Surface Engineering - Applied Research and Industrial Applications

Room Pacific Salon 1 - Session G2-FrM

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

Moderators: Tetsuya Takahashi, Kobe Steel, Ltd., **Etienne Bousser**, Ecole Polytechnique, Canada, **Satish Dixit**, Plasma Technology Inc., USA

8:40am **G2-FrM-3 YKK's Sustainable Development: Reduction of Mold Cleaning Load by Diecast Mold Coating and Release Agent**, ***Mai Mizubayashi***, *T Sakuragi, N Watanabe, M Ishida,* YKK Corporation, Japan*; K Matsuda,* University of Toyama, Japan*; M Nose,* Hokuriku Polytechnic College, Japan **INVITED**

In recent years, as a common philosophy in the preservation of the global environment, there is a sustainable development as a concept that is internationally widely recognized.This time, we will introduce the development of die coating and mold release agents, which are working on the continuous development of YKK and die casting technology. In the past technological development, the point of view of material strength and efficiency has been emphasized. We are working on a comprehensive development from the viewpoint of improving the total efficiency of the equipment by reducing the mold cleaning load and reducing operator safety, health care and environmental impact. The result was very good this time. The combination of the developed an amorphous carbon film (a-C film) and the release agent, from the time of combination with the nitriding type and conventional release agent, it was confirmed that the workability is an item that was improved about 15%. The joy of the developers is that the people on the scene are satisfied with the results of the development. We want to make the most of the feature and the charm of the coating, and challenge the next generation manufacturing. I am deeply grateful to all the people who have helped me with this study.

9:20am **G2-FrM-5 Effect of Plasma Electrolytic Oxidation Process on Surface Characteristics and Tribological Behavior**, ***Ran Cai***, *C Zhao, X Nie,* University of Windsor, Canada

Alumina coatings prepared by PEO (plasma electrolytic oxidation) process have been proposed and in a validation process to replace heavy cast iron liners for internal combustion engines. The bipolar current mode in the PEO process is known as an excellent coating preparation condition. However, the industrial production would require an optimized as well as cost-efficient process. The unipolar current mode can si gnificantly reduce the investment on coating facilities. Thus, this research was to use the unipolar mode to prepare oxide ceramic coatings on Al-Si alloy samples with different durations, i.e., 20%, 30% and 40% durations of 1000Hz. One of the samples was used with a normal bipolar mode for comparison. The influence of duty ratios on the coating's deposition rate, porosity and wear resistance was investigated. At a similar coulomb charge input (I × t), the change of duty ratios from 0.8 to 0.2 had an insignificant effect on the coating deposition rates, but the coating's porosities decreased and wear resistance increased after the coated samples were polished to Ra around 25 microns and 20 microns. Dry and lubricated pin-on-disc tests indicated that the coatings produced by unipolar current mode at the lower duty ratio had comparable properties of the one prepared with the bipolar current mode. The tribological behavior of the polished surfaces was analyzed based on their surface morphology characteristics (Ra, Rpk, Vo, skewness and kurtosis). The work provides a new perspective for the optimization of PEO process for automotive application.

9:40am **G2-FrM-6 Effectiveness of Electromagnetic Interference Shielding of Sputtered Nitrogen-Doped Carbon Thin Films**, ***Dian-Hao Liu***, *Y Lai,* National United University Miaoli, Taiwan

In this work, nitrogen-doped carbon thin films are deposited on aluminum foils by RF magnetron sputtering with different N2 flow rates. Film properties are characterized by Raman spectroscopy, X-ray photoelectron spectroscopy, scanning electron microscopy, and transmission electron microscopy. The electrical properties are conducted by Hall measurements, and the shielding efficiency is extracted from network analyzer in the frequency range of 8.2-12.4 GHz. The Raman spectra confirms that adding small amounts of N in carbon films increases full width at half maximum of G-band and the intensity ratio (ID/IG). A red shift of the G-band is also observed. The Hall measurement reveals that the N doping acts as electron donor, leading to the increase of conductivity and carrier concentrations. Due to the improvement of electrical properties, the electromagnetic interference shielding efficiency, in terms of reflection and transmission loss, increases as well.

10:00am **G2-FrM-7 Challenges for Surface Solutions for Automotive Applications**, ***Jörg Vetter***, *J Becker,* Oerlikon Balzers Coating Germany GmbH, Germany*; P Ernst,* Oerlikon Metco AG, Switzerland*; J Crummenauer,* Oerlikon Balzers Coating Germany GmbH, Germany*; A Müller,* Oerlikon Surface Solutions AG, BTS, Balzers, Liechtenstein

Automobile manufacturers have to consider in addition to the expectations and satisfaction of customers regarding the reliability, functionality, comfort and safety, additional aspects such as: production, consumption and environmental issues. Regional environmental legislation and shorter product life cycles require higher quality and more stringent materials requirements. Higher specific loads (thermal, mechanical etc.),weight and friction reduction (CO2; NOx emission reduction), longer components lifetime, improved corrosion resistance are demanding for modern automotive systems, and multifunctional surfaces like sensory functions. In addition new surface solutions are required for green car development (e.g. HEV, BEV with range extenders). Within the last decades, high performance surface solutions and new or improved surface treatments, especially in the group of plasma assisted processes, both for diffusion and deposition processes (IONITOX, PVD, PACVD, Thermal Spraying) were developed to provide economic applications for automotive parts. It will be shown that these new treatments are becoming more common in engine applications and powertrain. Generating optimized surfaces for different types of substrate materials (e.g. Al-alloys, case hardened steels, plastics etc.) and geometries (e.g. bores) also impacts the running costs. Due to the new developments within these competing surface treatments, it becomes more and more common to substitute traditional treatment-substrate-systems with advanced treatments. Both the application potential and selected examples of different surface treatments will be shown. Besides the wear and friction reduction of various components also decorative applications even for multifunctional purposes are successful implemented in daily production. The potential of optimized functional surface generation by proper coating selection is demonstrated.

10:20am **G2-FrM-8 Hard Turning with PVD Coated p-cBN**, *C Charlton,* Kennametal Inc., USA*; **Joern Kohlscheen**,* Kennametal GmbH, Germany*; D Banerjee,* Kennametal Inc., USA*; C Bareiss,* Kennametal GmbH, Germany

We will give an overview of uncoated and PVD coated polycrystalline or p-cBN cutting tools that are used in finish turning on hardened steel. Examples include turning of automotive braking disks and precision shafts. Interestingly, PVD coatings can improve wear behavior in many applications. As the hardness of such thin films is comparable to the substrate values the improvement is explained by thermal and chemical protection. As many of the different p-cBN substrate materials show reduced electrical conductivity the deposition process has to be adapted. To improve adhesion and overall performance different interlayers and plasma etching cycles were applied in deposition of AlTiN arc ion plated coatings. Difference in adhesion were determined by indentation and scratch testing. Tool life was compared in turning tests of hardened steel (60 HRc) without coolant. The resulting wear patterns will be discussed.

10:40am **G2-FrM-9 Arc PVD (Cr,Al,Mo)N and (Cr,Al,Cu)N Coatings for Mobility Applications**, *K Bobzin, T Brögelmann,* ***Christian Kalscheuer***, RWTH Aachen University, Germany

Efficiency during operation is besides reliability and cost effective production one of the most important demands on machines and components. Especially within the automotive sector, components need to fulfill these requirements. Since the demands for high efficiency and reliability cannot be met solely by typical base materials such as case hardened steels, physical vapor deposition (PVD) coatings for the application on highly loaded components gain increasing importance. A possible approach to reduce friction and wear in tribological systems are triboactive and tribocatalytic coatings which contain triboactive elements such as Mo and Cu which can interact with lubricants and lead to the formation of friction and wear reducing tribochemical reaction layers. Besides coating development, also the design of lubricants is in the focus of research activities to reach friction reductions. Therefore increasing interest gains towards low viscosity lubricants e.g. for e-mobility applications.

Within the current work, triboactive (Cr,Al,Mo)N and (Cr,Al,Cu)N coatings were deposited by means of cathodic arc evaporation (Arc PVD) in an industrial scale coating unit. The contents of Mo and Cu were varied. As substrate material the case hardened gear steel AISI 5115 (16MnCr5E) was

used. The effects of Mo and Cu on the phase formation were investigated by means of X-ray diffraction (XRD). Analysis of the mechanical properties was conducted by nanoindentation (NI) measurements. Tribological behavior of the coatings was analyzed under continuous sliding conditions in pin on disc (PoD) tribometer under minimum quantity lubrication with lubricant amounts of V = 0.05 ml at a temperature T = 80 °C. As lubricants a low viscosity lubrication oil and a conventional mineral oil were used. Both lubricants contained Sulphur and Phosphorous (S-P) additives. Initial Hertzian contact pressure was set to $p_H \approx 1{,}600$ MPa. In order to investigate the influence of the counter body material on the tribological behavior, inert Si_3N_4 balls and 100Cr6 steel balls were used. Wear was analyzed by confocal laserscanning microscopy (CLSM) and scanning electron microscopy (SEM). Tribochemical interactions between the coatings and lubricants were studied by Raman spectroscopy. It was found that tribo chemical interactions between Mo of the coating and S of the lubricant can lead to the in situ formation of MoS_2 in tribological contact. Triboactive (Cr,Al,Mo)N and (Cr,Al,Cu)N coatings are a promising approach to achieve reduced friction and wear in tribological systems.

11:20am **G2-FrM-11 Ion Beam Stripping Process for Cutting Tools Reconditioning*, Alexey Remnev,*** ITAC Ltd., Group of ShinMaywa Industries, Japan

Presently, various kinds of hard film coatings are used in combination with cemented carbide (WC-Co) and high speed steel (HSS) cutting tools for increased longevity. For further improvement of the coated tools' life-span, their regrinding and recoating are commonly implemented. Successful recoating requires stripping off of a previous coating in order to provide sufficient adhesion. Wet electro-chemical etching (ECE) process is commonly applied for the stripping purpose. Although well established, the ECE method has some known issues such as cobalt binder leaching from the WC-Co tools, HSS corrosion, large amount of chemical waste produced. Moreover, the ECE stripping method cannot be applied to the carbon-based thin films, such as diamond and diamond like carbon (DLC), due to their chemical inertness. In this context new competitive stripping approaches are of high applicational importance.

In the present work we introduce a vacuum stripping process based on ion beam etching (IBE) of the hard films. The IBE method utilizes low energy (~1keV) high current (~0.1A) broad (~10cm) ion beams in order to create sufficient ion and radical fluxes on the tools' surface. In order to etch the metal based films, such as TiN, TiAlCrN, TiCN argon gas was introduced, while carbon based DLC and diamond films were IBE processed utilizing pure oxygen as a working gas for improved erosion rate and selectivity against the carbide material.

IBE erosion rates of commercial PVD and CVD hard coatings on various WC-Co cutting tools were experimentally measured and plasma-chemical aspects of diamond decomposition were discussed. Effect of tool geometry on the IBE uniformity was experimentally studied by measuring the local erosion rate over the tools' surface. Moreover, mathematical model of the IBE process, describing the erosion rate distribution was suggested. Surface condition of the WC-Co substrates treated by IBE were evaluated and no significant deterioration was found. Overall, it was shown that IBE provides sufficient erosion rate and uniformity without significant damage to the tool material for virtually any kind of hard coating used in today's cutting tools industry.

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