the possibility of maintaining the desired fcc-structure for high Al-contents in Al-rich AlTiN coatings. Additionally, this dedicated setup can be used for challenging CAE processes for “hard to evaporate materials” in combination with a dynamically controlled magnetic field for steering the arc spot. A homogenous erosion profile of the cathode material was achieved for the deposition of carbon coatings with adjustable hardness profile.

2:40pm **IA3-TuA-4 Advanced Cyclic Load Resistance of AlXN Coatings for Metal Forming Applications**, ***Simon Evertz [simon.evertz@eifeler-vacotec.com]**, Stefan A. Glatz, Tobias Oellers, Markus Schenkel,* voestalpine eifeler Vacotec GmbH, Germany

Cyclic loading is critical for the industrial application of PVD coatings, especially in metal forming applications. With the increasing interest in using thin super-high-strength steel sheets for forming bodies/parts with reduced component weight, light-weight design and less fuel consumption could be achieved for example in automotive industry. Consequently, the loads become more demanding on molding dies and therewith protective coatings. These applications require coatings resistant to cyclic mechanical and/or thermal loading and fatigue. The specific structure of voestalpine eifeler’s Duplex-VARIANTIC® -1400-plus with its multiple hard material AlXN layers overcomes the very demanding requirements in terms of strength, hot-hardness, and load-bearing capacity in such metal forming applications and outperforms other commercially used hard nitride protective coatings. This property profile makes voestalpine eifeler’s Duplex-VARIANTIC®-1400-plus the optimal solution for metal forming high-strength and advanced high-strength steel sheets.

3:00pm **IA3-TuA-5 Bistability and Process Control in Electrolytic Plasma Processes**, ***Nicolas Laugel [nicolas.laugel@manchester.ac.uk]**, Aleksey Yerokhin, Allan Matthews,* The University of Manchester, UK

Electrolytic Plasma Processes (EPP) encompass a variety of surface modification techniques, leveraging high power densities in aqueous electrolytes to induce plasma-assisted reactions at material interfaces. These processes have diverse applications, including Electrolytic Plasma Polishing (EPPo), thermal diffusion-based hardening, Cathodic Plasma Discharge Electrolysis (CPDE) for surface cleaning or superficial inclusion of trace metallic dopants, and Plasma Electrolytic Oxidation for ceramic coatings on valve metals. Their relevance spans major manufacturing fields, particularly in the automotive, aerospace, tooling and medical sectors. Since EPP are independent of workpiece geometry and rely on harmless electrolytes, they are uniquely well-suited for finishing additively manufactured components. Yet despite their versatility, EPP development remains constrained by the complex interplay of electrochemical and physical effects. In particular, the emergence of a bistable regime - caused by the coupling between rapid electrochemical reactions and slower evolution of gas phases in the electrolyte - often renders a large portion of the electrical parameter space practically inaccessible.

We introduce a basic first-principle model able to capture the essential dynamics of bistability without distracting complexity. This model serves as a guide to predict the qualitative effects of varying key process parameters. We identify qualitative convergences as well as discrepancies between model-based predictions and experimental observations in industrially-relevant conditions, using ammonium sulfate-based electrolytes and stainless steel workpieces. The parameters explored include the polarity of EPP, electrolyte composition, temperature, and electric field distribution, manipulated via radius of curvature of the treated surface. Particular attention is given to the parameters impacting the boundary between stable and bistable regimes under these conditions.

Since industrial applications of EPP typically favor conservative approaches that prioritize process stability, improving the predictability of bistability regime boundaries is an immediately relevant opportunity for fine-tuning. This could lead to optimizations in energy efficiency, processing time, and uniformity. Furthermore, recognizing the role of transient states and harnessing them may inspire innovative surface engineering strategies, expanding the potential of EPP beyond current implementations.

Surface Engineering - Applied Research and Industrial Applications
Room Golden State Ballroom - Session IA-ThP

Surface Engineering – Applied Research and Industrial Applications Poster Session

IA-ThP-1 Metallurgical Coating by Laser Metal Deposition of H13 Steel Powder for Die Repairs*, **Sheila Carvalho [sheila.m.carvalho@ufes.br]**,* Federal University of Espirito Santo, Brazil*; Vagner Braga,* Bruning Tecnolometal Co., Brazil*; Rafael Siqueira, Kahl Zilnyk,* Technological Institute of Aeronautics, Brazil*; Johan Nuñes,* University of Sao Paulo, Colombia*; Reginaldo Coelho,* University of Sao Paulo, Brazil*; Milton Lima,* Institute for Advanced Studies, Brazil

The H13 tool steel is a typical hot-work material that exhibits superior thermal resistance, excellent hardness, and exceptional resistance to high-temperature fatigue and wear. This steel is also characterized by its high resistance to softening at temperatures below 540 °C and is extensively used to produce hot forging dies, hot extrusion channels, and high-pressure dies for low-melting-point metals such as aluminum and magnesium. Components made of H13 steel wear out over time and must be replaced, generating high costs and considerable environmental impact. One way to mitigate these problems is through repair using metallurgical coatings, which involve machining the worn area of the tool and depositing one or more layers of H13 steel using thermal means, notably with a laser beam. In this study, the microstructural and mechanical properties of H13 powder deposited via laser metal deposition (LMD) on H13 hot-work tool steel substrates were examined before and after heat treatment. Scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), and electron backscatter diffraction (EBSD) were used to analyze the grain distribution, layer development, and carbide incidence. The mechanical properties were evaluated by Vickers hardness indentation tests. An α-ferrite matrix consisting of α'-martensite was identified along with a crack-free interface containing Mo- and Cr-rich precipitates between the cladded H13 steel and substrate. The EBSD results showed a highly consistent combination between the deposition and substrate, along with a structure consisting of columnar and equiaxial grains resulting from the directional solidification process. Wear resistance tests demonstrated that the H13-deposited region was in a better condition than the substrate because of the presence of martensite and carbides in the matrix, and the average wear decreased from 3.8×10^{-4} mm^3/Nm to 0.5×10^{-4} mm^3/Nm from the substrate to the laser cladding. The measured coefficient of friction for the die-repaired H13 rods did not undergo significant changes after laser cladding, with a COF of ~ 0.8. The average hardness levels of the substrate and deposition regions were determined to be 213 HV (α-Fe) and 671 HV (α'), respectively. The smooth transition in terms of hardness between the regions also indicates a tendency for lower stress concentrations. The results indicate that metallurgically coated H13 steel could be used to repair hot forming tools that extend the lifetime and decrease the discard of high-value components.

IA-ThP-2 Effects of Cathodic Current Density on the Growth Mechanism and Corrosion Resistance of Micro-Arc Oxidation Coatings on AZ31 Magnesium Alloy*, Shih-Yen Huang, **Chi-Hua Chiu [qiuqihua90@gmail.com]**, Yu-Ren Chu, Yueh-Lien Lee,* National Taiwan University, Taiwan

Despite decades of development, many growth mechanisms and properties of the micro-arc oxidation (MAO) process remain unclear, limiting further advancements in this surface treatment. Numerous studies have identified trends in MAO process parameters under specific conditions; however, altering these conditions often leads to varied results, highlighting the need for in-depth mechanistic studies. In this study, we address aspects of the formation mechanism of MAO under cathodic bias control. Preliminary results show that, while maintaining the electric current at a constant value, varying the cathodic current density significantly affects the microstructure and anti-corrosion properties of MAO coatings on AZ31B Mg alloy. Specifically, when the cathodic current density exceeds the anodic current density, a distinct cross-sectional microstructure develops, leading to a significant decrease in corrosion resistance. These findings demonstrate that the instantaneous cathodic current density critically influences the growth path of MAO coatings, altering their microstructure and, ultimately, their corrosion resistance.

IA-ThP-3 Suppression of Ionizing Radiation-Induced Degradation in Gate-All-Around Field Effect Transistor by Structural Surface Engineering*, **Kuei-Shu Chang-Liao [lkschang@ess.nthu.edu.tw]**,* National Tsing Hua University, Taiwan*; Dun-Bao Ruan,* Fuzhou University, China*; Shang-Hua Hsu,* National Tsing Hua University, Taiwan

Nowadays, Fin field effect transistors (FinFETs) were widely applied to follow the Moore's law at 14 nm technology node, and it is also believed that the gate all around field effect transistor (GAAFET) will become primary device architecture eventually. With the continuous scaling trend, the high-energy extremely ultraviolet has become the most promising light source for next-generation lithography. Hence, the radiation exposure on FinFET or GAAFET devices might be regarded as one of reliability issues in terms of lifetime and stability. In this work, an abnormal ionizing radiation damage suppression effect, which is related to the multi-gate structure, has been discussed in detail. It may provide an important theoretical foundation for the future device design and fabrication.

IA-ThP-4 Investigating the Impact of Rapid Thermal Annealing on the Interface between Sputtered Tellurium Capping Layer and Tin Monoxide Thin Films*, **Kai-Jhih Gan [jameswsalebron@gmail.com]**, Jialong Xiang,* Fuzhou University, China*; Bo-Syun Syu,* National Tsing Hua University, Taiwan*; Dun-Bao Ruan,* Fuzhou University, China*; Kuei-Shu Chang-Liao,* National Tsing Hua University, Taiwan

Herein, rapid thermal annealing (RTA) was employed to modulate the interface between the tellurium (Te) capping layer and tin monoxide (SnO) thin films, followed by a comprehensive structural and material characterization. X-ray diffraction was used to investigate the crystallographic evolution of Te-capped SnO films before and after RTA treatment, while interfacial chemical composition changes were characterized via X-ray photoelectron spectroscopy. Furthermore, the structural characteristics of field-effect transistors (FETs) fabricated with Te-capped SnO films were examined using transmission electron microscopy and energy-dispersive spectroscopy. The results reveal that RTA facilitates Te diffusion into the SnO layer and effectively modulates interfacial defect concentration. Under optimized conditions, the carrier concentration of the Te-capped SnO films exhibited a significant increase, highlighting the critical role of interface engineering in enhancing material properties.

IA-ThP-5 Surface Engineering Induced Improved Resistive Switching Characteristics of Wide Bandgap Amorphous Oxide Semiconductor Thin Films with Plasma Enhanced Rapid Thermal Annealing*, **Jialong Xiang [jialongxiang8@gmail.com]**, Dun-Bao Ruan, Kai-Jhih Gan,* Fuzhou University, China*; Bo-Syun Syu, Kuei-Shu Chang-Liao,* National Tsing Hua University, Taiwan*; Qiancheng Yang,* Fuzhou University, China

In this study, surface engineering of a wide bandgap amorphous oxide semiconductorgallium oxide (Ga_2O_3) thin film was carried out by using rapid thermal annealing, plasma treatment, and plasma enhanced rapid thermal annealing treatment, followed by a systematic analysis of material analysis and resistive switching characteristics. The surface morphology and structure of Ga_2O_3 thin films with different surface treatments were characterized by using scanning electron microscopy, X-ray diffraction, and atomic force microscopy. Furthermore, X-ray photoelectron spectroscopy was employed to analyze the oxygen vacancy concentration in the films under different treatment conditions. The influence of oxygen vacancy concentration on the resistive switching characteristics of Ga_2O_3 was also thoroughly investigated. Thanks to the precise control of oxygen vacancy distribution and improved thin film quality, the sample with plasma enhanced rapid thermal annealing treatment is promising for memristor application.

IA-ThP-7 Greybox Models for Wear and Service Life Predictions of Coated Cutting Tools*, Kirsten Bobzin, **Christian Kalscheuer [Kalscheuer@iot.rwth-aachen.de]**, Muhammad Tayyab,* Surface Engineering Institute - RWTH Aachen University, Germany

Due to the complex correlations involving coating properties, cutting tool materials, workpiece materials and process parameters, accurate wear prediction of the coated cutting tools remains a significant challenge. Analytical or simulation-based whitebox models mostly overlook the influence of coatings on tool wear and struggle to predict the instationary tool geometry changes during the cutting processes because of simplified boundary conditions. On the other hand, data-driven blackbox models may characterize the complex correlations but lack physical interpretability and robustness under varying conditions. As a result, imprecise tool life prediction models hinder the cost-effective qualification of coated cutting tools. To overcome these limitations, the combined strengths of whitebox and blackbox models can be leveraged with greybox modelling for accurate tool wear predictions. Greybox models require comprehensive datasets consisting of coating properties, realistic thermomechanical tool loading, cutting process data and tool wear behavior.

The priority research program SPP 2402, funded by German Research Foundation (DFG), is focused on development of such greybox models with holistic solution approach summarized in figure 1. Moreover, existing whitebox models will be improved for realistic calculations of coated tool thermomechanical loading. In addition to tool qualification, the greybox models may also advance the understanding of transient system behavior of coated cutting tools for knowledge-based development of coatings and cutting processes.The SPP 2402 consortium comprises of 11 research projects with interdisciplinary institutional collaborations in the fields of tool coatings, cutting processes, material technology and data processing. Moreover, 13 companies from the cutting tools business form the industrial advisory board. Five working groups with specific focus on residual stress measurement, cutting simulation, tool modeling, thermal conductivity and machine learning are supporting synergetic development of greybox models within the SPP 2402.

IA-ThP-8 Comparative Study of Nanometric Interface layers (NiCr, Ti) used in Stacks of Low-Emissivity Glazing, ***Hervé Montigaud* *[herve.montigaud@saint-gobain.com]***, SVI joint Unit CNRS/ Saint Gobain, 41 quai Lucien Lefranc, Aubervilliers, France; *Justine Voronkoff,* Saint Gobain Research Paris, 41 quai Lucien Lefranc, Aubervilliers, France; *Ekaterina Chernyscheva,* SVI joint unit CNRS/Saint Gobain Aubervilliers, France; *Rémi Lazzari,* Institut des NanoSciences de Paris, CNRS/Sorbonne Université, Paris, France, France; *Ludovic Largeau,* Centre de Nanosciences et de Nanotechnologies, CNRS/U. Paris-Saclay, Palaiseau France; *Denis Guimard, Xavier Caillet,* Saint-Gobain Research Paris, 41 quai Lucien Lefranc, F-93303 Aubervilliers, France

Functionalized glazing for reinforced thermal insulation such as low-emissivity products comprise a stack of thin layers (from 1 to a few tens of nanometers) of dielectrics, semiconductors and metals including a 10nm thick layer of silver. The performances of the glazing involve optimized reflection of far infrared radiation while maintaining high transmission of visible light. Sub-nanometric layers of titanium or nickel-chromium alloy are commonly used at the interfaces of the Ag layer. These layers improve the adhesion properties (rather poor [1]) of silver with the adjacent layers (mainly zinc oxide) but above all protect, the silver from oxidizing species during the magnetron sputtering deposition process and during thermal post-treatments.

This work presents the characteristics (*ie* the nanostructure and the oxidation state) of these nanometric layers commonly called "blocker layers" which are not the same whether it is located at the upper or the lower interface. The consequences on the properties of the silver layer also differ. Furthermore, their behavior during thermal post-treatment varies according to the nature of the blocker layer. Due to the complexity of the systems [ZnO/blocker/Ag], we have started to focus on simplified ones such as blocker/ZnO. In contact with ZnO, nickel oxidizes and diffuses into the adjacent layers [2] while titanium oxidizes to form metallic zinc which then diffuses [3]

IA-ThP-9 PVD Duplex Treatment of AISI M2 high speed steel additively manufactured by metal binder jetting, ***Julia Urbanczyk* *[julia.urbanczyk@tu-dortmund.de]***, *Nelson Filipe Lopes Dias, Tim Schäfer,* TU Dortmund University, Germany; *Patrick Köhnen, Simon Höges,* GKN Powder Metallurgy, Germany; *Wolfgang Tillmann,* TU Dortmund University, Germany; *Dominic Stangier,* Oerlikon Balzers Coating Germany GmbH, Germany

In tool manufacturing, additive manufacturing (AM) enables the production of tool steels with complex geometries, integrated cooling channels, and reduced machining post-processing. Among AM techniques, metal binder jetting (MBJ) stands out due to its high build rate and lower production costs. MBJ is a two-step process involving the printing of green bodies followed by sintering. Recent advancements have allowed the production of high-speed steel AISI M2 by MBJ. To enhance wear resistance and service life, tool steels typically undergo a duplex treatment comprising plasma nitriding and the deposition of a PVD thin film. Since MBJ-produced AISI M2 exhibits a distinct microstructure compared to conventionally manufactured AISI M2, its impact on the nitrided layer and subsequent PVD thin film properties has not yet been investigated. For this reason, both MBJ and conventionally manufactured AISI M2 with comparable hardness underwent duplex treatment, consisting of 2 h of plasma nitriding followed by cathodic arc-evaporated TiAlN thin film deposition.

For both steel types, plasma nitriding generated a diffusion layer of 20 µm without a compound layer and increased the surface hardness to 20 GPa due to N solubility in the α-Fe lattice. The similar nitrided layer properties are attributed to the nearly identical chemical composition and lattice parameter of the steels, promoting comparable interstitial diffusion of N in martensite. Regardless of the manufacturing method, the TiAlN thin film exhibited consistent hardness of 33-34 GPa. However, adhesion behavior of TiAlN was influenced by both plasma nitriding and the manufacturing method. Plasma nitriding improved adhesion strength by increasing the mechanical support, though slightly lower critical loads were observed for TiAlN on MBJ-produced AISI M2. This could be attributed to the larger grains and open porosity, which may promote adhesive failure and crack propagation. Nevertheless, adhesion strength was very high on both steel substrates. In tribological tests, the TiAlN thin film significantly enhanced wear resistance by preventing abrasive wear against the 100Cr6 counterpart. Overall, duplex treatment proves to be an effective method for improving the wear resistance of AM tool steels, though the influence of microstructural differences on thin film adhesion should be considered. Based on these results, MBJ shows great potential for additive manufacturing of tool steels suitable for subsequent PVD duplex treatment with thin film properties comparable to thin films grown on conventionally manufactured tool steels.

IA-ThP-10 Electrolytic Plasma Polishing of Ti 6Al-4V in Aqueous and Deep Eutectic Solvents, ***Nicolas Laugel [nicolas.laugel@manchester.ac.uk]***, *Aleksey Yerokhin, Allan Matthews,* The University of Manchester, UK

Electrolytic plasma polishing (EPPo) is a promising technique for refining metal surfaces, particularly in post-processing additive-manufactured components. However, the sustainability of EPPo depends heavily on electrolyte longevity and environmental impact. We present two key approaches to improving electrolyte efficiency in Ti 6Al-4V EPPo.

First, we investigate strategies to extend the useful lifespan of a proprietary fluoride-based aqueous electrolyte, in order to reduce waste production and process downtime. Second, we explore a deep eutectic solvent as electrolyte, which eliminates fluorides while enabling pulsed electrical inputs—an approach typically unstable in aqueous systems. These innovations aim to enhance the viability of EPPo for industrial adoption, minimizing resource consumption while maintaining high-quality surface finishing. The findings offer insights into electrolyte ageing mechanisms and the potential of DES electrolytes for sustainable, high-precision polishing of titanium and other valve metals.

IA-ThP-11 Microstructure and Properties of Oxide Coatings Produced on Aluminum Tape, ***Aleksander Iwaniak [aleksander.iwaniak@polsl.pl]***, *Andrzej Posmyk, Adrian Krysiak,* Silesian University of Technology, Poland

The windings of electric motors are made of copper wires. Due to the high density of this element, work is underway to replace copper wires with aluminum tapes. The windings of the valve timing actuators of combustion engines and the windings of electric motors of individual electric vehicle drives can be made of insulated aluminum tapes, which will reduce their weight.

The aim of the work was to determine the effect of the conditions of electrolytic oxide coating production on their insulating properties in terms of the application of aluminum tapes to electrical windings. As part of the research work performed, the possibility of shaping the insulating properties of oxide coatings by selecting the chemical composition of the electrolyte and oxidation parameters was determined.

As part of the conducted research, the microstructure and surface topography of the produced oxide layers were determined using electron microscopy (SEM, EDS) and 3D profilometry. The breakdown voltage of the anodized oxide layers was measured to determine the dielectric strength. In the case of selected process parameters, it was possible to obtain oxide layers with a continuous structure, without cracks. Breakdown tests showed that for some of the produced coatings the breakdown voltage Up was over 300V. The produced coatings could be conditionally used for electrical insulation.

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Coelho, Reginaldo: IA-ThP-1, 8
Coniff, John: IA2-2-TuM-7, 5
Costa, Felipe: IA2-1-MoA-3, 1
Coulmy, Nicolas: IA2-1-MoA-6, 1
— D —
Denkena, Berend: IA3-TuA-1, 6
— E —
Esselbach, Markus: IA2-1-MoA-11, **2**
Evertz, Simon: IA3-TuA-4, **6**
— F —
Fransen, Geert-Jan: IA2-1-MoA-5, 1
Fuchs, Andreas: IA2-1-MoA-5, 1
— G —
Gabriel, Herbert: IA1-TuM-4, **3**
Gan, Kai-Jhih: IA-ThP-4, **8**; IA-ThP-5, 8
Glatz, Stefan A.: IA3-TuA-4, 6
Graf, Dominic: IA3-TuA-1, **6**
Guimard, Denis: IA-ThP-8, 9
Guimond, Sebastien: IA2-1-MoA-10, 2
— H —
Hagenmuller, Pascal: IA2-1-MoA-6, 1
Herody, Jean: IA2-1-MoA-6, 1
Hoche, Holger: IA2-1-MoA-5, 1
Höges, Simon: IA-ThP-9, 9
Hsu, Shang-Hua: IA-ThP-3, 8
Huang, Shih-Yen: IA2-1-MoA-4, 1; IA-ThP-2, 8
— I —
Immich, Philipp: IA2-1-MoA-5, **1**
Iwaniak, Aleksander: IA2-2-TuM-6, **5**; IA-ThP-11, **9**
— J —
Jaggi, Matthias: IA2-1-MoA-6, 1
Janowitz, Julia: IA2-1-MoA-5, 1
Jaoul, Cedric: IA2-1-MoA-10, 2
Joshi, Shrikant: IA2-2-TuM-4, **4**
— K —
Kalscheuer, Christian: IA-ThP-7, **8**
Keraudy, Julien: IA2-2-TuM-7, **5**
Kirk, Matthew: IA2-2-TuM-7, 5
Köhnen, Patrick: IA-ThP-9, 9
Kolev, Ivan: IA2-1-MoA-5, 1
Krysiak, Adrian: IA-ThP-11, 9
Kuchi, Venkateswarlu: IA2-2-TuM-7, 5
Kurapov, Denis: IA3-TuA-2, 6
— L —
Largeau, Ludovic: IA-ThP-8, 9
Laugel, Nicolas: IA3-TuA-5, **6**; IA-ThP-10, **9**
Lazzari, Rémi: IA-ThP-8, 9
Lee, Yueh-Lien: IA2-1-MoA-4, 1; IA-ThP-2, 8
Lefebvre, Pauline: IA2-1-MoA-6, **1**
Liang, Huan-Chang: IA2-1-MoA-9, **2**
Lima, Milton: IA2-1-MoA-3, **1**; IA-ThP-1, 8
Lopes Dias, Nelson Filipe: IA3-TuA-1, 6; IA-ThP-9, 9
Lyu, Yezhe Lyu: IA2-1-MoA-8, 2
— M —
Maerten, Thibault: IA2-1-MoA-10, 2
Maj, Łukasz: IA2-2-TuM-3, 4
Mantoux, Arnaud: IA2-1-MoA-6, 1
Matthews, Allan: IA3-TuA-5, 6; IA-ThP-10, 9
Montigaud, Hervé: IA-ThP-8, **9**
Morgiel, Jerzy: IA2-2-TuM-3, 4
— N —
Neils, William K.: IA1-TuM-1, 3
Nie, Xueyuan: IA2-1-MoA-8, 2
Norymberczyk, Łukasz: IA2-2-TuM-6, 5
Nuñes, Johan: IA-ThP-1, 8
— O —
Oellers, Tobias: IA3-TuA-4, 6
— P —
Petersen, Hilke: IA3-TuA-1, 6
Polcik, Peter: IA2-1-MoA-5, 1
Posmyk, Andrzej: IA-ThP-11, 9
— R —
Rovere, Florian: IA2-2-TuM-7, 5
Ruan, Dun-Bao: IA1-TuM-3, 3; IA1-TuM-6, 3; IA-ThP-3, 8; IA-ThP-4, 8; IA-ThP-5, 8
— S —
Schäfer, Tim: IA-ThP-9, 9
Schenkel, Markus: IA3-TuA-4, 6
Siqueira, Rafael: IA2-1-MoA-3, 1; IA-ThP-1, 8
Spagna, Stefano: IA1-TuM-1, 3
Stangier, Dominic: IA3-TuA-3, **6**; IA-ThP-9, 9
Su, Chu-Chun: IA1-TuM-3, 3
Syu, Bo-Syun: IA1-TuM-6, **3**; IA-ThP-4, 8; IA-ThP-5, 8
— T —
Tayyab, Muhammad: IA-ThP-7, 8
Tegelaers, Louis: IA2-1-MoA-5, 1
Tillmann, Wolfgang: IA3-TuA-1, 6; IA-ThP-9, 9
Toboła, Daniel: IA2-2-TuM-3, **4**
Togni, Alessandro: IA3-TuA-2, **6**
Tristant, Pascal: IA2-1-MoA-10, 2
Trivedi, Chinmay: IA2-1-MoA-5, 1
— U —
Ulrich, Thomas: IA2-1-MoA-5, 1
Urbanczyk, Julia: IA-ThP-9, **9**
— V —
Vercoulen, Huub: IA2-1-MoA-5, 1
Vermland, Thomas: IA3-TuA-2, 6
Voronkoff, Justine: IA-ThP-8, 9
— W —
Wahlström, Jens: IA2-1-MoA-8, 2
Wang, Chaur-Jeng: IA2-1-MoA-9, 2
Wang, Sea-Fue: IA1-TuM-2, 3
Więcław, Grzegorz: IA2-2-TuM-6, 5
Wolfsperger, Fabian: IA2-1-MoA-6, 1
Wu, Po-Chun: IA1-TuM-6, 3
— X —
Xiang, Jialong: IA-ThP-4, 8; IA-ThP-5, **8**
— Y —
Yang, Qiancheng: IA-ThP-5, 8
Yerokhin, Aleksey: IA3-TuA-5, 6; IA-ThP-10, 9
Yerushalmi, Roie: IA1-TuM-7, **4**
— Z —
Zilnyk, Kahl: IA-ThP-1, 8