Plasma and Vapor Deposition Processes
Room Golden State Ballroom - Session PP-ThP

Plasma and Vapor Deposition Processes Poster Session

PP-ThP-1 Contact Resistance Improvement of IGZO Devices through the Introduction of a Boosting Technique in the Source/Drain Regions*, **Hyeonmin Jo [hyunmine.cho@g.skku.edu]**, Sungsoo Lee, Jinhong Park,* Sungkyunkwan University (SKKU), Republic of Korea

As silicon-based devices continue to scale down, leakage current has emerged as a critical issue. To overcome this challenge, indium–gallium–zinc oxide (IGZO)–based oxide semiconductors, with their wide bandgap and superior leakage suppression, have been highlighted as promising next-generation channel materials. However, IGZO films face important limitations. Their amorphous structure, relatively low carrier concentration, and high Schottky barrier height (SBH) result in poor contact resistance, which has become a major obstacle for memory applications.

In this study, we propose a novel contact engineering approach that has not been reported previously. Specifically, Carrier boosting has previously been applied to the channel region to modulate the threshold voltage (Vth) of devices. We extend the technique to the source and drain regions. **A boosting layer is selectively deposited using PVD method on the contact areas to enhance doping and improve interface properties**. By locally increasing the doping concentration through this approach, the contact resistance can be effectively reduced. Finally, a high-performance metal electrode is deposited to ensure excellent electrical contact.

This integrated strategy is designed to reduce contact resistance while simultaneously improving the overall device performance.

PP-ThP-2 CVD-Grown MoS_2 Structures: Spiral Growth Mechanisms and Mechanical Response*, **Daniela Lucio-Rosales [daniela.lucio@cimav.edu.mx]**, David Torres-Torres, Alejandra Garcia-Garcia,* Centro de Investigación en Materiales Avanzados S.C., Mexico

Two-dimensional transition metal dichalcogenides (TMDs), particularly molybdenum disulfide (MoS_2), exhibit remarkable mechanical and electronic characteristics that make them promising for flexible and strain-engineered devices. However, establishing a direct connection between their growth mechanisms and mechanical performance remains a key challenge. In this work, MoS_2 thin films were synthesized by Chemical Vapor Deposition (CVD) on Si/SiO_2 substrates, revealing triangular domains dominated by a spiral growth pattern. This morphology originates from screw dislocations that promote a continuous step-flow mechanism during layer formation. The nucleation and propagation of these dislocations are strongly affected by the substrate's surface topography, leading to distinct variations in domain size and layer stacking.

Raman spectroscopy confirmed the crystalline nature of the films, showing well-defined vibrational modes associated with MoS_2. The in-plane (E^1_{2g}) and out-of-plane (A_{1g}) modes appeared around 383 cm^{-1} and 408 cm^{-1}, respectively, while additional features near 176 cm^{-1}, 228 cm^{-1}, and higher-order peaks above 418 cm^{-1} indicated complex interlayer interactions and multilayer coupling. These spectral variations were used to assess the structural uniformity and thickness of the films.

Atomic Force Microscopy (AFM) analyses revealed the stepwise topology typical of spiral growth and enabled quantitative evaluation of the vertical layer spacing. Nanoindentation experiments demonstrated that the presence of screw dislocations enhances the mechanical resilience of the material, resulting in a combined elastic–elastoplastic response. The observed hardening behavior suggests that dislocation-mediated growth can be harnessed to modulate the toughness and strain accommodation of 2D materials.

Overall, this study provides fundamental insight into how growth dynamics influence the microstructural and mechanical characteristics of CVD-grown MoS_2. These results contribute to the development of robust and flexible TMD-based coatings for applications in nanoelectromechanical systems (NEMS), strain sensors, and energy-dissipative devices.

PP-ThP-3 Predictive Modelling of Magnetron Sputtering: Bridging Computational and Experimental Approaches for Metallic Glass Thin Films*, Jaroslav Zenisek, Tereza Schmidtova,* Masaryk University, Czechia*; Antonin Kubicek, Vjaceslav Sochora,* SHM, Czechia*; **Pavel Soucek [soucek@physics.muni.cz]**,* Masaryk University, Czechia

Computational simulations are rapidly transforming the way magnetron sputtering processes are designed, understood, and optimized. They offer a powerful means of increasing experimental efficiency, accelerating process development, and improving reproducibility—particularly when transitioning from laboratory-scale research to industrial-scale coating production. Despite major advances in plasma-assisted deposition, one fundamental challenge remains: precise control of particle sputtering from the target and their subsequent transport toward the substrate. These parameters govern the particle abundance and energy while arriving at the substrate, ultimately determining coating stoichiometry, phase structure, microstructure, and performance.

While compositional gradients and local variations can be highly beneficial for combinatorial thin-film research, they are detrimental in industrial environments, where uniformity in thickness, composition, and phase structure are essential for high-throughput and large-area coating.

In this contribution, we demonstrate the combined use of SDTrimSP and SiMTra simulation tools to predict industrial magnetron sputtering of metallic glasses based on Zr–Cu(–Ni/Al) systems and on W–Ni–B and W–Zr–B systems, representing examples with comparable and strongly contrasting atomic masses. The simulations provide detailed predictions of relative thickness profiles, elemental composition distributions, and the energy spectra of the arriving species under varying process conditions.

The calculated results are compared with experimental data obtained from thin films deposited under controlled conditions, enabling a quantitative assessment of model accuracy and applicability. Furthermore, the functional properties of the deposited metallic glass coatings are correlated with the predicted parameters, establishing a clear link between process simulation and coating performance. This integrated computational–experimental approach provides a valuable framework for scaling magnetron sputtering from laboratory research to robust industrial production of chemically relatively complex coatings.

PP-ThP-4 How to Predict the Deposition Rate During Reactive Sputtering Using an One-Volume Reference Resource?*, **Diederik Depla [Diederik.Depla@ugent.be]**,* Ghent University, Belgium

A longstanding challenge in reactive magnetron sputtering is the quantitative prediction of the deposition rate, which is primarily determined by the partial metal sputtering yield from the oxide layer formed on the target surface during poisoning. The first step in addressing this issue is to determine the total sputtering yield of the oxide. This has been accomplished by refining a published semi-empirical model. This model has been applied to fit an extensive set of oxide sputtering yield data from the literature, comprising 65 datasets for 21 different materials. The fitting process establishes a relationship between the surface binding energies of metal and oxygen atoms and the cohesive energy of the oxide. The calculated partial sputtering yield of metal from a poisoned target is then compared with previously published experimental data on the metal sputtering yield during reactive magnetron sputtering. While both yields are linearly correlated, the magnetron-based sputtering yields are approximately eight times lower than the model predictions. This reduction in yield is attributed to the formation of an oxygen-rich surface layer, a hypothesis supported by binary collision approximation Monte Carlo simulations. However, these simulations do not fully capture the mechanism, as a more detailed description of the surface oxygen origin is needed. Despite this limitation, the experimental correlation provides a practical strategy for predicting deposition rates during reactive magnetron sputtering in fully poisoned mode. As demonstrated, the oxide sputtering yield can be calculated using standard data sources, and the empirical correlation between the sputtering yields enables a reliable estimate of the metal partial sputtering yield in poisoned mode, thus allowing for an accurate estimation of the deposition rate.

D. Depla, Note on the low deposition rate during reactive magnetron sputtering, Vacuum 228 (2024) 113546D. Depla, J. Van Bever, Calculation of oxide sputter yields Vacuum 222 (2024) 112994

PP-ThP-5 Properties and Behavior of Infrared Materials : Towards High Efficiency and High Durability Antireflection Coating, ***Manon Dewynter [manon.dewynter@orange.fr]**, Fabien Paumier, Éric Le-Bourhis, Cyril Dupeyrat,* Institut Pprime - CNRS - ENSMA - Université de Poitiers, France

This PhD research focuses on developing advanced thin-film coatings for substrates with complex geometries, aiming to achieve uniform properties and enhanced resistance under demanding operational environments. The study emphasizes optimizing deposition parameters to ensure consistent film characteristics—critical for the performance and durability of optical components in optronic systems. These systems incorporate diverse optical elements, including windows, lenses, filters, and dichroic plates, all requiring precise functionalization through thin-film treatments to meet stringent optical, mechanical, and chemical specifications.

Front optics in optronic devices play a key role in detection, observation, and identification. Operating under harsh and variable conditions—such as corrosive, erosive, and chemically aggressive environments—these components require coatings that maintain high optical transmission while exhibiting robust mechanical and chemical stability.

Typically, coatings are deposited by vapor-phase techniques such as Electron Beam Physical Vapor Deposition (EB-PVD) and Ion Beam Assisted Deposition (IBAD), enabling the formation of dense, uniform multilayer interference stacks. However, substrates with complex geometries—characterized by large diameters or high curvatures—pose significant challenges for achieving uniform coating deposition. Variations in thickness, density, and mechanical properties across the surface can lead to performance degradation, including chemical attack, delamination, and loss of optical quality, particularly under critical conditions such as saline fog exposure.

This project aims to elucidate the underlying growth mechanisms and physical phenomena at the material scale, focusing initially on single-layer coatings to establish a solid foundation of knowledge. Comprehensive characterizations—including nanoindentation, ellipsometry, and strain measurements—are employed to assess mechanical and optical properties and to study the influence of deposition parameters. The insights gained will guide the design of novel multilayer architectures incorporating new materials and interfaces to enhance thermomechanical performance.

Ultimately, this research supports the evolving specifications of optronic devices by delivering coatings with improved robustness and consistent functional properties, thereby advancing the performance and reliability of front optics in demanding operational environments.

PP-ThP-6 Plasma Research Reactor to Validate Nanocalorimetry as a Prospective Plasma Diagnostics Technique, ***Carles Corbella [carles.corbellaroca@nist.gov]***, National Institute of Standards and Technology (NIST)/ University of Maryland, College Park, USA; *Feng Yi, Andrei Kolmakov,* National Institute of Standards and Technology (NIST), USA

Recent advances in microelectronics require techniques for faster, more accurate, and comprehensive characterization of plasma-based nanofabrication processes, such as film deposition and surface etching or cleaning. Our recent demonstration of using membrane-based differential nanocalorimetry to measure atomic radicals in reactive plasmas sensitively [Diulus et al, J. Vac. Sci. Technol. B 43, 020601 (2025)] has inspired the further development of this new plasma probe. This probe aims to analyze plasma parameters and fundamental plasma-surface interactions through heat exchange measurements.The present work describes a research plasma reactor equipped with adjustable ICP and CCP sources and standard plasma diagnostics tools to benchmark the nanocalorimeter output: (1) single and double Langmuir probes to provide plasma parameters and electron energy probability function (EEPF); (2) retarding field energy analyzer (RFEA) with a built-in quartz microbalance to evaluate ion energy distributions and mass variation rates, and (3) optical emission spectroscopy (OES) together with (4) quadrupole mass spectrometer for plasma/wall chemistry monitoring. Key nanocalorimeter characteristics, such as sensitivity, response time, lifetime, and stability, as well as parasitic signal interference, will be discussed. This new sensor is well-suited for monitoring surface modification processes in multiple plasma treatment applications.

PP-ThP-7 The Role of ALD Oxide Interlayer Thickness in Metal-Polymer Adhesion, ***Johanna Byloff [johanna.byloff@empa.ch]***, ETH Zurich, Switzerland; *Claus Trost,* Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, Leoben, Austria; *Vivek Devulapalli, Barbara Putz,* Empa, Swiss Federal Laboratories for Materials Science and Technology, Switzerland

Adhesion of metal-polymer thin film systems remains a critical challenge for flexible electronics, where interfacial failure can compromise device performance [1]. Here, we demonstrate how atomic layer deposition (ALD) of ultra-thin AlO_xH_y interlayers systematically improves the interface quality of aluminum films on polyimide substrates. Using a novel ALD-PVD cluster system with in-vacuo transfer for precise control of interlayer thickness from 0.14 to 25 nm, we identify four distinct interfacial regimes. Distinction is based on structural and chemical transmission electron microscopy analysis of the interfacial region correlated with delamination, crack initiation and propagation during uniaxial tensile testing studied with in situ electrical resistance measurements and post-mortem atomic force microscopy. Ultra-thin ALD coverage (0.14 nm) enhances native Al-O-C complex formation and adhesion, while a 1 nm-thick ALD later results in unfavorable island-growth coverage, which generates an inhomogeneous interface acting as stress concentrators. At optimum intermediate thicknesses (5-10 nm), a homogeneous and ductile AlO_xH_y interface is formed, while thicker interlayers (≥ 25 nm) induce embrittlement following an intrinsic ductile-to-brittle transition. We show that a 5-10 nm ALD interlayer facilitates plasticity in the Al layer, which results in a 35% increase in interfacial shear strength and maintained electrical conductivity up to 8% applied strain. These findings provide a framework for engineering robust metal-polymer interfaces without the embrittlement associated with traditional adhesion-promoting interlayers, offering pathways for enhanced reliability in flexible electronics applications.

[1] Lu M., You J., Gao M., Li W., Zhang C., Zhu B., Peng C., Wu S., Ren W., Li G., Guo C. F., Yang J., Interfacial adhesion in flexible electronics: Materials, structures and applications, Coordination Chemistry Reviews, Volume 523 (1), 2025, 216278

PP-ThP-8 Ion Acceleration on Insulating Substrates: Synchronized Floating Potential HiPIMS for AlN and AlScN Thin Film Growth, ***Oleksandr Pshyk [oleksandr.pshyk@empa.ch]**, Jyotish Patidar, Kerstin Thorwarth, Lars Sommerhäuser, Sebastain Siol,* Empa - Swiss Federal Laboratories for Materials Science and Technology, Switzerland

Ion acceleration is one of the main process tools in the field of ionized physical vapor deposition (IPVD) for thin-film microstructure manipulation. However, the acceleration of film-forming ions onto insulating substrates has been limited, if not impossible, using conventional approaches. Recently, the demonstration of synchronized floating potential HiPIMS (SFP-HiPIMS) has opened new avenues for controlled metal-ion acceleration on insulating substrates [1].

In this presentation, we report on systematic studies of two industrially relevant materials – AlN and AlScN thin films – grown on a range of insulating substrates using SFP-HiPIMS. The substrates include single-crystalline silicon (001), Z-cut quartz, c-cut sapphire, and amorphous borosilicate glass. The concept of SFP-HiPIMS is based on synchronizing the arrival of film-forming ions at the substrate surface with the build-up of the negative floating potential. Since the sputtered species in HiPIMS are time-separated and the build-up of the negative floating potential is transient, achieving this requires precise synchronization between the HiPIMS pulse-on time and the floating potential-on time (defined as the time offset). Such synchronization allows the attraction of film-forming ions to the substrate while avoiding Ar^+ process gas ion bombardment and incorporation into the growing film. Although the SFP-HiPIMS can be implemented using at least two HiPIMS pulses, we demonstrate its feasibility not only for a multiple-magnetron configuration but also for a single-magnetron setup. We evaluate the microstructural quality of AlN and AlScN thin films grown by conventional HiPIMS and SFP-HiPIMS under different magnetron configurations and time offsets in terms of rocking-curve full-width at a half maximum (FWHM), Ar content, and surface roughness.

References:

[1] Nature Communications (2025) 16:4719

PP-ThP-9 Effect of Si and B Incorporation in TiCN-based Thin Film on Physical Properties by Direct Current Plasma Chemical Vapor Deposition*, Rizu Kurogi [ss25435t@st.omu.ac.jp], Takeyasu Saito, Noki Okamoto, Mika Kawamoto,* Osaka Metropolitan University, Japan

Ti-based carbonitride thin films such as TiN, TiC, and TiCN have been used to enhance wear resistance and lifetime of cutting tool. Recent studies employed additional elements such as Si or B to form multi component thin films like TiSiCN and TiBCN to improve oxidation resistance and thermal stability. These films are considered to consist of Ti(C,N) nanocrystals dispersed in amorphous TSiCN or TiBCN, which effectively suppresses grain coarsening and also enhances oxidation resistance.

However, most of the TiSiCN and TiBCN thin films have been synthesized to date by physical vapor deposition methods such as magnetron sputtering or arc evaporation, which often result in poor step coverage and interfacial adhesion strength on complex-shaped substrates. Most of previous studies employed physical vapor deposition methods such as magnetron sputtering or arc evaporation, while plasma enhanced chemical vapor deposition (CVD) provides potential advantage on higher conformality, stronger interfacial adhesion and low temperature fabrication for complex-shaped tools and components.

In this study, TiSiCN and TiBCN thin films were deposited on Si and cemented carbide (WC–Co) substrates using direct current plasma CVD at around 600 ℃ where WC–Co substrates were pretreated with aqua regia to improve interfacial adhesion.

The precursor gases were $TiCl_4$, CH_4, N_2, tetramethyl silane (TMS), and BBr_3. The effects of deposition parameters on the film structure and physical properties were systematically investigated using X-ray diffraction, X-ray photoelectron spectroscopy, and nanoindentation.

Si content in the TiSiCN thin films increased with increasing TMS flow rate, while the B content in the TiBCN thin films also increased with increasing BBr_3 flow rate. TiSiCN thin films exhibited higher hardness as maximum value of HV 2585 than that of TiCN thin film. However, the hardness of TiSiCN film decreased according to increase of Si content in the film. The effects of addition of Si and B on grain refinement and structural densification will be discussed.

PP-ThP-10 RF Plasma Nitriding of Quartz*, Stephen Muhl [muhl@unam.mx], Julio Cruz,* UNAM, Mexico*; Enrique Camps,* ININ, Mexico

Plasma nitriding is a valuable and well-established technique for surface hardening of metals to improve their mechanical and tribological properties, such as hardness and wear resistance. Typically, plasma nitriding involves the use of a glow discharge of a mixture of nitrogen and hydrogen, where the metal component to be treated is the cathode and the chamber wall is the anode. The low-pressure plasma (15–1500 Pa) produced by the application of a DC potential (0.3–1.0 kV) contains nitrogen ions, which are accelerated towards the cathode and implanted in the surface of the metal. The treatment time, surface concentration of nitrogen, and temperature of the metal component determine the depth and gradient of the nitride layer, but various tens of microns are often formed. The same process cannot directly be used to nitride insulators since such materials cannot be used as an electrode in a DC plasma.

We have developed a variant of the normal plasma nitriding scheme where the discharge is produced by applying an RF potential and the piece to be nitrided is mounted on a magnetron cathode. This is, of course, the same as a RF magnetron sputtering system. It is known that the DC voltage bias generated on the surface of such an insulting target with a RF magnetron sputtering cathode depends on the following factors: the relative areas of the anode and cathode, the applied RF power, the gas pressure and composition, and the degree of matching of the impedance of the electrical supply to the impedance of the plasma. We have measured the DC bias potential and the rate of sputtering of a quartz target mounted on a 2” MAK magnetron cathode in a pure nitrogen gas discharge as a function of the area of the anode, the applied power, and the degree of matching indicated by the ratio RF(Reflected Power) / RF(Forward Power). Using conditions which produced a minimum sputter etching of the target, we produced three nitrided samples. We present the dimensions and composition of the nitride layers measured using XPS and RBS, the hardness and wear resistance and the optical properties measured using multi-wavelength ellipsometry of these layers.

Author Index

Bold page numbers indicate presenter