Plasma and Vapor Deposition Processes
Room Town & Country A - Session PP1-2-TuA

PVD Coating Technologies II

Moderators: Christian Kalscheuer, RWTH Aachen University, Germany, **Vladimir Pankov**, National Research Council of Canada

1:40pm **PP1-2-TuA-1 Use of van der Waals Layers and Ultrahigh Vacuum Environment to Control Composition and Crystallinity in Sputter-Deposited Thin Films***, **Suneel Kodambaka (kodambaka@vt.edu)**,* Virginia Tech, USA*; K. Tanaka, A. Deshpande, P. Arias, A. Aleman, H. Zaid, M. Liao,* University of California at Los Angeles, USA*; C. Ciobanu,* Colorado School of Mines, US*; M. Goorsky,* University of California at Los Angeles, USA **INVITED**

Compositional control in sputter-deposited thin films is typically achieved via changing the deposition parameters, such as partial pressure of the reactive gases, substrate temperature, deposition fluxes, and the target composition. Common approaches to improve crystallinity, to increase grain size and the grain orientation in thin solid films typically involve the use of single-crystalline substrates, high substrate temperatures combined with low deposition fluxes, and energetic ion beams.

In this talk, I will present approaches involving the use of ultra-low (e.g., 0.002%) partial pressures of the reactive gases and van der Waals (vdW) layers as buffer layers to grow thin films of desired composition and enhanced crystallinity. Using Ta-C and Mo-S as model materials systems, we demonstrate compositional tunability and improved crystallinity. We also shown that Ta_2C thin films grown on $Ta_2C(0001)$ covered with hexagonal boron nitride (hBN), a vdW-bonded material, are more highly oriented than those films grown directly on bare $Ta_2C(0001)$ under identical deposition conditions. That is, heteroepitaxial growth across a vdW layer seemingly yields better crystalline quality than homoepitaxy. We observe similar highly-oriented growth of face-centered cubic Pd, body centered cubic Mo, and hexagonal MoS_2 thin films on hBN-covered substrates. Our results provide new insights into the factors underlying the growth of highly-oriented thin films.

2:40pm **PP1-2-TuA-4 Generating Spokes in Direct Current Magnetron Sputtering Discharges by an Azimuthal Strong-to-Weak Magnetic Field Strength Transition***, **Martin Rudolph (martin.rudolph@iom-leipzig.de)**, W. Diyatmika,* Leibniz Institute of Surface Engineering (IOM), Germany*; O. Rattunde, E. Schuengel,* Evatec AG, Switzerland*; D. Kalanov,* Leibniz Institute of Surface Engineering (IOM), Germany*; J. Patscheider,* Evatec AG, Switzerland*; A. Anders,* Leibniz Institute of Surface Engineering (IOM), Germany

Spokes in magnetron discharges are zones of enhanced excitation and ionization that can be suspected to influence the ion ejection from the plasma toward a substrate and by that influence a deposited thin film morphology. Here, we show that spokes can be generated at a desired location by introducing a step in the magnetic field strength along the racetrack. For the experiments we use a magnetron with a 300 mm Al target operated in direct current mode. Two magnetic field strength transitions are obtained when splitting the racetrack into a section with a weak parallel magnetic field strength above the racetrack of ≈ 40 mT, and a strong magnetic field strength section with ≈ 90 mT. Using a gated intensified charge-coupled device (ICCD) camera, we observe the generation of spokes where drifting electrons transit from the strong to the weak magnetic field. The generated spokes move against the electron Hall drift into the strong magnetic field section, thereby creating a region of high spoke activity. The observation can be explained by an accelerating electron drift velocity as the magnetic field strength weakens. At the transition from the weak to the strong magnetic field, we observe a region of enhanced light emission that we attribute to the accumulation of electrons due to a lower drift velocity in a strong magnetic field. The observed effect is similar to a cross-corner effect known from rectangular magnetrons and we confirm here that this effect is primarily due to the change in the magnetic field strength and not caused by the geometry of the racetrack.

3:00pm **PP1-2-TuA-5 the Surface Temperature of a 2" Water-Cooled Ti Target Measured During DC Magnetron Sputtering***, **Stephen Muhl (muhl@unam.mx)**, J. Cruz, A. Garzon,* Universidad Nacional Autonoma de Mexico

The lateral temperature of a 2" diameter water-cooled titanium target was measured using an electrically floating fine, 0.005" wire, type K chromel-alumel thermocouple. The temperature measurements were performed as a function of the DC plasma power (power densities of 1.0, 2.2 and 4.1 W/cm2) and Ar gas pressures of 10 to 60 sccm. Typically, the temperature difference between the centre of the target and inside the racetrack was more than 200 oC, the racetrack temperature increased almost linearly with the applied power to a maximum value of ~840 oC.

The target temperature was also investigated as a function of the N_2 gas concentration in the Ar gas mixture (1 to 20%), and these measurements are compared with the elemental composition of the deposits produced.

4:00pm **PP1-2-TuA-8 Black Metal Thin Films Deposited on Cooled Substrates by Sputtering***, **Midori Kawamura (kawamumd@mail.kitami-it.ac.jp)**, H. Iino, H. Mori, Y. Otomo, T. Kiba, Y. Abe,* Kitami Institute of Technology, Japan*; M. Ueda,* Hokkaido University, Japan*; M. Micusik,* Slovak Academy of Sciences, Slovakia*; M. Hruska, M. Novotny, P. Fitl,* University of Chemistry and Technology, Czechia

Black metal thin films with a porous structure being broadband light absorber are attractive for various applications such as photothermic conversion and photodetection. Recently, they are expected to be applied to gas sensors, due to their large surface area. In addition to vacuum evaporation, sputtering has also been reported as a method for preparation of black metal thin films1). It has been well known that porous films can be obtained at low substrate temperature and high Ar gas pressure based on the structure zone model by Thornton. We have attempted to prepare black Al, Ag and Au thin films by sputtering on the substrate cooled with liquid nitrogen to suppress surface diffusion of atoms. The sputtering power and Ar gas pressure were also changed to obtain the films with porous structure. An RF magnetron sputtering system, in which the substrate can be cooled by liquid nitrogen, was mainly used for the deposition. The films were deposited on glass and Si substrates at room temperature, -80°C, and -170°C with Ar gas pressure of 6.5 - 33.3 Pa and sputtering power of 100 - 150 W at background pressure below 3.3 × 10^{-5} Pa. The deposited films were characterized by four point probe, SEM, AFM, XRD, XPS, and spectrophotometer.The Al films obtained at low temperature were black in color. However, metallic luster was observed from the backside of glass substrate. It means that a porous layer was formed after a thin dense layer was formed on the substrate. It was also found that black films formed by deposition at high Ar gas pressures and high RF powers. The light absorption of the films obtained was as high as 80% for the black Al films. The samples had a columnar structure and (100) crystal orientation.In conclusion, our results show that black metal films can be obtained by sputtering at low temperatures, high gas pressures and high RF powers. As shown in the figure, conditions which we explored for Al deposition are beyond the SZM. We are currently engaged in experiments with new deposition conditions, such as sputtering in Kr gas and DC power discharge, and results of these experiments will be presented as well.

Acknowledgement This work was supported by JST SICORP Grant Number JPMJSC2108, Japan, the Ministry of Education, Youth and Sports of the Czech Republic project No. 8F21008, and project No. JP22420 from the International Visegrad Fund.

Reference [1]J. More-Chevalier *el al.*, RSC Advances,10, 20765-20771 (2020).

[2] J. A. Thornton, J. Vac. Sci. Technol. 11, 666–670 (1974)

4:20pm **PP1-2-TuA-9 Advanced Process Control for PVD Coating Technologies in Production Lines***, **Thomas Schütte (schuette@plasus.de)**, J. Urbach, P. Neiß, M. Radloff,* PLASUS GmbH, Germany

As specifications in the thin film industry become more and more demanding, high production yields and cost effective production becomes a major factor in this competitive market. Increasing demands for better specifications and lower scrap rates drive the demand for efficient process control systems which gather comprehensive in-situ data of the process conditions as well as product properties.

Spectroscopic plasma process monitoring is a standard measurement technique to acquire data from the actual coating process in real-time. Also, time-resolved electrical measurements of generator power, voltage and current provide valuable process information especially in pulsed plasma applications. In addition, in-situ broadband photometric measurements can reveal important properties of the growing coating such as film thickness or color values.

This presentation will introduce the combined in-situ data acquisition from spectroscopic plasma monitoring, electrical measurements and photometric thin film measurements in demanding coating processes like metallic and reactive sputtering, HIPIMS, PECVD and microwave driven processes. By combining information from the different measurement techniques in a single system and evaluating the comprehensive data in real-time process control becomes more accurate and reliable and in turn enhances production stability and improves product quality.

Examples from various coating applications in industry and R&D are presented, including tribological, optical and architectural glass coating processes.

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