Surface Engineering - Applied Research and Industrial Applications
Room Town & Country C - Session G1-WeM

Advances in Application Driven Research: New Methods, Materials, and Equipment for PVD, CVD, and PECVD Processes

Moderators: Ladislav Bardos, Uppsala University, Sweden, **Vikram Bedekar**, The Timken Company, USA

8:00am **G1-WeM-1 Improve Cutting Performance of Carbide Cutting Tools with Multilayer TiAlxN-Based Arc-Cathodic PVD Coating for Industrial Applications***, **Fernando Santiago,*** SADOSA, Mexico*; D. Melo,* ITESM, Mexico

Multilayer TiN/TiAlxN coating deposited by arc-cathodic PVD method evaluated in this work. The adhesion of the single or multiplayer coating was studied and stress formation as the function of bias voltage during the deposition process in solid carbide. Industrial Arc-cathodic PVD with a balanced magnetron was used to coat end-mills carbide. The samples coated were tried in slotting operation in the CNC machine center using extreme cutting parameters.

8:20am **G1-WeM-2 Correlation between Deposition Conditions, Properties and Cutting Performance of Al-Rich AlCrN Wear Protective Coatings Produced by Reactive Arc Evaporation***, **Alexandre Michau,** D. Kurapov, I. Iovkov, S. Fabbro,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; L. Zauner, H. Riedl,* CDL-SEC at TU Wien, Austria*; D. Cahill,* University of Illinois at Urbana-Champaign, USA

Due to its outstanding wear protective properties, the AlCrN system is used in a broad range of cutting and forming tools. For many wear protective applications, AlCrN layers with higher Al content are of particular interest. This might be attributed to a combination of excellent mechanical properties, oxidation resistance, phase stability at high temperatures as well as low thermal conductivity. Having a tool coated with a low thermal conductivity layer during a cutting operation is crucial, as it provides thermal barrier properties. More heat can be dissipated into the chips, preventing the substrate from overheating, improving significantly tool performance.

The reactivity of the arc-deposited AlCrN system is mainly governed by the Al/Cr ratio. If a fcc lattice can be obtained for lower ratios, <70/30 at.%, incorporating more Al triggers gradually the appearance of a hcp-AlN phase. This crystalline transition is accompanied by several other transitions. If the hcp phase exceeds a critical amount, the morphology shifts from columnar to fine-grained and mechanical properties start to decline, with lower values of Young's modulus (E), hardness and residual stress, degrading the wear resistance. Typically, for wear protective applications, AlCrN coatings with fcc crystal structure and E above 400 GPa are preferred.

In this work, AlCrN was deposited by cathodic arc with targets having an Al/Cr ratio from 70/30 to 90/10. Magnetic field configuration as well as bias voltage were varied to adjust the energy influx into the growing film. Influence of the Al/Cr ratio on the morphology, crystal structure, composition and mechanical properties of deposited coatings was investigated at room temperature and after a series of vacuum annealing up to 1200°C, by scanning electron microscope, x-ray diffraction and nanoindentations. Thermal conductivity of the coatings was evaluated by time-domain thermoreflectance as a function of the Al content. It was found that the AlCrN system reactivity towards the bias voltage is independent of the magnetic field configuration, an increasing bias voltage leading to less Al in the films. However, a proper adjustment of the magnetic field configuration allows the deposition of AlCrN films, containing up to 80 at% Al, maintaining fcc crystal structure with columnar morphology and E above 400 GPa. The magnetic field on the cathode surface significantly influences the plasma conditions near the substrate. The coating analysis shows strong dependence of the plasma characteristic on the coating structure and properties. The correlation between the growth conditions of the coatings and their cutting performance is discussed.

8:40am **G1-WeM-3 Designed for Impact: Successful Forming of 3rd Generation Advanced High Strength Steels in Electric Vehicles' Body-in-White***, **Tobias Brögelmann,** T. Hurkmans,* IHI Ionbond Netherlands B.V., Netherlands*; J. Owens-Mawson, G. Savva,* IHI Ionbond LLC, USA

The main goals of the mobility driven global energy system transformation are to increase the efficiency and environmental compatibility of conventional and renewable energy to reduce the global CO_2 footprint. More than 60% of all product innovations are based on the development of new and improved high-performance materials, which requires continuous optimization of associated production technologies and manufacturing processes. Here, the right coating solution produced by physical vapor deposition (PVD), chemical vapor deposition (CVD) and plasma-assisted CVD (PACVD) can increase productivity and ensure excellent product quality while minimizing production downtime and scrap rate in forming and molding tool applications.

Within the automotive sector, there is a prime example of continuous development of new materials in the use of press hardened steels (PHS), martensitic and multi-phase ultra-high strength steels (UHSS), dual phase advanced high strength steels (AHSS) and aluminum alloys in the automotive body-in-white. The associated forming applications cover a broad stress profile that results in complex demands on the forming tools, e.g. a high resistance to impact fatigue and crack formation under cyclic loading and a high resistance to abrasive and adhesive wear. One encouraging way of forming these materials is to reduce the frictional forces between the die and the workpiece to obtain an optimum material flow, and to reduce stresses on the die by extending the work-hardening of the workpiece material. The optimum friction state while minimizing costly and environmentally harmful lubricant usage can be set by incorporating the lubrication properties into the coating.

This paper deals with the investigation of hard coatings with self-lubricating properties for industrial forming applications. Three different lubricant concepts in the as-deposited state are discussed, i.e., solid lubricants with layer-lattice structure such as sulfides (MoS_2) and diamond-like carbon (DLC) as well as oxides. Current R&D needs and the preferred coating solutions are introduced based on the performance during industrial field tests. The gap between basic analysis of the coating solutions and time- and cost-intensive field tests is closed by application-oriented model tests. In collaboration with industrial associations and academia, these cover a strip-pull test and an impact fatigue test. Results from the impact fatigue test demonstrate the importance of plasma nitriding to improve the load-carrying capacity for the PVD coating. The improved impact fatigue behavior of such duplex coatings is also reflected in improved performance in the forming application.

9:00am **G1-WeM-4 In-Situ Incorporation of Nanocontainers During Plasma Electrolytic Oxidation***, S. Al Abri, A. Rogov, A. Matthews, B. Mingo,* ***Aleksey Yerokhin,*** The University of Manchester, UK

Plasma electrolytic oxidation (PEO) is a surface treatment technique employed to light metals to enhance their properties such as heat, wear, and corrosion resistance. The coating comprises of inner thin layer and a porous outer layer. The inner layer provides passive protection separating the substrate from the surrounding environment. However, the presence of the porous outer layer allows the propagation of aggressive ions toward the substrate initiating localized corrosion.

This study aims to functionalise PEO coating by incorporating corrosion inhibitors encapsulated into nanocontainers in a single-step process. The inhibitors will be released when detecting electrochemical activity associated with corrosion initiation, providing corrosion protection on demand. The incorporation of nanocontainers in a single step allows the homogenous distribution of the nanocontainers through the coating matrix, but the integrity of the nanocontainers might be compromised due to the high temperatures developed at microdischarge sites. To prevent this, the thermodynamic conditions of the plasma process will be optimised by establishing the soft spark regime at the earliest stage of the PEO process, which allows the non-reactive incorporation of nanocontainers.

The presence of nanocontainers in PEO coating was confirmed by scanning electron microscopy and the corrosion behaviour of PEO coating was assessed by electrochemical impedance spectroscopy.

9:20am **G1-WeM-5 High-Resolution Investigation of the Microstructural Features and Crystal Forms of Industrial Ti(C,N) CVD Thin Hard Coating***,*
Idriss El Azhari, Saarland University, Germany*; J. García,* Sandvik Coromant R&D Materials and Processes, Sweden*; C. Pauly, J. Barrirero, M. Engstler, F. Soldera,* Saarland University, Germany*; L. Llanes,* Universitat Politècnica de Catalunya, Spain*; F. Mücklich,* Saarland University, Germany

In metal cutting industry, Ti(C,N) is one of the most used thin hard coating during the last two decades. Recently, the authors carried out a multi-scale testing and characterization campaign in which industrial cutting tools coated with Ti(C,N) is contrasted to Zr(C,N). The objective was to reveal the microstructural features that influence their mechanical behavior for milling applications. The more compatible coefficient of thermal expansion of Zr(C,N) with the substrate, better cohesive strength at the grain boundaries and plastic deformation were found to assign to the Zr(C,N) better structural integrity and fracture toughness during intermittent cutting in comparison to the inserts coated with Ti(C,N). In the present work, light is shed on unexplored other characteristics related to the grain boundary complexions and crystal shapes of Ti(C,N). State of the art characterization techniques were used such as atom probe tomography (APT), high-resolution secondary ion mass spectrometry imaging (nano-SIMS) and 3D electron backscatter diffraction (EBSD). Approaches to tailor the microstructure of these compounds to enhance the ductility and maintain the strength are suggested.

Author Index

Bold page numbers indicate presenter