

# Friday Morning, April 24, 2026

## Surface Engineering - Applied Research and Industrial Applications

### Room Town & Country D - Session IA1-FrM

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

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

8:00am **IA1-FrM-1 Effect of Alumina Coating and Testing Condition on Tribological Behaviors and the Oxidative Potential of Brake Wear Particles**, Minh Khoi Phan, Ran Cai, Xueyuan Nie [xnjie@uwindsor.ca], Jimi Tjong, University of Windsor, Canada; D.T.A. Matthews, University of Twente, Netherlands

Brake wear particles (BWPs) are known for contributing to adverse respiratory and cardiovascular health outcomes primarily via their oxidative potential (OP). Plasma electrolytic aluminating (PEA) coating can reduce wear and corrosion of cast iron brake rotor and thus BWPs. However, the effect of the alumina coating and testing conditions on OP of BWPs has not been characterized yet. In this study, BWPs were generated and collected after pin-on-disc (POD) wear test, brake dynamometer test and vehicle road test, respectively. Besides the study on tribological behavior of uncoated and PEA-coated brake disc, the ascorbic acid (AA) depletion assay was used to investigate the OP behavior of those BWPs. The results showed that BWPs from the uncoated brake system exhibited a higher AA depletion rate (meaning a higher OP), whereas those from PEA-coated brake system showed a lower depletion rate after both POD test and dyno test cases. This difference was consistent with the metallic content in BWPs. The AA depletion rate was higher for BWPs from the dyno test than from POD test, suggesting significance in negative impact of high dyno braking temperature. Effect of road environment during the vehicle driving test was even more profound. Given a similar tribological behavior and considerable reduction in wear of the coated brake system, this indicates that PEA coating technique can reduce overall oxidative burden and thus reduce harm to health without compromising the braking performance.

8:20am **IA1-FrM-2 Memristive Effects in PEO Alumina: Mechanisms and Technical Implications**, Aleksey Rogov, Allan Matthews, Aleksey Yerokhin [Aleksey.Yerokhin@manchester.ac.uk], University of Manchester, UK **INVITED**

Modern trends towards sustainable, resource- and energy efficient manufacturing bring surface engineering of light alloys at the forefront of research interest. Plasma Electrolytic Oxidation (PEO) attracts significant attention as an advanced technology platform for high-performance ceramic coatings on light alloys, which enables lightweighting of structural components, improved protection from wear and corrosion as well as development of new functional devices and consumer products. PEO is an electrochemical technique which utilises pulsed bipolar polarisation to grow anodic oxides above the potentials of dielectric breakdown. A large number of experimental variables and significant non-linearity provide major challenges for process optimisation, diagnostics and control, hindering its broader adoption in industry. We attempt to address these challenges by developing a mechanistic understanding of the behaviour of metal-oxide-electrolyte systems using original in-operando process diagnostic techniques. Recent studies of PEO treatments of Al indicate that this behaviour is influenced by dynamic rearrangements in the barrier layer of the anodic alumina grown under alternating cathodic and anodic polarisation. In contrast to common presentation of anodic oxides as dielectric barriers, the revealed dependence on polarisation history implies that such films should be treated as a memristive structures. This new understanding allows explaining unusual discharge behaviour observed during PEO treatments, including soft sparking transition and appearance of scanning waves propagating perpendicular to the direction of electric field. Although the barrier layer occupies a small portion of PEO coating located at the interface with the metal substrate, its evolution appears to influence both structural and morphological transformations in the whole coating. The presentation will therefore discuss the mechanisms underlying structural rearrangements in the barrier layer, their practical significance and implications for process energy efficiency and real-time control over coating characteristics and properties.

9:00am **IA1-FrM-4 Advanced Coating Strategies to Combat Friction and Wear in Low-Viscosity Fuel Systems**, Eun Cairns [Euan.Cairns@woodward.com], University of North Texas, USA; Satish Dixit, S. Berkebile, Plasma Technology Inc., USA; Diana Berman, Samir M. Aouadi, Andrey A. Voevodin, University of North Texas, USA **INVITED**

Fuel pump components operating with low-viscosity hydrocarbon fuels (< 3 cSt) experience high failure rates due to poor lubricity, leading to scuffing, seizure, and accelerated wear in boundary-lubricated metal contacts. Conventional steel surfaces, both uncoated and coated, are particularly vulnerable under these conditions. This work investigates advanced coating strategies to mitigate friction and wear in multi-fuel pump environments, focusing on hard wear-resistant coatings, soft solid lubricant films, and duplex systems.

A systematic evaluation of state-of-the-art industrial hard coatings was conducted using fuel surrogates (ethanol, decane, dodecane) and F-24 jet fuel. Several coatings demonstrated superior tribological performance, making them strong candidates for multi-fuel applications. In parallel, the potential of solid lubricant coatings, specifically MoS<sub>2</sub> deposited via spray techniques on steel and WC-17Co substrates, was explored. Tribological testing of solid lubricants in low-viscosity hydrocarbons was complemented by surface characterization using X-ray Photoelectron Spectroscopy (XPS), Raman spectroscopy, and Scanning Electron Microscopy (SEM). These analyses reveal how hydrocarbon properties, such as polarity, water affinity, chain length, viscosity, and contact angle affect chemical and structural changes in MoS<sub>2</sub>, influencing micro- and nano-scale lubrication mechanisms. Additionally results show how duplex architectures, utilizing a hard, wear resistant underlayer, and a soft lubricious solid lubricant layer, are a step towards developing a more robust coating for low-viscosity fuel pump applications.

9:40am **IA1-FrM-6 Cu Grain Engineering and Plating Process Reliability Study for Heterogeneous Integration**, Shan-Yuan Wu [t113c77009@ntut.org.tw], Ying-Chao Hsu, Po-Chun Chen, Sheng-Ru Hsiao, National Taipei University of Technology, Taiwan

The continuous improvement of integrated circuit (IC) performance is mainly driven by transistor scaling and advanced packaging technologies. In 3D heterogeneous integration with hybrid bonding and 2.5D interposers using through-silicon or through-glass vias (TSV/TGV), advanced packaging plays a vital role. Each application presents distinct reliability challenges: hybrid bonding requires strong adhesion at low temperatures, while TSV/TGV structures demand low stress and void-free filling. Ultra-fine-grained (UFG) copper addresses these issues by enhancing grain boundary diffusion and enabling low-temperature bonding, while its fine-grained structure promotes bottom-up via filling and suppresses seam voids during electroplating.

The formation of Ultra-fine-grained Cu is closely related to organic additives in the electrolyte, particularly polyethylene glycol (PEG) and bis-(sodium-sulfopropyl)-disulfide (SPS). In this study, various additive formulations were investigated under identical plating conditions. Electron backscatter diffraction (EBSD) results revealed that optimized additives reduced the average grain size from above 1 μm to 390 nm, demonstrating a strong correlation between additive control and microstructural refinement.

To elucidate the electrochemical influence of additives, linear sweep voltammetry (LSV) and electrochemical impedance spectroscopy (EIS) were performed using an Admiral Squidstat Plus potentiostat. The working electrode was a silicon wafer coated with a 100 nm PVD Cu seed layer.

The presence of PEG introduced a pronounced suppression effect due to the formation of a PEG-Cu-Cl adsorption layer on the cathode surface. In LSV, this suppressor layer increased the overpotential from 0.45V to 0.65V under the 100mA/cm<sup>2</sup> current density, reducing the critical nucleus radius and promoting finer grain formation. This monolayer structure was further characterized by EIS, where the high-frequency semicircle in the Nyquist plots represented the impedance of the additive-adsorbed layer. Its gradual shrinkage during plating indicated additive depletion and a weakened suppression effect, while recovery after PEG replenishment reflected restored electrolyte stability. These findings provide a practical strategy for monitoring and maintaining plating bath quality through electrochemical analysis.

This study integrates EBSD and EIS to establish a quantitative and time-efficient framework for evaluating electrolyte stability and predicting Ultra-fine-grained Cu formation, offering valuable insights for optimizing copper electroplating reliability and grain size in advanced packaging processes.

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10:20am **IA1-FrM-8 Surface Property Enhancement of Al 7075 Alloy via MAO-Based Boron-Reinforced Composite Coatings**, Erhan Karaca, Turkish State Railways, Turkey; **Suleyman Sukuroglu** [[ssukuroglu@gumushane.edu.tr](mailto:ssukuroglu@gumushane.edu.tr)], Gümüşhane University, Turkey

Al 7075 alloy is a strategic engineering material widely used in the aerospace and defense industries, as well as in the automotive sector, due to its low density, high specific strength, excellent machinability, ductility, high toughness, and superior fatigue resistance. Despite these outstanding mechanical properties, its relatively low fracture toughness, limited damage tolerance, and susceptibility to environment-dependent corrosion restrict its application in certain advanced structural components. These limitations, particularly encountered under long-term service conditions in aircraft structures, increase the demand for effective surface modification techniques.

Ceramic-based coating methods applied to aluminum and its alloys offer a promising solution for improving surface properties by providing high hardness, enhanced wear resistance, and improved corrosion performance. In this context, ceramic coatings produced by the Micro Arc Oxidation (MAO) method have emerged as an effective and widely adopted surface engineering approach.

In this study, composite coatings were fabricated on Al 7075 aluminum alloy using the MAO technique with three different boron-based additives ( $B_5H_{10}NaO_{13}$ ,  $B_4C$ , and h-BN) to enhance the surface characteristics of the alloy. The microstructural, mechanical, tribological, and corrosion properties of the resulting coatings were comprehensively investigated. The findings demonstrated that boron-reinforced composite coatings significantly improved the surface performance of the Al 7075 alloy, particularly by providing remarkable enhancements in wear and corrosion resistance.

10:40am **IA1-FrM-9 Advanced HiPIMS Coating Equipment for High-Performance Cutting Tools Amid Tungsten Price Increase**, **Yafen Chen** [[chenyafen@hsvacuum.com](mailto:chenyafen@hsvacuum.com)], Wei Zhou, Guangdong Huasheng Nanotechnology, China

Recent increases in tungsten prices have driven up the cost of tungsten carbide cutting tools, making high-performance coatings—which extend tool lifetime and reduce replacement frequency—more critical than ever for cost-effective precision manufacturing. Cathode arc evaporation (CAE) and direct current magnetron sputtering (DCMS), the most prevalent PVD techniques for cutting tool hard coatings, face critical limitations: CAE generates detrimental droplets that compromise coating integrity, while DCMS produces loose microstructures, both severely restricting cutting tool service lifetime. High-power impulse magnetron sputtering (HiPIMS) overcomes these drawbacks, enabling the deposition of dense, droplet-free hard coatings. Huasheng Nanotechnology's G4Ultra HiPIMS coating system elevates performance further via integrated synchronized bias, reverse bias, and ultra-high pulsed bias technologies. These features yield coatings with superior hardness, ultra-smooth surfaces, and significantly extended cutting tool lifetime. To address HiPIMS' inherent low deposition rate, we additionally integrate HiPIMS with high-power impulse arc, achieving a balance between high coating quality and enhanced production efficiency. Our solutions provide advanced, industry-adaptable PVD equipment for high-performance cutting tool hard coatings, well-aligned with the evolving demands of precision manufacturing.

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