Surface Engineering - Applied Research and Industrial Applications
Room Town & Country C - Session IA1-MoA
Advances in Application Driven Research and Hybrid Systems, Processes and Coatings

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

1:40pm **IA1-MoA-1 PVD Thin Film Coating Materials in Semiconductors and Impact of CHIPS Act***, Shlok Sundaresh (sshlok91@gmail.com),* Tosoh SMD, Inc., USA **INVITED**

The CHIPS and Science Act in the United States has led to significant investments in domestic semiconductor manufacturing recently. It details the importance of building a resilient domestic supply chain with funding emphasis on construction, expansion, or modernization of commercial facilities. Semiconductor manufacturing involves numerous processing steps and one of those critical steps is thin film deposition of materials on wafers to form various patterns using PVD technology. Continued pursuit of Moore's law warrants advances in technology, and materials innovation plays a key role for achieving this. PVD sputtering target material developments are extremely critical for the performance of semiconductors as these are used as consumable sources for building them. The CHIPS Act has recognized this providing specific examples of PVD sputtering targets. The talk will thus focus on advances in manufacturing of key materials for sputtering these thin films in semiconductors along with the potential boost from the CHIPS Act towards this technology.

2:20pm **IA1-MoA-3 Production and Characterization of Coating-Substrate Combinations for Ceramic Data Storage Media***, Erwin Peck (erwin.peck@tuwien.ac.at),* TU Wien, Institute of Materials Science and Technology, Austria*; B. Hajas,* TU Wien, Austria*; A. Kirnbauer, L. Kreuziger,* TU Wien, Institute of Materials Science and Technology, Austria*; C. Pflaum,* Ceramic data solutions holding GmbH, Germany*; G. Liedl,* TU Wien, Austria*; P. Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria

Nowadays data storage and its sustainability is a topic of great importance, not only for cloud providers but also for other companies and even for people in their personal lives. Most of the data stored is referred to as cold data, meaning it is very rarely changed and accessed (e.g. photos, research results). That cold data must be stored, in order to do that, cloud providers run server farms utilizing hard drive discs (HDD). In that way they make the data available on the users' demand. Those server farms need a lot of energy, and the storage capacity is limited. To overcome the issue of needed energy and limited capacity, a new form of storage media is in the focus of our research. By utilizing a certain coating-substrate combination, it is possible to write data into ceramic data carriers using a femtosecond laser. By applying this method, it is possible to write a large amount (1.25 Gigabyte) of data onto a relatively small area (100 cm^2) of the ceramic data carrier. Within our research we analyzed different coating-substrate combinations regarding their mechanical properties and laser ablation characteristics. The coatings investigated were synthesized by magnetron sputtering and argon nitrogen gas mixture using different composite targets e.g. Ti, Cr, TiAlCr, and AlCrNbTaTi. The coatings were deposited on different substrates including sapphire, silicon, glass, and austenitic steel. All the coatings were investigated by XRD showing a single-phase fcc-structure and hardness values ranging from 21 to 33 GPa. After investigating structure and mechanical properties, laser ablation tests were conducted to determine the laser ablation threshold and to find suitable coating-substrate combinations for the aimed application. Furthermore, after writing data into the samples, the samples were tested for their thermal stability, oxidation resistance, and corrosion resistance. These studies prove the exceptional stability and durability of such ceramic data storage media. Once written, storing the data is almost without any energy consumption and such ceramic data carriers would allow to save 99% of the currently used energy for storing such data.

2:40pm **IA1-MoA-4 Microstructure Tuning of MXene ($Ti_3C_2T_x$) Systems for Device Applications***, Sangeeta Kale (sangeetakale2004@gmail.com), S. Kale, D. Sable,* Defence Institute of Advanced Technology, India **INVITED**

Titanium Carbide (Ti_3C_2Tx, MXene)materials, which are obtained via systematic removal of Aluminium (Al) layers from Ti_3AlC_2 (MAXene) system, have caught extreme due to their interesting structure of alternating two-edge shared octahedral layers of Ti_6C and highly porous accordion-like structure [1-2]. MXene shows work-function tuneability, porosity variations and varied surface-chemistry interplay, as a function of different synthesis processes [3]. Sensors, Schottky diodes, energy harvesters, and storage devices are envisaged from these materials [4].

Removal of Al layers using hydrofluoric acid (HF) is one common approach to convert MAXene to MXene and create porous structures and active surface states between the inter-digited octahedra structures. On the other hand, along with various other physical processes, pulsed laser deposition (PLD) system yield a range of thin films from stoichiometric high-quality thin films to defect-engineered films.

This talk will explore three different studies: i) bulk studies on the HF-etched-Ti_3AlC_2, yielding a tuneable work-function system, as a function of acid concentration [3] ii) thin films of Carbon-deficient Ti_3AlC_2 using PLD showing semiconducting behaviour on n-Si substrate [4]; and iii) bulk chemical treatment of MXene- molybdenum oxide (MoO_3) [5] nanocomposites to form a mutually synergistic system for gas (NH_3) sensing at room temperature. Ti_3AlC_2 material show p-type behavior; when deposited on n-Si or Alumina substrate, with strained growth depending upon the substrate; with different termination groups and morphological differences. Chemically synthesized MoO_3-MXenenanocomposites evolve as a synergistic system with improved room-temperature sensing sensitivity of MoO_3 along with a stable, yet highly reactive -O, -OH and -F sites of MXene surface. These studies are further explored for wide range of device applications.

References

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3:20pm **IA1-MoA-6 Decorative Coatings in Watch Making Industry: From Laboratory to Industry***, Joël Matthey (joel.matthey@positivecoating.ch),* Positive Coating SA, Switzerland*; O. Banakh,* Haute Ecole Arc Ingénierie, Switzerland*; L. Steinmann,* Positive Coating SA, Switzerland

Discovered in the late 1960's, the atomic layer deposition (ALD) is nowadays an established and widespread technology implemented in the industry. Despite being still predominantly applied to semiconductor devices, ALD has recently found its path into new sectors. One of them is the watchmaking niche market where design and reliability play a major role in luxury products. Due to its unique features, ALD offers attractive decorative coatings on complex components and brings innovation in terms of corrosion barrier. It is especially valid when combining the benefits of ALD with other technologies such as magnetron sputtering or electroplating. The aim of this presentation is recounting the extremely fast technology transfer of ALD from laboratory experiments to industrial scale processes. Through results and achievements, the fruitful collaboration between the University of Applied Sciences (HE-ARC) and Positive Coating SA is presented. Throughout the manufacturing sequence, the demanding requirements to obtain high-quality decorative coatings are discussed. When operating ALD technology to color tridimensional parts, simulated and experimental results show that fluidics regularly prevails over ALD process parameters. Furthermore, innovative processes using ALD as a substitute for obsolete technologies are addressed: namely red-gold anti-tarnishing, brass corrosion protection, and two-colored process without masking. Despite successful accomplishments, the technical and industrial challenges to tackle in the coming years are listed to evolve the ALD technology from the semiconductor to the decorative world. The conclusion is illustrated by specimens of luxury watches where decorative coatings highlight superb designs.

4:00pm **IA1-MoA-8 Real-Time Particle Detection for Enhanced Coating Deposition Processes***, Sylvain LeCoultre (sylvain.lecoultre@bfh.ch), C. Rieille,* Berner Fachhochschule ALPS, Switzerland **INVITED**

Coatings and the associated vacuum deposition processes will play an increasingly significant role in upcoming technological trends, particularly in the fields of photonics, optics, and Industry 4.0. However, the demands for these applications are imposing increasingly stringent requirements in terms of defect size and particle inclusions within functional layers. This is primarily attributed to the ongoing reduction in the size of device structures. Particles ranging in size from a few hundred nanometers to a few microns have proven to be a major challenge during various deposition processes. These minuscule particles often lead to component failures, resulting in unacceptably high rejection rates. Therefore, the development of deposition technologies capable of monitoring and significantly reducing the incorporation of particles into coatings is essential to access and succeed in these emerging markets.

As part of a multi-partner research project, we are focusing on the development of methods for the detection and real-time monitoring of particles generated in physical vapor deposition (PVD) processes, with particular emphasis on electron beam deposition and sputtering systems. Our research objectives include understanding the different sources of particle generation, whether related to the process, mechanical movements or the cleanliness of the deposition reactor during a production campaign. It also involves determining their size distribution and tracking their velocity in the vacuum environment with spatial and temporal resolution. In addition, we aim to contribute to the development of applicable strategies for eliminating particle sources during the vacuum deposition process, thereby increasing production yields.

To achieve these goals, we are engaged in the research and development of an in situ particle detector solution based on the fundamental principles of visible light beam scattering by particles. The chosen method will be compared with other possible particle detection methods suitable for high vacuum environment. First results on particle detection during different phases of a deposition batch will be presented. In addition, a first insight into the development of a data analysis algorithm that could enable informed decisions to be made for the maintenance of parts to be changed will be discussed.

4:40pm **IA1-MoA-10 Microscopic Characterization of Optical Properties and Film Thickness Using Imaging Spectroscopic Ellipsometry***, H. Noh,* ***Alejandro Ponilla (alejandro@parksystems.com)****,* Park Systems, USA

Ellipsometry is a well-known, non-destructive optical method to measure a thin film's thickness and optical properties. It has been widely used to characterize the complex refractive indices of materials or to control the quality of a film's thickness in manufacturing processes. Demands on microscopic characterizations of optical properties have been greatly increased for new materials and structures such as 2D materials, photonic devices, to name a few. Conventional ellipsometry, however, has been restricted to a spatial resolution of several tens of microns due to the spot size limitation. Here, we introduce imaging spectroscopic ellipsometry (ISE), which enables 1-micron lateral resolution, and its application to novel materials and structures. The ISE technique can be extensively used for new materials research and quality control of industrial applications.

5:00pm **IA1-MoA-11 Plasma PVD by Small Spiral Ta Hollow Cathode***, H. Baránková, N. Suntornwipat,* ***Ladislav Bardos (ladislav.bardos@angstrom.uu.se)****,* Uppsala University, Angstrom Laboratory, Sweden

Small spiral hollow cathodes represent interesting options for local plasma processing applications. The radio frequency powered small diameter spiral hollow cathodes made from 0.45 mm diameter Ta wire rolled around 0.5 mm diameter rod have been tested in coatings by physical vapor deposition (PVD) on silicon substrates at gas pressure of 3 Ttorr. Both the reactive PVD of TaN in pure nitrogen and Ta in pure argon resulted in similar rates of about 0.1 µm/min with maximum thickness in the centre of the coating spots. However, central parts of the spots can often contain large amounts of droplets from the melted spiral outlet. At higher RF powers the droplets from the melted sharp tip of the spiral can damage the coating and even melt the Si substrate. The heating of the spiral outlet was more intense in nitrogen than in argon. After 20 min also temperature of the sample table reached 500 °C in nitrogen plasma and up to 400 °C in argon. The sharp cut of the wire at the outlet of spiral can increase the local electric field and intensify eroding of the sample. Similar effect was confirmed by sharp ended stainless-steel medical needle with 1 mm outer diameter used as the hollow cathode.

5:20pm **IA1-MoA-12 Improvement of Surface Adhesion of Fluoropolymer Using Linear Ion Beam Source***,* ***Sunghoon Jung (hypess@kims.re.kr)****, J. Yang, E. Byeon, D. Kim, S. Lee, J. Park,* Korea Institute of Materials Science, Republic of Korea

Fluoropolymers, known for their excellent chemical and thermal resistances and low dielectric constants, play a pivotal role across diverse sectors. The inherent low surface energy of fluoropolymers, however, presents a notable challenge in terms of compatibility with other materials. Traditional methods to integrate fluoropolymers with different substances have largely relied on sodium-based chemical etching. These methods, while effective, often compromise the surface smoothness and are not environmentally sustainable.

In this study, we propose an innovative technique for the surface enhancement of fluoropolymers utilizing a linear ion beam source. By meticulously adjusting the ion beam process parameters, we have developed fluoropolymer bases with significantly improved hydrophilic characteristics. Additionally, this advanced technology has successfully increased the adhesive strength between fluoropolymer surfaces and the copper layers in flexible copper-clad laminates. The adoption of this novel surface modification method holds immense potential, especially in fabricating components for next-generation 6G mobile communication technologies, where strong and reliable adhesion is critically important.

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