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, **Vikram Bedekar**, Timken Company, USA

8:00am **IA1-FrM-1 Hybrid Sealing Post-Treatments for Plasma Electrolytic Oxidation Coatings***, **Beatriz Mingo [beatriz.mingo@manchester.ac.uk]**,* The Univeristy of Manchester, UK

Plasma Electrolytic Oxidation (PEO) is an increasingly popular surface modification technique used as an environmentally friendly alternative to conventional anodizing treatments. PEO coatings usually present a layered morphology, formed by a compact inner layer and an outer layer with variable porosity. Over extended periods of exposure, aggressive electrolytes penetrate through the porosity compromising the barrier properties of the coating.

This study aims to address this issue by developing a novel hybrid post-treatment based on fibrous silica, which incorporates cerium as corrosion inhibitor. This treatment is applied using a hydrothermal technique to seal the coating's external porosity. The Ce-containing nanoparticles cover the material's surface, penetrating pores and defects and blocking potential entry points for the electrolyte. This significantly enhances the corrosion performance, improving it by up to two orders of magnitude. The synthesized materials are thoroughly characterized in terms of composition and morphology and their corrosion performance is evaluated using electrochemical techniques.

8:20am **IA1-FrM-2 Memristive Effects in PEO Alumina: Mechanisms and Technological 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 form 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 Application-Driven Research in Surface Engineering for Advanced Cutting Tool and Component Applications - 25 years of cooperation between Plansee and Oerlikon -***, **Peter Polcik [peter.polcik@plansee.com]**, Szilard Kolozsvari,* Plansee Composite Materials GmbH, Germany*; Denis Kurapov,* Oerlikon Surface Solutions AG, Liechtenstein*; Helmut Riedl, Paul Heinz Mayrhofer,* Institute of Materials Science and Technology, TU Wien, Austria **INVITED**

The persistent challenges in the field of PVD coatings—both in established and emerging applications—can be effectively addressed through close collaboration along the entire value chain. This paper highlights key milestones achieved through the long-standing partnership between Plansee Composite Materials and Oerlikon Surface Solutions, which has now spanned more than two decades. Substantial support from the Austrian Christian Doppler Research Association has enabled a strong collaboration between industry and a broad network of scientists from leading Austrian research institutions: Montanuniversität Leoben, the University of Innsbruck, and Technische Universität Wien.

Initiated in 2000, this collaboration was guided by clear objectives to advance the development of TiAl- and AlCr-based nitride coatings. Plansee contributed through innovations in target materials design, while Oerlikon provided the industrial platform for PVD coating processes. This paper provides an overview of systematic investigations on how variations in composition influence the properties of PVD-deposited thin films, ultimately leading to the industrial implementation of novel AlCrB- and AlCrSi-based hard coatings. These achievements were realized by establishing fundamental concepts, evaluating new coatings in both laboratory settings and industrial PVD systems, and consistently integrating findings into iterative development cycles.

To address new applications in machining, forming, and high-temperature environments, the research scope expanded beyond nitrides to include borides and carbides, with particular emphasis on enhancing oxidation resistance without compromising hardness.

The outcomes of this collaboration led to the development and successful market introduction of several coating solutions that contribute to a more sustainable and environmentally responsible economy.

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 $100 mA/cm^2$ 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.

10:20am **IA1-FrM-8 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_2 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_2, 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.

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