Tuesday Morning, May 13, 2025

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.

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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.

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