Surface Engineering - Applied Research and Industrial Applications
Room Town & Country B - Session G2-ThM
Surface Modification of Components in Automotive, Aerospace and Manufacturing Applications

Moderators: Satish Dixit, Plasma Technology Inc., USA, **Heidrun Klostermann**, Fraunhofer FEP, Germany

8:00am **G2-ThM-1 Surface Engineering Opportunities: Harsh Environments Meeting New Strategies for Microstructural Designs (Virtual Presentation)***, Chris Berndt (cberndt@swin.edu.au),* Australian Research Council, Industrial Transformation Training Centre, Australia **INVITED**

Harsh and extreme environments arise when the operating regime is at high temperature under corrosive conditions. Examples of such environments are numerous as industries seek greater plant efficiencies and transportation platforms strive to operate under increasingly arduous conditions. That is, engineers desire greater productivity and length of operation before refurbishment: both commercial ambitions that rest on the component lifetime.

With the above pragmatic backdrop in mind, this presentation considers adding value and performance to traditional materials by surface engineering. Examples will be drawn from the biomaterial, mining and hypersonic vehicle sectors where Surface Engineering has provided solutions that address a variety of harsh and extreme environments.

The key issue in all cases, and which connects apparently disparate applications, is 'the microstructure'. Thus, the aim of this talk is to outline the highly defective nature of the coatings that enhance the performance of components. Although the focus will be on thermal spray technology, the theme of leveraging defects for their performance attributes crosses many areas of materials science and engineering. The defective nature is controlled by the processing variables of the surfacing method. Hence, process feedback loops are necessary so that the composite-like microstructural design can be controlled.

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8:40am **G2-ThM-3 Plasma Nitriding of Forming Tools for the Automotive Industry - Challenges and Opportunities***, Manuel Mee (manuel.mee@oerlikon.com),* Oerlikon Balzers Coating Germany GmbH, Germany **INVITED**

To increase the service life of forming tools, coatings by physical vapor deposition (PVD) or chemical vapor deposition (CVD) have been used for decades. However, upscaling to ensure robust processes for large tools is difficult. In this regard, hard chrome electrodeposition has proven to be a common practice. One disadvantage in particular is the limited durability, which in the context of service life, using the example of a car body side tool, is manifested in multiple decoating and recoating involving the use of environmentally critical chemicals. In contrast, plasma nitriding is a thermochemical diffusion process for surface hardening in which the surface layer of a workpiece or component is enriched with nitrogen at low to moderate temperatures. The technology used by Oerlikon allows a loading of up to 40 tons on an area of 3x10m. Thus, an environmentally friendly surface treatment is available even for massive tools, which, compared to hard chrome, requires only a single treatment.

Nevertheless, it should be noted and taken into account that in principle a start-up of these tools have already been done beforehand and therefore process-side interactions with impurities, passivation as well as any pre- and post-treatments are possible. This applies in particular to areas hardened and welded in advance, as well as to subsequent modifications where the already nitrided surface has to be welded. Possible consequences are material-specific and manifest themselves in tempering effects, outgassing and degradation phenomena.

The main topic of the presentation will be the requirements of users and manufacturers of forming tools and the resulting challenges. In addition to various applications and the respective restrictions with large forming tools whose mass can be far more than 10 tons, the measures derived from this to ensure process stability and quality will be discussed.

9:20am **G2-ThM-5 Enhanced Wear and Corrosion Properties of Stainless Steel by Electron Induced Plasma Nitriding***, Petros Abraha (petros@meijo-u.ac.jp),* Meijo University, Japan

In this study, we focus on recent advances in plasma source technology for materials processing applications. The plasma source used in conventional plasma nitriding treatment apply direct current, radio frequency, and microwave power between electrodes, and the potential difference accelerates electrons and ions in an electric field to generate plasma. In such a plasma source, normally, a high voltage of several kV is applied, and the generated plasma ions have high kinetic energy and large flux that bombard the surface of the sample.

Although high surface hardness can be obtained by conventional plasma nitriding treatment for austenitic stainless steel, the formation of chromium nitride reduces the chromium concentration of the base material and impairs corrosion resistance. In addition, sputtering due to ion collision also occurs, which significantly deteriorates the surface roughness. Therefore, there is a need for a nitriding method that improves the mechanical properties and corrosion resistance of austenitic stainless steel while maintaining the surface finish of the nitrided samples.

In this study, a low power plasma nitriding device with a relatively uniform plasma was used to nitride austenitic stainless steel. The results of our experiments show that the surface hardness of the nitrided samples were more than double the untreated sample while maintaining the roughness (RMS 10nm) of the mirror finished surface.

9:40am **G2-ThM-6 Tribological and Machining Performance of TiSiN(Ag) Coatings Deposited by HiPIMS***, Diogo Cavaleiro (diogoacavaleiro@gmail.com), S. Carvalho, F. Fernandes,* University of Coimbra, Portugal

Titanium alloys are one of the most common materials used in the aerospace industry. The need to machine parts in this industry poses as one of the main problems, since these alloys are well-known to be difficult to machine materials, mainly due to their low Young's modulus and poor heat conductivity. The consequent restriction in the use of high cutting speeds limits the productivity which lead to the development of self-lubricant coatings as a promising way to improve the lifetime and performance of machining tools. The main focus of this work was to investigate the effect of Ag alloying on the high temperature tribological behaviour and machining performance of TiSiN coatings. The coatings exhibit relatively high hardness (32 to 15 GPa). Tribological behaviour was assessed in pin-on-disc tests at room temperature and at 900ºC, sliding against TiAl6V4 balls. Ag addition show a general decrease in the COF values across all the test temperatures. Increasing the Ag content and the temperature seems to show a beneficial effect in reducing the wear and the amount of adhered ball material. This is a promising result to reduce the built-up edge effect on the machining tests. The machining behaviour during turning of the TiAl6V4 alloy, showed that Ag additions had a beneficial effect on the machining performance of the films, especially for the higher cutting speeds. As observed for tribology, a clear reduce in the BUE was also found in machining when Ag was added to the coatings.

10:00am **G2-ThM-7 Crystal Structure, Localized Surface Plasmon Resonance and Sensing Properties of Infrared Transparent Conductive Thin Films***, Liangge Xu (xuliangge@aliyun.com),* Harbin Institute of Technology, China

Tin oxide (SnO_2) has been widely explored for various applications due to its excellent n-type semiconductor properties, low resistance, and high optical transparency in the visible range. However, few studies on the preparation of SnO_2 films using high power pulsed magnetron sputtering have been reported. Oxygen content is a critical parameter in the practice of SnO_2 thin films by high-power pulsed magnetron sputtering. the average free range of Sn atoms is usually much smaller than O atoms. SnO_2 films deposited in a pure Ar atmosphere are likely to be oxygen-deficient and form O vacancies. and such oxygen vacancies will cause lattice distortion, which will affect the mobility of charge carriers in the SnO_2 film. Therefore, oxygen is the main factor affecting the electrical conductivity of SnO_2 films.

In this paper, the crystal structure and infrared transparent conductive properties of SnO_2 films prepared at 600°C were investigated at different oxygen partial pressures. Then, it is described that integrating SnO2 transparent conductive film into a multi-resonant surface enhanced infrared absorption (SEIRA) platform can overcome the shortcomings of poor selectivity and opacity of multi-gas sensing, and can simultaneously sense ultra-low concentrations of greenhouse gases on-chip. And realize the application in the transparent window scene. This strategy takes advantage of the near-field intensity enhancement (over 1500 times) of the multi-resonance SEIRA technology and the infrared light reflectivity that can be modulated by the SnO2 infrared transparent conductive film. Experiments have proved that the MOF-SEIRA platform realizes synchronous on-chip sensing of VOCs, with fast response time, high accuracy, high visible light transparency, and excellent linearity in a wide concentration range. In addition, the excellent scalability to detect more gases was explored. This work opens up exciting possibilities for the realization of integrated, real-time and on-chip multi-gas detection.

10:20am **G2-ThM-8 Research on the Anti-Reflection Performance of Tetrahedral Amorphous Carbon Coatings by Ga Doping**, ***HoeKun Kim (ndkim2@naver.com)***, *K. Lee, S. Lee,* Korea Aerospace University, Korea (Republic of)

The improvement of radiation resistance in the space solar cells(SC) is still of great importance. The main reason for space SC efficiency degradation under the action of solar wind is a reduction in carrier concentration of the base region, so that the space SC must be protected by coverglass with good protective and optical properties. However, it is very important to reduce SC weight, especially for interplanetary application. To achieve this aim relatively thin protective coating should be applied. For the decade, it has been shown that diamond-like carbon (DLC) coatings are very promising anti-reflection (AR) and protective coatings for solar cell. The advantages of DLC include high chemical stability, radiation stability and high hardness with the possibility of changing their optical properties by varying the deposition conditions. Especially, tetrahedral amorphous carbon (ta-C) coatings with extremely high hardness, smooth surface, excellent wear resistance, and better thermal stability than DLC have been paid much attention to an alternative protective coating materials. Additionally, optical properties of the ta-C coating could be improved by various metals doping. In this study, various contents of Ga were doped in the ta-C coating to improve the mechanical and optical properties of the ta-C coatings. Filtered cathodic vacuum arc (FCVA) and sputter hybrid system was co-deposited to synthesize the metal doped ta-C coating. Microstructure of the Ga doped ta-C coatings showed a columnar "moth-eye" structure that is especially useful for reducing reflections and increasing transmission between materials by the roll of light absorption. Raman spectroscopy analysis showed that all the coatings had high sp3/sp2 fraction over 56%, and the hardness showed high values of 48 GPa. The ta-C coating with high Si content showed improved transmittance than other carbon based coatings, and these results indicate that the metal doped ta-C top-coating could be applied for protective & AR coating of satellite solar cell.

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