Surface Engineering - Applied Research and Industrial Applications
Room Sunset - Session G2

Component Coatings for Automotive, Aerospace, Medical, and Manufacturing Applications

Moderators: Osman Levent Eryilmaz, Argonne National Laboratory, USA, Jolanta Klemberg-Sapieha, Polytechnique Montréal

8:00am **G2-1 The Effects of Temperature and Gas Mixture Composition on the Microstructure and Tribological Properties of the Plasma Nitrocarburized DIN 100 CR6 Steel***, M Fontes,* Federal University of Sao Carlos, Brazil*; V Baggio-Scheid,* Sao Jose dos Campos, Brazil*; D Machado,* Tecumseh Products Company, Brazil*; L Casteletti,* University of Sao Paulo, Brazil*; **Pedro Nascente**,* Federal University of Sao Carlos, Brazil

Nitrocarburizing is considered one of the most important thermochemical treatments for surface modification of metallic materials, and involves the simultaneous diffusion of nitrogen and carbon onto the surface. Understanding and controlling the formation of the nitrocarburized layer have considerable industrial interest due to the improvements regarding wear, fatigue, and corrosion resistances. In this study, the DIN 100Cr6 steel was chosen due to its use as raw material in the manufacture of a mechanical component applied in hermetic compressors for refrigeration. The DIN 100Cr6 steel samples were treated by plasma nitrocarburizing for two hours, with two treatment temperature (550°C and 600°C) and four methane concentrations in the gas mixture composition (0%, 1.0%, 1.5%, and 2.0%) as variables. X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy dispersive spectroscopy (EDS) analyses, as well as wear resistance and micro-hardness tests, were used to characterize the modified samples. The results showed that the treatment temperature and atmosphere composition had considerable influence on the compound layer composition and morphology. The presence of carbon in the gas mixture contributed to the formation of the ε-$Fe_{2-3}N$ phase, which has a HCP crystalline structure, and elevated temperatures caused an increase in the thickness of the compound layer, diffusion zone, and micro-porosity layer. The nitrided samples had a compound layer composed only by the γ'-Fe_4N phase having a FCC structure. For the nitrocarburized samples, the compound layer was a mixture of ε-$Fe_{2-3}N$ and γ'-Fe_4N phases, with a columnar-like microstructure; the amount of each one of these phases was a function of the CH_4 percentage present in the treatment atmosphere. A micro-porosity layer was formed for all produced surface layers. A larger micro-porosity layer thickness was observed for samples nitrocarburized without CH_4. Higher nitrogen concentrations in the atmosphere resulted in more pores in the compound layer.

8:20am **G2-2 Selected Aspects of Industrial Applications of Hydrogen Free DLC Coatings Deposited by CVAE***, **Joerg Vetter**,* Oerlikon Balzers Coating Germany GmbH, Germany*; J Karner,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; J Becker, M Markus,* Oerlikon Balzers Coating Germany GmbH, Germany*; N Beganovic,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; E Billot,* Oerlikon Balzers Coating Germany GmbH, Germany*; H Rudigier,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein, Switzerland

The number of industrial applications of hydrogen free ta-C and a-C coatings continues to increase, primarily for tribological coatings to reduce wear and friction. Tetrahedrally-bonded hydrogen-free coatings (ta-C) provide the highest hardness, and are successfully applied in many cutting and forming applications, while various softer a-C coatings are also useful in various tribological applications. Recent research and industrial solutions for generating carbon-based coatings by CVAE (cathodic vacuum arc evaporation) are described. The performance of the coatings are influenced both by process parameters (coating architecture) and by topographical effects. Laboratory scale tribological investigations will be presented. Selected aspects of basic prerequisites for industrial applications are highlighted.

8:40am **G2-3 Erosion Resistant PVD Coatings for Gas Turbine Compressor Blades***, **Lin Shang**, C Acikgoz,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; S Moser, G Szyndelman,* Oerlikon Metco AG, Switzerland*; O Jarry,* Oerlikon Balzers, Oerlikon Balzers Coating Germany GmbH, Germany*; M Arndt,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein

Although advancements in turbine materials have contributed to enhancing engine power ratings and efficiency levels, solid particle erosion (SPE) which occurs most prominently in the compressor section of aircraft engines during taking-off and landing still remains as a critical issue since the consequence removal of the turbine blade material degrades the aerodynamic performance, inducing reduced engine efficiency. Hence protecting turbine blades against erosion by applying PVD coatings can be a solution to maintain high level engine performance and lower maintenance costs.

In this work, TiAlN based coatings deposited by cathodic arc were applied on IN718, TiAl6V4 and stainless steel substrate materials. The influence of thermal exposure, coating thickness, hardness and residual stress on the SPE resistance of the coatings have been studied. SPE tests have been performed at 20° and 90° impact angles. Furthermore, the salt spray corrosion, SPE by water jet and cavitation resistance and fatigue behaviour of these coatings have been tested. The water jet erosion test was performed at different angles and also compared to HVOF sprayed WC-CoCr based coating. Compared to the uncoated substrate materials, the PVD coated substrates have been proven to have much higher erosion resistance.

9:00am **G2-4 Synthesis and Characterization of Ta-C, Hf-C and Ta-Hf-C Coatings Obtained by Cathodic Magnetron Sputtering in Reactive Conditions***, **Alexis de Monteynard**,* Nogent International Center for CVD Innovation, LRC CEA-ICD LASMIS UMR6281, UTT, Antenne de Nogent, France*; A Billard,* Institut FEMTO-ST, CNRS, UTBM, Univ. Bourgogne Franche-Comté, Site de Montbéliard, France*; F Sanchette,* Nogent International Center for CVD Innovation, LRC CEA-ICD LASMIS UMR6281, UTT, Antenne de Nogent, France

Ultra-high temperature ceramics (UHTCs) have received a particular interest due to their high melting point leading to a well thermal protection for structures in extreme conditions [1]. The Ta-Hf-C system offers the possibility to create binary or ternary alloys having a melting point above 4000 K. Structural and thermal properties of bulk materials (TaC, HfC and Ta-Hf-C with a wide range composition) have already been investigated [2]. Influence of non-reactively magnetron-sputtering deposition parameters on Ta-C and Hf-C coatings properties has been studied, showing a strong impact of carbon content on structure, morphology, mechanical properties as well as thermal stability [3].

Ta-C, Hf-C and Ta-Hf-C thin films were deposited by cathodic magnetron sputtering of pure Ta and Hf targets in reactive condition (CH_4 being the reactive gas). Structural, morphological and mechanical properties have been studied. The influence of carbon content on coatings properties is discussed.

[1] W. G. Fahrenholtz, E. J. Wuchina, W. E. Lee, and Y. Zhou, Eds., Ultra-High Temperature Ceramics: Materials for Extreme Environment Applications. Hoboken, NJ: John Wiley & Sons, Inc, 2014.

[2] O. Cedillos-Barraza et al., "Investigating the highest melting temperature materials: A laser melting study of the TaC-HfC system," Sci. Rep., vol. 6, p. 37962, Dec. 2016.

[3] H. Lasfargues et al., "Non-reactively sputtered ultra-high temperature Hf-C and Ta-C coatings," Surf. Coat. Technol., vol. 309, pp. 436–444, Jan. 2017.

9:20am **G2-5 Thin and Thick Coatings and Applications in Aerospace Industry***, **Satish Dixit**,* Plasma Technology Inc., USA **INVITED**

Coatings for wear, erosion, corrosion etc. have been implemented on over 500 different applications in aerospace industry. This includes, aircraft's used for commercial as well as military purposes along with critical components used in the Space exploration applications. In this talk I will be primarily focusing on thin and thick film coatings particularly applicable to functional aerospace components that are subjected to severe wear, corrosion, erosion etc. Thin films are critical where post processing is not an option and thick films are essential on more robust applications where endurance and strength is desired. I will be highlighting some of the applications developed in house as well as the applications prevalent predominantly within the industry at large.

10:00am **G2-7 HNT-Containing Ceramic PEO Coatings for Active Corrosion Protection of Magnesium Alloys***, B Mingo,* ***Yue Guo,*** *A Matthews, A Yerokhin,* The University of Manchester, UK

The growing interest for magnesium in weight-sensitive applications has triggered the development of surface modifications techniques capable of improving its properties mainly, its corrosion resistance. Amongst them stand out Plasma Electrolytic Oxidation (PEO), which is a high voltage electrolytic-plasma surface treatment capable of obtaining highly stable ceramic coatings with excellent hardness, adhesion, corrosion and wear resistance. However, these coatings only provide passive protection, i.e. act only as a physical barrier between the metallic substrate and the aggressive environment.

The aim of this study is to develop a functional ceramic coating on a commercial magnesium alloy capable of interacting with its surrounding by responding selectively to specific triggers. For that, halloysite nanotubes (HNT) are incorporated into the coating, which can be loaded with different active agents such as corrosion inhibitors, lubricants or drugs.

Halloysite nanotubes are biocompatible natural clays composed by two layers of aluminosilicates arranged in a hollow tubular shape. These nanotubes can be loaded by mechanical (vacuum-induced capillarity) or chemical (ion-exchange) processes, so the release of their content can be trigger by different stimulus e.g. mechanical damage, time or pH variations. At neutral pH the inner part of HNT is positively charged, which means that it is able to host negatively charged agents attracted by electrostatic interactions, however when increasing pH the charge of the lumen of the nanotube changes, which forces the release of the incorporated agent. This is especially interesting for corrosion protection of magnesium alloys, where corrosion inhibitors can be released to the media when detecting electrochemical activity arisen from pH variations, remaining encapsulated while the coating is intact.

The main challenge faced in this work is to achieve the non-reactive incorporation of the loaded nanotubes to PEO coatings since the high temperatures and pressure reached during the coating synthesis might compromise the 3D integrity of the nanotubes. The obtained materials are evaluated in terms of characterization and corrosion resistance.

A positive outcome would not only increase the life-time of PEO coated components used in high performance applications, but also would expand their applicability to other fields, potentially to biomaterials, with the development of drug-loaded coatings used in orthopaedic implants.

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