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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