Surface Engineering - Applied Research and Industrial Applications
Room Sunrise - Session G6

Application-driven Cooperation between industry and Research Institutions

Moderators: Hamid Bolvardi, Oerlikon Balzers, Oerlikon Surface Solutions AG, Kirsten Bobzin, Surface Engineering Institute - RWTH Aachen University, Germany

3:30pm **G6-7 Research Behind a High Performance Metal Cutting Tool*,*** ***Jacob Sjölén,*** SECO Tools, Sweden **INVITED**

The research and development of metal cutting tools has over the last century led to incredible improvements in manufacturing. Cost efficient solutions, more advanced materials and super-alloys are key-words in a modern machine shop, meaning demands on increased productivity and new solutions for machining of difficult materials. This, in turn, generates extreme conditions at the cutting tool edge, comprising e.g. high pressure, high thermal load and chemical interaction.

To meet the demand of endurance at these circumstances, there is a need for a deep material understanding combined with the continuous development of material properties, tool design and cutting process. Thus, this requires combined efforts over the entire R&D-chain covering activities from fundamental research to field testing, including co-operations over the borders between academia and industry and compiling all this knowledge into a High Performance Metal Cutting Tool.

This work will present examples of how such collaboration between academia and industry leads to an increased understanding of existing conditions, improved productivity of new tools and technology platforms for the development of next generation metal cutting tools. More specifically, how application driven research of the wear properties in the metal cutting processes connects to the thermal, chemical and mechanical behavior, which further relates to synthesis, composition and structure of materials used for metal cutting tools, for detailed understanding of the whole system in order to continuously push the limits for the tools.

4:10pm **G6-9 Residual Stress Measurement Technique for Static and Dynamic Coating Processes using Micro-machined Stress Sensors for Scientific and Industrial Applications***, L Banko,* ***Dario Grochla,*** *A Ludwig,* Ruhr-Universität Bochum, Germany

The mechanical behavior of the thin film-substrate compound strongly correlates with residual stress especially with respect to the hardness, adhesion and tribological performance. The film stress is affected by different contributions like interfacial stress or different coefficients of thermal expansion as well as dislocations, impurities, voids and grain boundaries. Several stress components are related to the film´s microstructure and can indicate the presence of phases. Failure mechanisms like buckling or cracking often can be ascribed to intrinsic and/or extrinsic film stress.

Quantitative determination of thin film stress can be challenging, especially for very thin films, e.g. optical or barrier coatings < 100 nm. XRD strain measurement might fail because of low intensity or texture. Curvature stress measurements base on the Stoney equation to calculate the stress knowing the substrate thickness, film thickness and the radius of curvature. However, in thin coatings the bending force might not be strong enough to deflect standard available substrates that are usually 200 – 500 µm thick. The appropriate selection of the substrate thickness is the key to control the sensitivity of the curvature method. By adequate tuning of the substrate thickness a high measurement resolution (few MPa) can be obtained in any film thickness range.

Micro-machined cantilever stress sensors (6.55 x 7.4 mm^2) have been developed to meet this criterion. Sensors were fabricated with a substrate thickness in the range of 30 – 120 µm. The Sensors were validated in several research and industrial type plasma-based depositions with film thicknesses ranging from < 10 nm to 3 µm and have been applied in static as well as dynamic coatings processes. The small sensors allow localized stress determination in different places of the deposition chamber. The combination of the stress sensor and an optical holography test stand, provides a fast and easy point-and-click measurement to quantify residual stress. Additionally, the coefficient of thermal expansion can be calculated by thermal cycling of the sensors on a heating platform as the Young's modulus is known. Furthermore, it will be shown, how residual stress measurements can help to understand different thin film behaviors and reveal non-uniformities in the coating processes. The stress sensors can be used as an indicator (figure of merit) in industrial deposition processes, to easily monitor thin film quality over long time periods.

Acknowledgment: SFB-TR 87

4:30pm **G6-10 Improvement of Thermal Stability and Oxidation Resistance of Molybdenum Nitride*,*** ***Fedor F. Klimashin,*** CDL-AOS TU Wien, Austria*; M Arndt,* Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein*; P Polcik,* Plansee Composite Materials GmbH, Germany*; H Euchner, N Koutná,* TU Wien, Austria*; D Holec,* Montanuniversität Leoben, Austria*; P Mayrhofer,* TU Wien, Austria

The ever-growing industry demands challenge researchers to develop ever-better performing materials. Evidently, the industry–university collaboration, implying funding for the research activities and monetization of the developed cutting-edge technologies, is mutually beneficial, and one of the most effective ways of engaging the knowledge exchange between industry and research institutions is a direct research collaboration of both.

The present research – conducted in cooperation with Oerlikon Balzers AG and Plansee Composite Materials GmbH – aimed at improving thermal stability and oxidation resistance of the cubic-structured molybdenum nitride γ-MoN_x. The refractory metal Mo is successfully used as alloying element (for nitrides in particular) for the purpose of improving hardness[1], toughness[2,3], friction coefficient[4], while the application of γ-MoN_x – though high-temperature allotropy – is strongly limited to 300–500 °C unless an oxygen-free atmosphere is provided. Optimizing the composition of alloying elements (able to form a dense oxide scale at elevated temperatures, e.g. Al and Cr) and vacancies (inherent in Mo-based nitrides), superhardness (over 40 GPa) combined with high resistance to plastic deformation (~0.4 GPa) and significantly improved thermal stability and oxidation resistance (both > 900 °C) could be achieved.

References:

1 Endrino, J. L. & Derflinger, V. The influence of alloying elements on the phase stability and mechanical properties of AlCrN coatings. *Surface and Coatings Technology* **200**, 988-992 (2005).

2 Sangiovanni, D. G., Hultman, L. & Chirita, V. Supertoughening in B1 transition metal nitride alloys by increased valence electron concentration. *Acta Materialia* **59**, 2121-2134 (2011).

3 Zhou, L., David, H. & Mayrhofer, P. H. Ab initio study of the alloying effect of transition metals on structure, stability and ductility of CrN. *J. Phys. D: Appl. Phys.* **46**, 365301 (2013).

4 Glatz, S. *et al.* Influence of Mo on the structure and the tribomechanical properties of arc evaporated Ti-Al-N. *Surface and Coatings Technology* (2017).

4:50pm **G6-11 Empirical Alloys-by-design Theory Calculations to the Microstructure Evolution Mechanical Properties of Mo-doped Laser Cladding NiAl Composite Coatings on Medium Carbon Steel Substrates***, C Lin,* ***Wei-Yu Kai,*** National Taipei University of Technology, Taiwan

An experimental investigation is performed into the microstructure and mechanical properties of Mo-doped (0, 3, 6, 9,12 and 15wt% Mo) NiAl coatings deposited on medium carbon steel substrates with a laser cladding process. It is shown that as the Mo content increases, the density of the Mo-rich phase network structure increases and the grain size of the laser-clad coating reduces. Furthermore, the hardness and wear test results indicate that a higher Mo addition not only increases the strength of the NiAl coating, but also improves its toughness and wear resistance. On the other hand, the underlying mechanism of phase formation and elements diffusion has been firstly studied by first principle simulation and DICTRA corresponding to the SEM micrographs of cross-section and coating-substrate interface. It is presented that pure NiAl and Mo phase exist a lowest formation enthalpy complying with the results of Thermocalc simulation. What more, the diffusion of Fe from substrate controlled by the addition of refractory element of Mo and the solid or liquid state of coatings during cladding process. Thus, with a combination of alloy design, the role of laser cladding process, and the theoretical calculation, this study provides a potential guideline for evolution and practical application of intermetallic compound in the future. In general, with a combination of alloy design, the role of laser cladding process, and the theoretical calculation in this study provide a useful source of reference for extending the applications of NiAl composite coatings in the aerospace field and other advanced industries.

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