Hard Coatings and Vapor Deposition Technologies
Room Town & Country C - Session B1-2-ThA

PVD Coatings and Technologies II

Moderator: Frank Kaulfuss, Fraunhofer Institute for Material and Beam Technology (IWS), Germany

1:20pm **B1-2-ThA-1 Ultra-Precision Optical Surface Processing by Reactive Atmospheric Plasmas and Low Energy Ion Beams (Virtual Presentation)**, ***Thomas Arnold (thomas.arnold@iom-leipzig.de)***, Leibniz Institute of Surface Engineering (IOM), Germany; *J. Bauer,* Leibniz Institute of Surface Engineering (IOM), Germany , Germany; *G. Boehm, H. Müller,* Leibniz Institut of Surface Engineering (IOM), Germany **INVITED**

High-performance optical elements such as lenses and mirrors require high accuracy regarding figure error, waviness, and roughness. Furthermore, the complexity of surface shapes increases and an increasing demand for individually and complex shaped optical elements like non-standard aspheres, acylinders, or freeform elements is observed. In particular, the use of free-form elements in optical systems offers new functions in illumination and imaging applications and leads to fewer optical surfaces and thus more compact system designs. Recent advances in manufacturing technology are giving optical system designers more and more freedom. However, once the machinability of complex shaped surfaces is proven, tolerances become more stringent. Especially for scientific devices, e.g. space- and earth-based spectrometers or telescopes, or for laser beam shaping applications, high precision of free-form optical surfaces is required.

Depending on the material to be machined different non-conventional processing methods have been developed that are based either on atmospheric pressure reactive plasma jet etching or ion beam etching to deterministically remove material from the surface or for finishing.

Fluorine plasma jet-based methods are usually applied on materials like optical glasses, silicon, SiC or ULE. Here the specific chemical interactions between reactive radicals formed in the plasma and the surface constituents must be taken into account to achieve predictable results with respect to form accuracy, roughness, and laser damage threshold. The presentation gives an overview over different plasma jet based processing chains for precise freeform optical lens generation and finishing.

Ion beam etching technology has been recently shown to be applicable to aluminium surfaces. Increasing demands on applications of high-performance mirror devices for visible and ultraviolet spectral range call for new processing schemes. Reactively driven ion beam machining using oxygen and nitrogen gases allows direct figure error correction up to 1 µm machining depth while preserving the initial roughness. Machining marks originating from preliminary surface shaping by single-point diamond turning often limit the applicability of mirror surfaces in the short-periodic spectral range. Ion beam planarization with the aid of a polymeric sacrificial layer is shown as a promising process route for surface smoothing, resulting in successfully reduction of the turning mark structures. A combination with ion beam direct surface smoothing to perform a subsequent improvement of the microroughness is presented.

2:00pm **B1-2-ThA-3 A Combinatorial Approach to Developing Sputter-Deposited Heavy-Metal Alloy Films for Inertial Confinement Fusion Applications**, ***Leonardus Bimo Bayu Aji (bayuaji1@llnl.gov)***, *A. Engwall,* Lawrence Livermore National Laboratory, USA; *J. Bae,* General Atomics, USA; *A. Baker, S. Shin, S. McCall, J. Moody, S. Kucheyev,* Lawrence Livermore National Laboratory, USA

Magnetically-assisted inertial confinement fusion (ICF) could push current National Ignition Facility (NIF) implosions closer to ignition. The application of a pulsed magnetic field to an ICF target requires the development ofnew hohlraums, which are sphero-cylindrical canswith wall thicknesses of over about 10 µm made from heavymetals. Magnetized ICF targets require heavy metal hohlraums with an electrical resistivity of over 100 µΩ cm at cryogenic temperatures of about 20 K. Such requirements cannot be met by the Au and depleted U hohlraums traditionally used for ICF. Here, we present results of our systematic study by combinatorial direct-current magnetron co-sputtering, aimed at developing a family of binary Au-Ta and Au-Bi films with the microstructure, stress, mechanical properties, and electronic transport favorable for ICF applications.

This work was performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA27344.

2:20pm **B1-2-ThA-4 Machine Learning Based Model for Plasma Prediction in HPPMS Processes**, *K. Bobzin, C. Kalscheuer, M. Carlet,* ***Julia Janowitz (Janowitz@iot.rwth-aachen.de)***, Surface Engineering Institute - RWTH Aachen University, Germany

The coating development using Physical Vapor Deposition (PVD) is time intensive and expensive. The coating processes are usually developed and improved based on the operator's experience. In order to improve the understanding of the processes during coating deposition, methods of plasma diagnostics can be used in the coating process. However, this is also time intensive and requires the installation of special diagnostics. The aim of the current study is to build a model of PVD processes for prediction of the intensity of the plasma species during the coating process. Through this, a contribution to data based coating development can be achieved. Machine learning methods are used to build a model of the PVD process to predict the intensity distribution of the species in the plasma during coating deposition. Based on measured data of different coating processes, the models were trained and tested. Therefore, a broad database was established by measuring the ion intensities of the species in the plasma. The data was collected for chromium and aluminum based hard coatings using an industrial magnetron sputtering unit for coating deposition. The data was measured for hybrid processes of direct current (dcMS) and high power pulsed magnetron sputtering (HPPMS). Here, the gas flow of the reactive gases oxygen and nitrogen was varied. Ion intensities were measured using optical emission spectroscopy (OES) with six substrate side positioned collimators to measure the influence of all cathodes used. The data was measured time resolved during the coating process. The predictions of the intensities show similar trends for the measured intensities of the species within the coating chamber. The predicted intensity range is in good agreement with the measured data. The built models can be used for a more targeted process development. This can contribute to the application oriented adjustment of the coating processes and the coating properties. Within the scope of this study, it was possible to predict the intensities of the plasma species in the coating process for an industrial coating unit using hybrid processes dcMS/HPPMS.

2:40pm **B1-2-ThA-5 Oxidation Stability of Oxynitride CrAlON Hard Coatings**, *K. Bobzin, C. Kalscheuer,* Surface Engineering Institute - RWTH Aachen University, Germany; *G. Grundmeier, T. de los Arcos, S. Schwiderek,* Technical and Macromolecular Chemistry - University of Paderborn, Germany; ***Marco Carlet (carlet@iot.rwth-aachen.de)***, Surface Engineering Institute - RWTH Aachen University, Germany

Hard coatings like CrAlN deposited by physical vapor deposition are state of the art for wear and oxidation protection of cutting tools. High power pulsed magnetron sputtering (HPPMS) leads to a higher degree of ionization in plasma compared to direct current magnetron sputtering (dcMS). This enables the deposition of coatings with denser structures and smoother surfaces. Conducting a dcMS/HPPMS hybrid process combines the advantages of HPPMS with the high deposition rates of dcMS. Adding oxygen to CrAlN leads to the oxynitride coating system CrAlON. A reduced friction against steel was found for CrAlN coatings with an oxynitride CrAlON toplayer in previous studies. Since this decreases the thermal loadings on the coated cutting edge, it is beneficial during cutting. Nowadays, the interest of industry in oxynitride hard coatings is rising. However, the oxidation behavior of the quaternary oxynitride CrAlON has hardly been investigated yet. Therefore, the influence of the oxygen content in CrAlON hard coatings on the coating properties and on the oxidation stability was taken into account in the current study. The morphology of the coatings was investigated by scanning electron microscopy (SEM). The chemical composition of the bulk was measured by electron probe micro analysis and of the reaction layer by X-ray photoelectron spectroscopy. The phase composition of the coatings was investigated by X-ray diffraction (XRD) and the elastic-static properties by nanoindentation. Subsequently, the coated cemented carbide samples were heat treated at T = 900 °C and T = 1,000 °C for t = 0.5 h in ambient atmosphere. Finally, the heat treated samples were investigated by SEM and XRD again. A higher oxygen ratio of y = O/(N+O) of the coatings increased the indentation hardness and the resistance against plastic deformation. A moderate oxygen ratio of y = 13.2 % of the oxynitride coating increased the aluminum content of the reaction layer to x = Al/(Al+Cr) = 37.4 % compared to x = 27.3 % for the nitride coating and to x ≤ 30.2 % for the oxynitride coatings with higher oxygen contents of y ≥ 33.3 %. As shown by XRD, this enhanced the oxidation stability of the oxynitride coating with a moderate oxygen content of y = 13.2 % from T = 900 °C to T ≥ 1,000 °C.

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