Functional Thin Films and Surfaces
Room Town & Country A - Session MB4-MoM

2D Materials: Synthesis, Characterization, and Applications

Moderators: Chih-Yen Chen, National Sun Yat-sen University, Taiwan , Ying-Hao Chu, National Tsing Hua University, Taiwan

10:00am **MB4-MoM-1 Influence of Plasmonic Coupling and Size Effect on Photocatalysis of MoS$_2$/Au Hybrid Nanostructures for Water Splitting**, *Yi-Hsueh Chen (t870116@gmail.com), J. Ruan,* NCKU, Taiwan

Hydrogen energy is a clean andsustainable form of energy for our environment, serving as a viable alternative energy source that can be used without the production of greenhouse gases. Utilizing solar energy to split the water and generate hydrogen in the presence of photocatalysts is a promising and economic approach to address the current energy and environmental crisis. MoS$_2$ has been recognized as the most efficient photocatalyst for hydrogen evolution among non-noble metals. In particular, MoS$_2$ nanosheets exposed lots of active sites for the attachment of proton and later reduction reactions, and the efficiency is better than nanoflowers or bulk morphology. However, the absorption wavelength of MoS$_2$ nanosheets is almost within the UV region, in addition to the challenge of high electron/hole pairs recombination rate. Visible light accounts for 95% of sunlight and UV light occupies only 5%. It is vital for photocatalysts to efficiently harvest visible light and avoid exciton recombination. The absorption of visible light is able to cause strong localized surface plasmon resonance (LSPR) of gold nanoparticles (AuNPs), which has been widely investigated to promote light absorbance. Nevertheless, the desired dispersion patterns of AuNPs for the optimization of plasmonic resonance are less achievable. As an approach to maximize the amount of energy absorbed from the sunlight, we aim to design and fabricate hybrid particles composed of AuNPs and MoS$_2$ nanosheets with the control of coupling effect among AuNPs and the size of AuNPs. We have successfully grown MoS$_2$ nanosheets directly on the (111) planes of gold nanoparticles to form the core-shell structure with controlled thicknesses. Furthermore, the extent of enhancement of plasmonic coupling for gold nanoparticles with different diameters, i.e. 16 nm and 38 nm has been verified. Through the achieved adjustment of edge-to-edge distances among AuNPs and the size of AuNPs, the required condition for the best plasmonic resonance to absorb visible light is able to be clarified and thus optimizes the hot electron transition from AuNPs to MoS$_2$, which critically enhances desired hydrogen production.

10:20am **MB4-MoM-2 Sputter Deposition of Hexagonal Boron Nitride Films**, *Minsuk Seo (seo3@llnl.gov),* L. *Bayu Aji,* Lawrence Livermore National Laboratory, USA; *Y. Tzeng, S. Kim,* Stanford University, USA; *Y. Zhou, L. Wan, C. Kim, B. Wang, T. Heo, L. Zepeda-Ruiz,* Lawrence Livermore National Laboratory, USA; *S. Chu,* Stanford University, USA; *S. Kucheyev,* Lawrence Livermore National Laboratory, USA

Hexagonal boron nitride (hBN) films are attractive for several emerging energy-related applications. Extensive previous research has focused on the growth and properties of either ultrathin hBN films with thicknesses up to a few monolayers or cubic BN films. The synthesis of wafer-scale hBN films with controlled thickness above ~10 nm with desired properties remains a challenge. Here, we present results of our ongoing systematic study of polycrystalline hBN films with thicknesses in a wide range of 50-6000 nm deposited by several variants of reactive magnetron sputtering with a radiofrequency (RF) driven discharge. We describe how the plasma discharge characteristics and, hence, resultant major film properties can be controlled by the magnetron source design, the confining magnetic field, and process parameters such as the working gas pressure (influencing landing neutral atom ballistics and energetics), substrate temperature (adatom mobility), and substrate bias (bombarding ion energy). Even without epitaxy, with substrates held close to room temperature, hBN films are polycrystalline, characterized by a FWHM of the major E$_{2g}$ Raman vibrational mode (1370 cm^{-1}) in the range of 40 – 100 cm^{-1}, depending on deposition conditions. The FWHM reduces to ~30 cm^{-1} when a higher deposition temperature of 600-800 $^{\circ}$C is used. Interestingly, all as-grown films are polycrystalline (turbostratic, with asymmetrically stacked layers) rather than amorphous even for a high deposition pressure of 50 mTorr, characterized by low landing atom energetics. We also describe how these film growth and characterization experiments are guided by results of in-situ plasma diagnostics.

10:40am **MB4-MoM-3 Advancing 2D Materials for Future Electronics: Selective Synthesis, Transferring Processes, and Device Integration**, *Ching Yuan Su (cysu@ncu.edu.tw),* National Central University, Taiwan **INVITED**

Two-dimensional (2D) materials like graphene and transition metal dichalcogenides (TMDs) have attracted significant attention due to their exceptional electrical properties, holding promise for next-generation nanoelectronics. However, integrating 2D materials into IC devices presents challenges, including precisely controlled synthesis methods, defect-free transfer processes, and back-end-of-line (BEOL) device integration.

In this talk, I will discuss advancements in selectively seeding growth of high-quality 2D materials on insulating substrates using a new precursor and advanced process. Additionally, an efficient and reliable method for the wafer-scale transfer of graphene and other 2D materials, ensuring integrity and cleanliness, will be presented. Finally, I will highlight the concept of a heterogeneously integrated 3D-IC, combining a 2D-based field-effect transistor (FET) with high-performance memory, showcasing the potential for BEOL and monolithic integration of 2D-based 3D-ICs.

11:20am **MB4-MoM-5 Reduced Electrocatalytic potential of Nitrate to Ammonia through MoS$_2$ Deposited Carbon Felt based Flexible Electrode**, *Prateek Sharma (prateeksharma1688@gmail.com), C. Liao, Y. Chang, D. Huang, W. Hsu, J. Huang, Y. Lai,* Ming Chi University of Technology, Taiwan

The increasing need, for environment friendly and energy efficient methods to remove nitrate from water has prompted the investigation of inventive electrocatalytic techniques. This work highlights an approach to convert nitrate into ammonia at low potential using carbon felt coated with Molybdenum disulfide (MoS$_2$) nanosheets as a flexible electrode. The layered structure of MoS$_2$, with exposed edge sites, provides active catalytic sites for the reduction reactions. This enhances the catalytic activity compared to other materials, contributing to more efficient nitrate ion degradation, making it a potential candidate for sustainable water treatment.MoS$_2$ can be deposited on flexible substrates, such as carbon felt, creating flexible electrodes.the flexible nature of the MoS$_2$-deposited carbon felt electrode enhances the catalytic activity, allows for easy integration into existing water treatment systems, providing adaptability and scalability for practical applications. This research contributes towards the formation of efficient MoS$_2$ nanosheets as catalyst material for the advancement of electrocatalysis for sustainable water treatment but also underscores the significance of flexible electrodes in enhancing the adaptability and efficiency of the nitrate to ammonia conversion process. The findings presented in this conference aim to foster discussions and collaborations towards the development of energy-efficient and environmentally friendly technologies for nitrogen removal from water sources.

Keywords: Nitrate ion reduction, Electrocatalysis, Flexible electrode, Electrodeposition, MoS$_2$ nanosheets

Functional Thin Films and Surfaces
Room Town & Country A - Session MB1-MoA

Thin Films and Surfaces for Optical Applications

Moderators: Jörg Patscheider, Evatec AG, Switzerland, **Juan Antonio Zapien**, City University of Hong Kong

1:40pm **MB1-MoA-1 Improvements to Multilayer Dielectric Coatings to Enable Internal Confinement Fusion at the National Ignition Facility (NIF)**, *Colin Harthcock (harthcock1@llnl.gov)*, Lawrence Livermore Laboratory, USA **INVITED**

Since the advent of the laser, it has been theorized that high power lasers could be used as drivers for inertial confinement fusion (ICF), which has the possibility of revolutionizing our energy generation and dependance.As such, the US Department of Energy (DOE) has invested in this technology since the early 1970s, culminating in the building of the National Ignition Facility (NIF) from 1997 - 2009. However, it was quickly understood that the damage to the multilayer dielectric (MLD) interference coatings in the laser system may be key fluence and power limiting components. As such there was a huge, interdisciplinary effort to understand laser matter interactions leading to damage and the associated laser-damage prone precursors and mitigations. In this talk, we will discuss the basic layout of the NIF laser system and the associated coatings. Notable were the issues with the coating of high quality, meter-sized optics with good uniformity and high damage performance – this necessitated the use of electron beam evaporation for many of the high fluence, large aperture mirrors. For each of these MLD coating types, we will discuss the typical issues, typical damage-prone precursors and the associated mitigations. For many of the mirrors, nodular-type defects have been shown to increase the local electric field, absorption and greatly decrease the damage resistance of the coating. Furthermore, we will discuss other defects, such as stoichiometric issues, crystallinity, and nanobubbles.

2:20pm **MB1-MoA-3 Investigating Thin Ito Films for Light Detectors at Cryogenic Temperatures**, *Giorgio Keppel (giorgio.keppel@lnl.infn.it)*, O. Azzolini, C. Pira, A. Kotliarenko, M. El Idrissi, D. Ford, Legnaro National Laboratories, Italian National Institute for Nuclear Physics, Italy

Indium tin oxide (ITO) is a widely used transparent conductive oxide thin film. ITO shows promising behaviours in various applications, such as biosensors, flat panels, and photovoltaics, due to its excellent electrical conductivity and optical transparency [1]. However, there has been limited recent research on its performance and characterisations at low temperatures [2].

In our study, we propose using ITO thin coatings for bolometric light detectors, which are currently used in cryogenic experiments for detecting rare events. It includes the direct detection of dark matter and the search for neutrinoless double-beta decay. Calorimetric detectors provide a straightforward solution for photon detection at cryogenic temperatures (mK) [3]. According to the authors' knowledge, there are preliminary measurements of ITO films below 12 K [2].

In our work, ITO thin films were deposited onto silicon wafers and quartz samples by magnetron sputtering technique using ITO target at room temperature on DC mode. The 90 to 900 nm deposited samples were characterized using X-ray diffractometry (XRD) to study their crystallinity and stoichiometry and scanning electron microscopy (SEM) to analyze their morphology and growth behaviour. The electrical characteristics of the ITO films were evaluated at both room temperature and cryogenic temperature (77 K and 4.2 K) using an upgraded resistive measurement system [4].

As a result, we present a study on the electrical properties of thin ITO coatings at cryogenic temperatures below 12 K in correlation with their optical properties. Additionally, we demonstrate the initial findings on developing silicon-based light detectors that incorporate ITO films and utilize the Neganov-Luke effect.

[1] Aydın, Elif Burcu et al. TrAC Trends in Analytical Chemistry, 97(2017): 309-315.

[2]Pawlak, et al., P. Sensors,17(2017),51.

[3] Novati, V., et al. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 940, (2019) 320-327.

[4]D. Ford et al.. LNL Annual Report (2022),162.

2:40pm **MB1-MoA-4 Key Success Factor of Solid-Phase Crystallization Through Postannealing Under Atmospheric Conditions on Amorphous Conductive W-Doped In₂O₃ Ultra-Thin Films with Thicknesses of Less Than 10 Nm**, *Rajasekaran Palani (palani.rajasekaran@kochi-tech.ac.jp)*, T. Yamamoto, Kochi University of Technology, Research Institute, Japan; M. Maehara, Y. Okada, K. Kinoshita, Sumitomo Heavy Industries, Ltd., Industrial Equipment Division, Japan

In this work, for wide applications of W-doped In_2O_3 (IWO) films, we investigate the structural, electrical, and optical properties of amorphous and polycrystalline W-doped In_2O_3 (WO_3: W content of 1 wt. % (=0.6 at.%)) ultra-thin films. First, amorphous (a-IWO) films with thicknesses (t) ranging from 5 to 50 nm were deposited on glass substrates without intentionally heating of the substrates by reactive plasma deposition with dc arc discharge. Then, under atmosphere-condition for 30 min, we carried out the solid-phase crystallization (SPC) of a-IWO films at different temperatures of 200 and 250°C. Experimental results yield that the postannealing temperature is a key factor to improve the properties of polycrystalline IWO (p-IWO) films. Concerning the effects of the SPC on structural properties of ultra-thin IWO films, we used in-plane X-ray diffraction (XRD: Rigaku SmartLab) which is very effective to study the microstructure characterization of the thin films. Electrical and optical properties were determined by Hall-effect (Nanometrics HL5500PC) and UV-Vis-NIR spectrophotometer measurements (Hitachi U-4100), respectively. We observed not sharp diffraction peaks but just broad ones in case of as-deposited IWO films with t of a 10 nm or less. As a result of the SPC concerning IWO films with t of 7 and 10 nm, we found the polycrystalline IWO films, regardless of the postannealing temperature (T_p); those films have a cubic bixbyite crystal structure (space group of Ia-3). In-plane XRD measurement results showed as follows: for 10-nm-thick p-IWO films at different T_p, we found that an increase in T_p promoted (111) directed orientation, whereas we observed no above effect of T_p for 7-nm-thick p-IWO films. Hall-effect-measurement results showed that the transformation from a- to p-IWO films reduces carrier concentration (n_e) together with enhanced Hall mobility (μ_H) at any given t. This implies that SPC decreased the density of n-type donor defects, oxygen vacancies. The analysis of the data of optical absorption coefficients indicated the distinct difference in the effects of T_p on the electrical and structural properties between 7- and 10-nm thick p-IWO films. For 10-nm-thick IWO films, an increase in T_p enhanced the crystallographic (111) orientation between grains. On the other hand, for 7-nm-thick IWO films, the above increase remarkably improved the lattice order in the grains: We, thereby, have achieved μ_H of 60.5 cm²/(Vs) and n_e of 0.81×10^{20} cm⁻³ higher than those of 10-nm IWO films. In order to tailor electrical properties combined with optical properties of IWO films, the optimization of postannealing is essential.

4:00pm **MB1-MoA-8 Multifunctional Bragg-Reflector-Enhanced Electrochromic Devices with Adjustable Optical Performance**, *M. Crouan, B. Baloukas, O. Zabeida, J. Klemberg-Sapieha, Ludvik Martinu (ludvik.martinu@polymtl.ca)*, Polytechnique Montréal, Canada

Electrochromic (EC) all-solid-state devices (ASSDs) are of great interest in various industrial applications, such as smart glass for buildings, airplane windows, lenses, and mirrors. These devices possess allow one to dynamically change their optical properties, transitioning from a bleached state to a colored state through a redox reaction following the application of a low voltage. Due to the inherent properties of EC materials, ASSDs exhibit significant absorption and transmission modulation and, as a result, a limited capacity for reflection modulation. Yet, achieving a reflection increase upon coloration can offer new functionalities in terms of aesthetics and the development of innovative optical filters.

The implementation of EC Bragg mirrors (ECBM) using WO_3 and ITO bilayers in an ASSD hence holds significant promise as a means of reaching a substantial increase in reflection at specific wavelengths during coloration. In this work, we compared a conventional ASSDs with various ECBM configurations incorporated into an ASSD. Specifically, via a comprehensive optical modeling study, we designed an ASSD which changes from a transparent anti-reflective state to a mirror-like opaque state within the visible spectrum. The fabricated antireflective ASSD with 2-bilayers of WO_3/ITO displayed an increase in R_{lum} from 1.4% in the bleached state to 8.9% in the colored state. By minimizing the constraints on the antireflective properties, we achieved a reflection increase of 19.8% upon coloration, opening new possibilities for dynamic optical interference filters.

Monday Afternoon, May 20, 2024

4:20pm MB1-MoA-9 Quantitative Strong Optical Nearfield Enhancement by Coupling Bloch Surface Wave Packet and Localized Surface Plasmon of Aunp for Surface-Enhanced Raman Spectroscopy, *M. Phoo, A. Adesina, Y. Foo,* City University of Hong Kong*; M. Zerrad,* CNRS, Central Marseille, France*; C. Amra,* CNRS, Centrale Marseille, France*; Juan Antonio Zapien (apjazs@cityu.edu.hk),* City University of Hong Kong

We present the ultra-high near-field enhancement ($EF\sim10^8$) that results from exciting Localized Surface Plasmon in gold nanoparticles (AuNP) using the high-Q photonic resonance from a Bloch Surface Wave (BSW) stack. The BSW stack is composed of a16 dielectric SiO_2 and Ta_2O_5 layers with total thickness ~2 um. Optical characterization is performed by spectroscopic ellipsometry (SE) in the spectral range (400-1200 nm). Excellent agreement between the SE data and modelling from i) standard Fresnel equations and matrix transfer formalism (FE- model) and ii) Finite-Difference Time-Domain (FDTD) method demonstrate efficient coupling between the photonic (BSW) and plasmonic (LSP) modes. Furthermore, the BSW stack enables high photonic confinement acting as an energy reservoir inside the multilayer stack; the high Q, ~5000, BSW photonic mode efficiently pumps the AuNP LSP, resulting in total near-field enhancement $\sim10^8$. Our experimental results and modelling demonstrate dual sensing with chemical identification, from Surface-Enhanced Raman Scattering (SERS), with simultaneous quantification, via BSW sensing.

4:40pm MB1-MoA-10 Strongly Thermochromic VO₂-Based Smart Coatings for Room-Temperature Applications Prepared on Glass, *Michal Kaufman (mkaufman@kfy.zcu.cz), J. Vlček, J. Houška, S. Farrukh,* University of West Bohemia, Czechia

Vanadium dioxide (VO_2) exhibits a reversible phase transition from a low-temperature monoclinic VO_2 (M1) semiconducting phase to a high-temperature tetragonal VO_2 (R) metallic phase at a transition temperature of approximately 68 °C for the bulk material. The automatic response to temperature and the abrupt decrease of infrared transmittance without attenuation of luminous transmittance in the metallic state make VO_2-based coatings a promising candidate for thermochromic smart windows reducing the energy consumption of buildings.

To meet the requirements for large-scale implementation on building glass, VO_2-based coatings should satisfy the following strict criteria simultaneously: a deposition temperature close to 300 °C, a transition temperature close to 25 °C, an integral luminous transmittance $T_{lum} > 60\%$, a modulation of the solar energy transmittance $\Delta T_{sol} > 10\%$, long-term environmental stability, and a more appealing color than yellowish or brownish colors in transmission.

The paper deals with a scalable sputter deposition technique for the preparation of strongly thermochromic YSZ/W and Sr co-doped VO_2/SiO_2 coatings on standard soda-lime glass at a relatively low substrate surface temperature (320 °C) and without any substrate bias voltage. The W and Sr co-doped VO_2 layers were deposited using a controlled high-power impulse magnetron sputtering of a V-W target combined with a simultaneous pulsed DC magnetron sputtering of a Sr target in argon-oxygen gas mixtures. The bottom antireflection Y-stabilized ZrO_2 (YSZ) layers were deposited using a controlled reactive high-power impulse magnetron sputtering of a Zr-Y target, while the top antireflection SiO_2 layers were deposited using a reactive mid-frequency bipolar dual magnetron sputtering of two Si targets.

The fundamental principles of this technique, and the design, structure and optical properties of the thermochromic coatings are presented. The coatings exhibit a transition temperature of 22-25 °C with an integral luminous transmittance T_{lum} up to 64% (at almost the same luminous transmittance above the transition temperature) and ΔT_{sol} =11%. Such a combination of properties, together with the relatively low deposition temperature (320 °C), has not yet been published by other teams for thermochromic VO_2-based coatings prepared by a scalable deposition technique compatible with the existing magnetron sputter systems in glass production lines and in large-scale roll-to-roll deposition devices.

5:00pm MB1-MoA-11 Nanostructured Metal Thin Films with Enhanced Mechano-Optical Properties for Solar Radiation Isolation, *A. Xomalis,* NTNU Trondheim, Norway*; Barbara Putz (barbara.putz@empa.ch),* Empa, Swiss Federal Laboratories for Materials Science and Technology, Thun, Switzerland*; X. Zheng,* KU Leuven, Belgium*; A. Groetsch,* Empa, Swiss Federal Laboratories for Materials Science and Technology, Thun, Switzerland*; G. Vandenbosch,* KU Leuven, Belgium*; J. Michler, J. Schwiedrzik,* Empa, Swiss Federal Laboratories for Materials Science and Technology, Thun, Switzerland

Thin metal films on flexible polymer substrates are used widely in satellite missions as they show extreme thermal isolation and high interface strength at a minimum specific weight. Here, we show how nano-structuring of Al thin films on polyimide can create plasmon resonances, allowing interplay with visible radiation while reflecting the unwanted infrared responsible for device heating. Focused ion beam milling was used to create areas of a repetitive ring pattern in Al thin films (100 nm thickness), with variations of the ring diameter (1.9 and 2.2 µm), periodicity (2.4 and 3.1 µm) and trench thickness (partially or fully perforation the Al films). Uniaxial tensile tests with *in situ* optical measurements reveal that the nano-patterning of the thin films results in crack-free domains, leading to resilient optical resonances withstanding applied strains up to ~20%. We also perform nanoscale electromagnetic and mechanical simulations to evaluate the thin films' mechano-optical behaviour. Our simulations well fit the experimental positions of strain localization, resulting in crack formation and thin film damage. The central parts of the ring pattern in the structured thin films remain crack-free at applied strains exceeding the crack onset strain of unpatterned, continuous coatings by >84%. Fragmentation analysis shows how, in contrast to unpatterned films, the developing crack pattern and spacing can be tailored by choosing appropriate structural parameters. Such small-footprint, resilient, and lightweight devices are highly desirable for heat rejection, communications, and spectroscopies in harsh environments.

Functional Thin Films and Surfaces
Room Town & Country D - Session MB2-1-WeM

Thin Films for Electronic Devices I

Moderators: Klaus Boebel, Oerlikon Surface Solution AG, Liechtenstein, **Panos Patsalas**, Aristotle University of Thessaloniki, Greece, **Jörg Patscheider**, Evatec AG, Switzerland

8:00am MB2-1-WeM-1 N-Doped Ba(Ti,Zr,Ta,Hf,Mo)O₃ Films Based Thin Film Transistors for UV Sensing, *Van Dung Nguyen (dungk57v@gmail.com)*, National Cheng Kung University (NCKU), Taiwan, Viet Nam; *K. Chang,* National Cheng Kung University (NCKU), Taiwan

In this research, N-doped Ba(Ti,Zr,Ta,Hf,Mo)O₃ dielectric films were integrated into ZnSnO-channel thin film transistor for a UV detector. The combinatorial sputtering was developed to fabricate the N-doped Ba(Ti,Zr,Ta,Hf,Mo)O₃ film. N-doped Ba(Ti,Zr,Ta,Hf,Mo)O₃ film exhibited a high dielectric constant (k ≈ 322), low leakage current density (J $_L$≈ 10^{-11}), and low dielectric loss of approximately 0.1, which is promising for gate dielectric layer in TFT applications. The resulting TFTs exhibited a high on/off current ratio of 10^8, high saturation mobility (µsat) of 196.36 $cm^2V^{-1}s^{-1}$, low threshold voltage (V_T) of 0.02 V, and low subthreshold swing of 0.072 $Vdec^{-1}$. Moreover, the devices exhibited stable performance with small V_T shifts and negligible changes in the maximum drain current under gate bias stress (GBS). Furthermore, the N-doped Ba(Ti,Zr,Ta,Hf,Mo) O₃-based phototransistor exhibited high sensitivity (S) up to 10^6 and high responsibility (R) of 1171.85 A/W.

8:20am MB2-1-WeM-2 Electrical Properties Based on 2D GaSe Nanobelts on the Metal-Semiconductor-Metal Photodetector, *Bo-Lin He (money332482587@gmail.com)*, *C. Wang,* National Taiwan University of Science and Technology, Taiwan

Gallium Selenide (GaSe) nanobelts grows in the furnace through gold catalysis methods. Scanning electron microscopy (SEM) image can observe that on the top of GaSe nanobelts have an Au particle. It shows the growth mechanism is vapor liquid solid (VLS) on the substrate. Firstly, the X-ray diffraction pattern (XRD) shows that GaSe exhibits a hexagonal crystal structure, where gallium and selenium atoms are arranged in alternating layers, forming a layered structure. Secondly, the Raman spectrum shows the different vibration modes at different four peaks. Lastly, GaSe demonstrates a direct bandgap of approximately 2.12 eV, in the ultraviolet-visible (UV) analysis shows the direct bandgap of approximately 2.33 eV.

In this work, GaSe nanobelts device with Ni electrodes are used the rapid temperature annealing (RTA) to control it and the results of SEM, EDS and line scan show the Ni is diffusing into the GaSe nanobelt, thus, forming the NiGaSe/GaSe heterojunction structure, the electrical characteristic results also imply the structural transformation of nanobelt. The varied temperature measurement results that determined the value of Schottky barrier is ~ 0.2 eV and the band alignment structure also proves the contact type is Schottky barrier. The electrical measurement results prove that the electrical property is improving and the performance of photodetector exhibits different to the device without annealing. The electrical results of MOSFETs of GaSe nanobelts by increasing drain currents with higher minus gate voltage means the electron-holes are the mainly charge carriers in the GaSe nanobelts, the results also show the electron-holes are leading the drain currents and it indicates that the GaSe is a p-type semiconductor. The gm (Transconductance) which defined as the ratio of changing out-put current at changing in-put voltage is about 3 × 10^{-13} S, and the mobility reveals how easy of charge carriers flow into the semiconductor and the value is about 1.5 × 10^{-3} $cm^2/V·S$.

Keywords: nanobelts, hexagonal, vapor liquid solid (VLS), direct bandgap, rapid temperature annealing (RTA), heterojunction structure, electrical characteristic, Schottky barrier, photodetector, MOSFETs

8:40am MB2-1-WeM-3 Strain-Induced Self-Rolled-Up Thin Films for Extreme Miniaturization and Integration of Passive Electronic Components, *Xiuling Li (xiuling.li@utexas.edu)*, The University of Texas at Austin, USA **INVITED**

The fundamental physical principle underlying self-rolled-up membrane (S-RuM) nanotechnology is the strain-driven spontaneous deformation of 2D membranes into 3D architectures. S-RuM technology offers a unique solution for achieving 3D functional hierarchical architectures without the challenges associated with processing in three dimensions. Through strain engineering, it opens up new possibilities by facilitating the creation of practically unlimited complexity in L-C circuits, integrated photonics, and lab-on-a-chip integration of soft and hard materials. Importantly, these advancements are achieved through the utilization of well-established CMOS-compatible planar processing techniques.

In this talk, I will present examples of S-RuM based passive electronic components, including on-chip inductors, transformers, L-C networks.I will discuss how S-RuM technology can potentially to break the constraints of size, weight, and performance of RFICs and power electronics.

9:20am MB2-1-WeM-5 Electrolyte Gated Transistors for Neuromorphic Signal Processing and Biosensing, *Luke Sylvander (luke.sylvander@rmit.edu.au)*, *P. Le, C. Tan, H. Tran,* RMIT University, Australia; *D. McKenzie,* University of Sydney, Australia; *D. McCulloch, J. Partridge,* RMIT University, Australia

An Ar plasma immersion ion implantation (PIII) process has been employed to introduce free-radical covalent binding sites in spin-on polymer layers. These layers have been incorporated as dielectric layers into lateral electrolyte-gated transistors (EGTs) with characteristics resembling those of biological synapses. Specifically, if the gate electrode of the EGT is taken to be the pre-synapse and voltage pulses are applied, the resulting source-drain output mimics aspects of postsynaptic signals. Notably, this postsynaptic output is sensitive to the dynamics of the double layers (DLs) that are formed at the two polymer/electrolyte interfaces when the presynaptic voltage is applied. If biomolecules are covalently immobilised on the PIII-treated polymer dielectric layer, the dynamics of the DL formation/decay are altered, as are the postsynaptic signals. This provides a neuromorphic detection signal and enables the EGTs to be used as artificial sensory synapses. This talk will cover the PIII treatment of the polymer layers, device fabrication/characterisation and biosensing measurements from the EGTs.

11:20am MB2-1-WeM-11 Tracking the Metal-Insulator Transition at YTiO₃/LaTiO₃ Interfaces Grown by the Soft Chemical Method, *Alexandre Simoes (zirpoli.simoes@unesp.br)*, UNESP, Brazil

In the last couple of years, perovskites and transition metal oxides have demonstrated high potential for energy storage/processing applications. Materials usually used in random access memory devices, such as perovskites and transition metal oxides (TMO), have shown potential to be applied in the fabrication of other types of nonvolatile memories. Correlated electron random access memories (CeRAMs) were recently developed for exhibiting partially filled *3d* bands in addition to showing resistive switching as a result of strong electronic correlations. It is worth mentioning that the band structure of related electronic materials depends not only on the d-orbitals of the transition metals, but also on the p-orbitals of neighboring oxygen atoms. In this work, oxide interfaces with piezoelectric, magnetic and metal-insulator transition based on YTiO₃/LaTiO₃heterostructured films were investigated. The Mott insulator, YTiO₃, was deposited onto a Mott insulator, LaTiO₃,via polymeric precursor method. Spin coating was performed to obtain a YTiO₃/LaTiO₃ heterostructured thin films deposited onto Pt/TiO₂/SiO₂/Si substrates. Structure, morphology, and electrical properties of the films were assessed. The YTiO₃/LaTiO₃heterostructures exhibit ferromagnetic and piezoelectric behavior ($d_{33máx}$≈8.11 pm/V), which may be attributed to smaller grain (average grain size≈20.00 nm) and, thus, a higher grain boundary density, and stress in the film plane due to the different properties of the interface. The dielectric permittivity and dielectric loss at 1 KHz were found to be 70 and 0.41, respectively. *I-V* measurements on different electrode areas confirmed a metal-to-insulator transition, indicating a potential application in correlated electron random access memory (CeRAM).

11:40am MB2-1-WeM-12 Adsorbing Chiral Molecules on High Entropy Iron Vanadate (FeVO₃) for Biomolecule Detection and Photoelectrochemical Cell Applications, *Amit Kumar Sharma (z11212022@ncku.edu.tw)*, *Y. Su,* National Cheng Kung University (NCKU), Taiwan

Chiral-induced spin selectivity (CISS) is at the forefront of photoelectrochemical water splitting and energy storage applications. CISS addresses the inhibition of hydrogen peroxide production by polarizing the spin of the ˙OH radical, thereby reducing the overpotential required by the photocatalyst to achieve high current density. This is achieved by conjugating chiral molecules with photocatalysts via self-assembly to induce electron spin selectivity from the electrolyte. Concurrently, numerous investigations have demonstrated the manipulation of spin polarization in metal oxides to foster spin selectivity and charge separation. However, such modifications are largely governed by the coordination structure and valence states of the transition metal. Additionally, the

conjugation of chiral molecules onto metal oxides encounters obstacles such as sensitivity to light exposure, high conductivity barrier, and inadequate active sites.

To address these challenges, we have fabricated high entropy iron vanadate metal oxide to serve a dual purpose as a biomolecular sensor and photoelectrochemical cell-based energy generator. High entropy oxides (HEO) have established their photocatalytic prowess in the UV regime of the light spectrum. To expand their applicability in visible light photocatalysis, HEOs should exhibit narrow bandgap, high electron-hole separation rate, low electron-hole recombination rate and an electronic band structure conducive to water splitting reaction.

In light of these studies, we investigate $FeVO_3$ nanosheets synthesized through solid-state reaction for enhanced near-infrared (NIR) absorption capability, magnetic property, and chromic response upon oxidation under prolonged exposure to visible light during photocatalysis. Furthermore, three enantiomers, viz. L- and D-arginine, L- and D-cysteine, L- and D-tryptophan, will be conjugated on the surface of the nanosheets to create a composite structure. The dual oxidation state of vanadium in $FeVO_3$, i.e. VO^{2+} and VO_2^+, assists in NIR absorption and provides interaction sites for chiral molecules through surface defects. The chemical adsorption and CISS for ˙OH radical will be assessed using circular dichroism (CD) and absorption spectroscopy. At the same time, the altered magnetic properties of the composite will be examined via magnetic force microscopy (MFM) and superconducting quantum interference device (SQUID). The selective binding affinity of the chiral amino acid towards the nanosheet will be assessed by optical and electrochemical measurements to differentiate between the L- and D- enantiomers. Appropriate composites will be selected rationally based on the visible to NIR absorption, reduced sensitivity to visible light, and photocurrent density in electrolytes.

Wednesday Afternoon, May 22, 2024

Functional Thin Films and Surfaces
Room Town & Country D - Session MB2-2-WeA

Thin Films for Electronic Devices II

Moderators: Klaus Boebel, Oerlikon Surface Solution AG, Liechtenstein,
Panos Patsalas, Aristotle University of Thessaloniki, Greece

2:00pm **MB2-2-WeA-1 Electro-optic Thin Film Switch for Silicon Photonics Quantum Computer**, *Vimal Kamineni (vimal@psiquantum.com),* PsiQuantum Ltd., USA **INVITED**

A general-purpose quantum computer has a broad range of applications from finance, healthcare, climate, security, computing, materials, to other industry verticals as companies continue to explore the possibilities. PsiQuantum is on a mission to build and deploy the world's first useful quantum computer utilizing integrated silicon photonics. Photonic qubits uniquely overcome the scaling challenges associated with error correction for implementing a large-scale fault tolerant quantum computer. These photonic qubits are implemented in an integrated custom process stack, co-developed with our semiconductor foundry partners. The talk will cover our development towards building a scalable integrated silicon photonics platform with focus on a high performance electro-optic thin film switch. Our linear optics operations are probabilistic, and efficiency of successful events is boosted by multiplexing using an electro-optic switch. The electro-optic material induces an optical phase shift when voltage is applied, and it is fabricated using barium titanate (BTO). Thin film BTO was downselected for our application as it offers the highest Pockels coefficient at room temperature when grown epitaxially as a thin film on silicon substrates. BTO enables high speed phase shifters with low loss and power consumption which are critical metrics for a quantum computer.

KEYWORDS
Silicon photonics, quantum computing, qubit, electro-optic switch, barium titanate

2:40pm **MB2-2-WeA-3 The Path to Deterministic Chaos in Resistively Switching $Hf_{0.5}Zr_{0.5}O_2$ Thin Films via Period-Doubling Bifurcations**, *Sebastian Obernberger (sebastian.obernberger@inrs.ca),* K. Kohlmann, Institut national de la recherche scientifique - Centre Énergie Matériaux Télécommunications, Canada; A. Sarkissian, Plasmionique Inc., Canada; P. Antici, Institut national de la recherche scientifique - Centre Énergie Matériaux Télécommunications, Canada; C. Schindler, Munich University of Applied Sciences, Germany; A. Ruediger, Institut national de la recherche scientifique - Centre Énergie Matériaux Télécommunications, Canada

The burgeoning interest from industry, research, and policymakers in cutting-edge domains of information technology, such as artificial intelligence, quantum computing, and quantum cryptography, underscores the pressing need for advanced electronic infrastructure. One promising development lies in the creation of novel "neuromorphic" memory cells designed to function as artificial synapses within neural networks, leveraging their intrinsic "spike-timing-dependent plasticity." While the simulation of such behavior has historically proven inefficient on conventional von-Neumann-architecture computers, our study unveils an intriguing opportunity: the observation of period-doubling bifurcations in ReRAM (Resistive Random-Access Memory) based neuromorphic cells.

Herein, we detail the fabrication and analysis of RF-magnetron sputtered $TiN/Hf_{0.5}Zr_{0.5}O_2$ (HZO)/Au capacitors, elucidating their switching behavior. Our investigation delves into the resistive switching mechanisms within the HZO layer, encompassing the formation and dissolution of conductive filaments and the modulation of tunneling barriers via the tunneling electroresistance effect (TER). Through this analysis, we discern energy dissipative phenomena culminating in a negative feedback loop in the "spike-timing-dependent plasticity." Crucially, this negative feedback loop engenders bifurcations within the cell's switching dynamics, serving as a conduit to deterministic chaos. Harnessing and controlling these bifurcations not only enhances the efficacy of neuromorphic cells as artificial synapses but also facilitates their deployment as rapid-switching, easily managed random number generators.

3:00pm **MB2-2-WeA-4 Stoichiometric Engineering of Rotary Metal Oxide Targets for Thin Film Applications: A Focus on Zinc Oxide Based Alternatives**, *Jing Yang (jyang@sciengineeredmaterials.com),* SCI Engineered Materials, Inc., USA

Indium Tin Oxide (ITO) is the most widely used transparent conductive oxide (TCO) for flexible electronics. With its demand increasing for applications such as liquid crystal displays, smart windows, thin film photovoltaics,architectural windows, and polymer-based electronics, the historically volatile pricing of Indium presents a concern for manufacturers. Zinc Oxide based materials, given Zn's abundance in Earth's crust, emerge as a cost-effective alternative for thin film applications.

Zinc Tin Oxide (ZTO), a potential candidate as the TCO layer in OLED, the channel layer in Thin Film Transistor (TFT), and the interlayer for low-E glass, faces challenges in DC-sputtering due to the spinel structure of Zinc Stannate. One solution is to employ reactive sputtering of Zinc and Tin metal targets. This approach introduces difficulty in terms of precise stoichiometric control and overall quality of finished film. Alternatively, RF sputtering of a ZTO target may be employed, but the film growth rate is very slow.

In this study, we explore the use of a conductive, sintered oxide target as the solution that offers controlled DC sputtering and high-quality film production. We demonstrate compounding various ratios of Zinc and Tin oxides into single targets to create conductive targets in both planar and rotary geometries for DC sputtering. The study assesses the stoichiometric impact on target manufacturing and the subsequent thin film properties, comparing the electrical and optical properties of ZnO-based films with traditional TCOs like ITO. We also present a conductive rotary target designed for high power density, crucial for high-throughput industrial applications.

3:20pm **MB2-2-WeA-5 Few-layered Multi-transition Metal Dichalcogenide Alloy Absorber for High-performance Photodetector**, *I-Hsi Chen (telescope50311@gmail.com),* T. Nguyen, J. Ting, National Cheng Kung University (NCKU), Taiwan

Low-dimensional materials including quantum dots, nanowires, and two-dimensional materials have attracted increasing research interest in the fields of electronics and optoelectronics. Photodetector is no exception as the use of monolayer two-dimensional (2D) material in photodetector has attracted a great deal of attentions. Among them, 2D transition metal dichalcogenide (TMDC) offers unique semiconductor properties, including quantum spin Hall effect, valley polarization, and two-dimensional superconductivity.

We report the growth of few-layered multi-metallic TMDC alloys with salt-assistance on SiO2/Si substrates with controllable composition using a chemical vapor deposition (CVD) technique. Composition control has been investigated by varying the concentration of individual precursors. Various analyses were carried out to understand the material properties, including structural, physical, chemical properties, and the performance of TMDCs in photodetectors.

3:40pm **MB2-2-WeA-6 Growth of Nanostructured Molybdenum Disulfide (MoS_2) Thin Film for the Application of Electronic Materials**, *I. Giwa, K. Qian, F. Sanchez, E. Mawire, S. Dong, E. Smith, Q. Yuan, Zhigang Xiao (zhigang.xiao@aamu.edu),* Alabama A&M University, USA

We report the fabrication of molybdenum disulfide (MoS_2) thin films–based electronic devices. Nanostructured molybdenum disulfide (MoS_2) thin films are grown as the active semiconducting channel material for the fabrication of MoS_2-based field-effect transistors using plasma-enhanced atomic layer deposition (ALD). MoS_2–based electronic devices such as MoS_2 field-effect transistors, inverters, and ring-oscillators are fabricated with the ALD-grown MoS_2 film using the clean room-based micro- and nano-fabrication techniques. Hydrogen sulfide (H_2S) gas is used as the S source in the growth of molybdenum disulfide (MoS_2) while molybdenum (V) chloride ($MoCl_5$) powder is used as the Mo source. The MoS_2 film will be analyzed by the high-resolution tunnel electron micrograph (HRTEM), scanning electron micrograph (SEM), X-ray photoelectron spectroscopy (XPS) analysis and Raman spectrum analysis. The fabricated MoS_2 device wafer will be annealed at high-temperatures (800 – 900 °C), and the electrical property of the MoS_2–based electronic devices will be measured before and after the high-temperature annealing and will be compared. The characterization results of the nanostructured molybdenum disulfide (MoS_2) thin films and

the measurement results on the fabricated MoS_2–based electronic devices will be reported in the ICMCTF 2024 Conference.

4:00pm **MB2-2-WeA-7 BaTiO₃ Epitaxial Thin Films Integrated on Si by Pulsed Laser Deposition for Electro-Optic Modulators**, *Heungsoo Kim (heungsoo.kim.civ@us.navy.mil), S. Mathews,* Naval Research Laboratory, USA*; A. Posadas, A. Demkov,* The University of Texas at Austin, USA*; A. Piqué,* Naval Research Laboratory, USA

$BaTiO_3$ (BTO) is a ferroelectric material that has large Pockels coefficient. Recently, there has been an increasing interest on epitaxial BTO films integrated on Si as a promising material platform for building electro-optic (EO) modulators.The Pockels, or linear-electro-optic effect is the first order change in the index of refraction under applied electric field and has an advantage over other optical modulation methods because it can operate at very low power and very high frequencies. Depending on lattice matching and thermal expansion difference with the substrate, BTO films can be grown either c-oriented BTO (elongated axis normal to the substrate surface) or a-oriented BTO (elongated axis parallel to the substrate surface). The electro-optic response in BTO films is highly dependent on their crystallinity and domain structures. For $BaTiO_3$ integration on Si, a $SrTiO_3$ (STO) buffer layer was first deposited on Si (001) substrate by molecular beam epitaxy. BTO films were then grown on STO-buffered Si template via pulsed laser deposition (PLD) at various oxygen pressures (10 – 50 mTorr) and substrate temperatures (600 – 760 °C). By optimizing the oxygen deposition pressure and substrate temperature, we were able to grow *a*-oriented domain structures of BTO films, which is a preferred domain structure for EO modulators due to a large Pockels effect in this configuration. We will present details of optimization processes to achieve *a*-oriented domain structures of BTO films along with their electro-optic responses.

Functional Thin Films and Surfaces
Room Palm 1-2 - Session MB3-1-ThM

Nanomaterial-based Thin Films and Structures I

Moderators: **Ondrej Kylian**, Charles University, Prague, Czechia, **Jörg Patscheider**, Evatec AG, Switzerland

8:00am **MB3-1-ThM-1 Dual Scale Structures Based on Nanocolumns and Nanoparticles**, *Lidia Martinez (lidia.martinez@icmm.csic.es)*, ICMM-CSIC, Spain; *J. García-Martín,* IMN-CSIC, Spain; *Y. Huttel,* ICMM-CSIC, Spain **INVITED**

Like the formation of alloys that combines the properties of different elements resulting in novel materials, the combination of different shapes and dimensions also leads to materials having novel properties, especially at the nanoscale. We will first briefly present the ultra-high vacuum physical methods used to grow the Nanocolumns (NCs) by Glancing Angle Deposition (GLAD) [1-2] and Nanoparticles (NPs) fabricated by means of a Multiple Ion Cluster Source (MICS) [3-4], highlighting the control over chemical composition, shape and dimensions of the fabricated nanostructures.Later, we will present some examples where the combination of NCs and NPs leads to synergic effects using materials like gold, silver, titania or iron oxide. In particular, we will present some examples of application as antibacterial coatings [5], photo-induced self-cleaning surfaces [6], SERS substrates [7], controlled wettability or catalysis among others.

References:

1. R. Álvarez et al., "Antibacterial Nanostructured Ti Coatings by Magnetron Sputtering: From Laboratory Scales to Industrial Reactors", Nanomaterials 9, 1217 (2019).

2. J. M. García-Martín et al., "Tilt angle control of nanocolumns grown by glancing angle sputtering at variable argon pressures", Appl. Phys. Lett. 97,173103 (2010).

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4. D. Llamosa et al., "The ultimate step towards a tailored engineering of core@shell and core@shell@shell nanoparticles", Nanoscale 6, 13483 (2014).

5. D. Medina-Cruz et al., "Synergic antibacterial coatings combining titanium nanocolumns and tellurium nanorods", Nanomedicine: Nanotechnology, Biology, and Medicine 17, 36–46 (2019).

6. F. Fresno et al., "Photo-Induced Self-Cleaning and Wettability in TiO2 Nanocolumn Arrays Obtained by Glancing-Angle Deposition with Sputtering", Adv. Sustainable Syst., 2100071 (2021).

7. G. Barbillon et al., in preparation.

8:40am **MB3-1-ThM-3 MGA Nanoparticle Thin Films for Enhanced Hydrogen Gas Sensing: Synthesis, Modeling, and Characterization**, *Stanislav Haviar (haviar@kfy.zcu.cz)*, T. Kozák, K. Shaji, University of West Bohemia, Czechia; *T. Košutová,* Charles University, Czechia; *B. Prifling, V. Schmidt,* Ulm University, Germany; *J. Čapek,* University of West Bohemia, Czechia

Thin films formed by nanoparticles from various metal oxides (WO_x, CuO_x, PdO_x) were synthesized using a magnetron-based aggregation cluster source (MGA). The mixing ratios of the oxide particles were adjusted to achieve the best conductometric sensorial response toward hydrogen gas.

(i) Single-material films were investigated utilizing electron microscopy, energy dispersive and photoemission spectroscopies and small-angle x-ray scattering (SEM, TEM, EDS, XPS, SAXS).

(ii) Results of these analyses were used as an input for hard-sphere packing algorithm simulations generating models of synthesized mixed-materials films.

(iii) Optimized finite element modeling was used to calculate the conductivity of modeled films. Various material parameters were adjusted to receive a quality estimation of mixed-materials behavior.

(iv) Output of the simulation was used as a lead for synthesizing films with optimum ratios of materials to generate nanoheterojunction-rich materials.

(v) Promising candidates were assembled as conductometric gas sensors and tested towards hydrogen gas.

In the talk, the details of MGA system orchestration will be discussed. Special attention will also be paid to the simulation strategy and the process of simulation results verification.

See illustrative figures in the Supplemented file.

[1] Batková; Kozák, T.; Haviar, S.; et al. *Surf. Coatings Technol.* 2021, **417**

[2] Haviar, S.; Čapek, J.; Batková, Š.; et al. *Int. J. Hydrogen Energy* 2018, **43**

[3] Shaji, K., Haviar, S., Zeman P et al. *Surf. Coatings Technol.*Controlled sputter deposition of oxide nanoparticles-based composite thin films, *submitted*

9:00am **MB3-1-ThM-4 Enhanced Dimer Sputtering and Production of Nanoparticles by Pulsed Magnetron Discharge**, *P. Čurda,* University of South Bohemia, Czechia; *R. Hippler,* University of Greifswald, Germany; *M. Cada,* Institute of Physics, Czech Academy of Sciences, Czechia; ***Ondřej Kylián (ondrej.kylian@gmail.com)***, Charles University, Czechia; *Z. Hubicka,* Institute of Physics, Czech Academy of Sciences, Czechia; *V. Stranak,* University of South Bohemia, Czechia

This study investigates the initial stage of nanoparticle formation in physical vapor deposition processes, emphasizing the role of atomic dimers as cluster nuclei. The process of metal nanoparticle formation and growth by gas aggregation starts with the release of free metal atoms and nuclei through magnetron sputtering followed by thermalizing collisions and by atom attachment and coagulation. By employment of energy-resolved mass spectrometry and scanning electron microscopy imaging, dimers originating in the discharge gas phase ($ArCu^+$, Ar_2^+) and dimers sputtered directly from the target (Cu_2^+) were examined. Our findings reveal that sputtered Cu_2^+ dimers which carry the high-energy tail of the Thompson distribution play a crucial role as nanoparticle nuclei. Haberland's concept aggregation source confirmed that the population of Cu_2^+ dimers is directly proportional to the mass transported by nanoparticles. The gas aggregation process can be optimized for enhanced nanoparticle production by the employment of a pulsed discharge, which leads to increased energies of impinging Ar ions and enhanced sputtering of metal dimers. There exist optimal conditions, where the dimer production is increased, but the plasma is not too hot for the nuclei and nanoparticles to decay. Under such conditions, the production rate can be increased by a factor of 10. This enhancement in nanoparticle yield is achieved with the same invested power as for the DC sputtering. Furthermore, the proposed mechanism and the role of dimers may be material-independent, as qualitative agreement was also observed for Ag nanoparticles. This research contributes to a deeper understanding of the fundamental mechanisms governing the early stages of nanoparticle synthesis through physical vapor deposition.

Acknowledgment
The research was financially supported by the Czech Science Foundation through the project GACR 21-05030K and by the Ministry of Education, Youth and Sports of the Czech Republic through the project "Solid state physics for the 21st century" CZ.02.1.01/0.0/0.0/16_019/0000760.

9:20am **MB3-1-ThM-5 Plasma Polymer - Ag Nanocomposites: Is the Gas Aggregation Source of Nanoparticles an Appropriate Technique for Their Synthesis?**, *Zdenek Krtous (krtousz@gmail.com)*, T. Kosutova, P. Pleskunov, Charles University, Prague, Czech Republic; *B. Baloukas, L. Martinu,* Polytechnique Montréal, Canada

Metamaterials or metasurfaces represent the emerging field of nanotechnologies focusing on pushing the limits of the standard optical coatings. One of the most promising types of metamaterials are plasmonic nanocomposites based on metallic nanoparticles. The usefulness of such materials was demonstrated for absorbers, plasmonic coloration, transparent electrodes and optical filtering. In this project, we investigate a classical type of plasmonic metamaterials – silver nanoparticles embedded in a plasma polymer matrix, prepared by simultaneous co-deposition of both organic and metallic components. The organic matrix is prepared by the recently developed Plasma Assisted Vapour Thermal Deposition (PAVTD). The PAVTD allows one to control the chemical composition and, as a result, the optical and mechanical properties of the matrix within a wide range. We investigate two different cases of synthesis of metallic nanoparticles. In the first case, which could be considered a more classical approach, the nanoparticles are formed by co-deposition of silver atoms by magnetron sputtering. The silver atoms form nanoparticles inside the polymeric matrix. The growth rate of the matrix limits the size of the growing inclusions. In the second case, the Gas Aggregation Source (GAS) was used to fabricate nanoparticles in the gas phase. Subsequently, pre-fabricated nanoparticles are landing on and being embedded into the growing matrix. Due to the different nanoparticle growth mechanisms, the

optical properties of such nanocomposites are not equivalent even at similar filling factors. Finally, the applicability of the PAVTD – GAS films is demonstrated by the fabrication of a nanocomposite-based Bragg´s reflector.

9:40am MB3-1-ThM-6 Fabrication of Ag-modified BaTiO₃ Nanorod Arrays and their Properties of Piezo-Photoelectric Catalysis, *Yu-Han Hsu (emilyanna5428@gmail.com), K. Chang, Y. Chiu,* National Cheng Kung University (NCKU), Taiwan

α-Fe$_2$O$_3$ is an attractive n-type semiconducting material in the visible-light photocatalytic application because of its characteristic of narrow energy band gap characteristics for absorbing the visible light. The optical property can be tailored through morphology control, elemental doping, or compositing with other materials. However, studies on the α-Fe$_2$O$_3$ nanorod arrays with the metalic nanoparticles directly through hydrothermal processes for the fabrication still lacking. In this study, well-aligned α-Fe$_2$O$_3$ nanorod arrays/Au nanoparticles were synthesized through a facile hydrothermal reaction and solution-based method. To optimize the morphology of Fe$_2$O$_3$ nanorod arrays for compositing with Au, hydrothermal parameters, including concentrations and types of precursor solutions, reaction time, and temperatures, were manipulated. And then, it composited with different amounts and sizes of Au nanoparticles, finding an optimized condition for the visible-light photocatalytic application with the LSPR effect from nanogold. X-ray diffraction and scanning electron microscopy were employed to determine the phase and morphology of the resultant composite samples. In addition, the interfaces between the materials were observed from the transmission electron microscopy. Uv-vis spectroscopy was utilized to measure the absorption and the energy band gaps of the materials, which were significant for building the energy band diagram of the system. The composites were further used in the visible-light photocatalytic application.

Keywords: α-Fe$_2$O$_3$ nanorod arrays, Au nanoparticles, hydrothermal reaction, LSPR, visible-light photocatalysis

10:20am MB3-1-ThM-8 Combinatorial Approach of Zr-Ti-Al Thin Films: Understanding Glass-Forming Behavior, Morphological Changes, and Thermal Stability, *Zil Fernández-Gutiérrez (zil.fernandez-gutierrez@univ-lorraine.fr), D. Pilloud, S. Bruyère, S. Hupont, J. Pierson,* Institut Jean Lamour - Université de Lorraine, France

The advancement of nanotechnology relies significantly on developing thin film metallic glasses (TFMGs), given their distinct attributes such as high strength and corrosion resistance at the atomic level. The exploration of new TFMG systems holds the potential to revolutionize technology, enhancing performance and durability across applications in electronics, coatings, and medical devices. In this study, we employed a combinatorial approach to investigate the glass-forming ability of Zr-Ti-Al thin films synthesized through magnetron co-sputtering. Our findings demonstrate that controlled variations in chemical composition influence the amorphous or crystalline state of the layers, with an observed reduction in grain size with increasing the Al content. The SEM images illustrate notable modifications in surface and cross-sectional morphology. However, despite the glassy form, electrical property determinations reveal that TFMGs maintain consistent electrical characteristics with their ternary crystalline counterparts of Zr-Ti-Al films. Values ranging between approx. 100 and 200 $\mu\Omega\cdot$cm have been measured for either crystalline or amorphous films. Lastly, the thermal stability of Zr-Ti-Al TFMGs was assessed through TEM and Raman analyses following annealing processes. The crystallization starts at temperatures higher than 300 °C. Since the annealing has been performed in air, the formation of oxides (ZrO$_2$ and TiO$_2$) has been evidenced by Raman.

10:40am MB3-1-ThM-9 The Impact of Laser Annealing on Electrical Resistivity and Mechanical Properties in Highly(111)-Oriented Nanotwinned Ag Thin Films, *Tsai-Shaun Kuo (shirlley.kuo2000@gmail.com), C. Yang, F. Ouyang,* National Tsing Hua University, Taiwan

Recently, with the trend of miniaturization in microelectronic devices, resistivity plays a crucial role in the performance of electronic devices. Isothermal furnace annealing is usually conducted to enable grain growth to possess lower resistivity on interconnects; however, furnace annealing is usually time-consuming. By approach of locally abnormal grain growth, the electrical resistivity could be much more improved and still remains good mechanical properties.

In this study, we proposed using laser annealing to facilitate the grain growth on the highly (111)-oriented nano-twinned Ag thin film. The laser pulse frequency was fixed at 100 Hz, the pulse width was fixed to 1 ms and the laser is incident from the side of the silicon substrate to heat the film in purpose to avoid high reflectivity of the silver thin film surface. The laser annealing experiments were conducted with low laser annealing power (8.54, 16.44, 19.08, 24.35 W) in long annealing time (3 and 5 minutes) or high laser annealing power (50, 60 W) win short annealing time (4-10 seconds). For temperature controlment, the thermal couple was used to measure the temperature in the central of substrate during the laser annealing process. Dual-beam focused-ion beam system (FIB) was used to observed the cross-sectional microstructure images of as-deposited and laser annealed silver films. And the surface orientation was analysed by electron backscatter diffraction (EBSD). X-ray Diffractometer (XRD) was introduced in detecting the preferred orientation. The surface microstructure was investigated by Scanning electron microscope (SEM). Finally, four-point probe was used to detect the resistivity and Nanoindenter (NIP) was used to study the hardness.

Exceptional abnormal grain growth of Ag films can be achieved at 210 °C in 3 min, being much faster and lower temperature than furnace annealing. The microstructural and property evolution during laser annealing and the corresponding mechanism were discussed in detail below.

11:00am MB3-1-ThM-10 Stainless-steel Nano-Pyramid Structure Coating to Enhance Oil/Water Separation, *Helmi Son Haji (d11104807@mail.ntust.edu.tw), J. P. Chu,* National Taiwan University of Science and Technology, Taiwan

The process of separating oil and water is crucial for modern human life. Oil waste can affect living environments and impact human health. Various industries require breakthroughs in this field, including the food, petrochemical, oil mining and semiconductor industries. The urgent need for oil waste treatment causes a growing focus on the research of oil effluent. An oil-water separation process's scalability, efficacy and efficiency are crucial factors in the successful purification of oily wastes. Therefore, this research proposed a highly scalable, low-cost production method for fabricating membranes with outstanding selectivity and permeability. The proposed membrane comprises mixed cellulose ester (MCE) with stainless steel (SS) nano-pyramidal structure coating on its surface. The unique morphological characteristics of nano-pyramidal stainless-steel coating exhibit superhydrophilic properties and superoleophobic underwater, which prevent oil adhesion and enable exceptional oil separation performance, achieving an impressive efficiency of up to 99% in the process of filtering oil with various solutions, reaching high recyclability up to 99% in four cycles, also have good stability performance at low until high temperature (60°C), and compatible with diverse environmental conditions from acidic (pH 1) to alkaline (pH 14) [1].

Keywords: Stainless-steel, Coating, MCE.

11:20am MB3-1-ThM-11 Study of Interfacial Reactions in Artificially Nanolayered Mg-Mo-N Thin Films, *B. Julien, Andriy Zakutayev (andriy.zakutayev@nrel.gov),* National Renewable Energy Laboratory, USA

Ternary nitrides are an exciting class of materials for various applications such as hard coatings, LEDs, magnets, superconductors, or topological materials. Many of the most interesting nitride phases are predicted to be metastable. In bulk synthesis, reactions necessary occur at the interfaces, and so solid-state diffusion is required to drive complete nucleation. This leads to condition of high temperature and long-time reactions, which can bypass metastable phases.

Thin-film synthesis of ternary nitrides often leads to cation-disordered structure yet predicted unstable by thermodynamics calculation. Post-deposition thermal annealing can sometimes overcome energetic barriers and lead to nucleation of the layered targeted phase. However, the kinetic window is often narrow and requires high temperatures to trigger atomic diffusion. Therefore, nanolayered thin-film structures with designed diffusion lengths and interface densities offer an opportunity to overcome this situation.

To investigate the interfacial nucleation, we propose to reduce the atomic diffusion length (typically ~1um in bulk synthesis) by fabricating multilayer nanolaminate structures of the binary precursors, as a model system. Post-deposition annealing, interlayer thickness, and the multilayer period modulation are studied as a mean to control the structural properties of the nitride thin films.

In this study, we focus on the Mg-Mo-N system, in which MgMoN$_2$ phase is predicted to be thermodynamically stable and exhibits a natural layered structure built up by alternating layers of edge-sharing MgN$_6$ octahedra and MoN$_6$ trigonal prisms. This makes it a good candidate for this work as in a

thermodynamics point of view, the structure tends to naturally form a layered structure and should be more favorable to nucleate from a layered precursor.

The nanolayered films are fabricated by RF co-sputtering, using a computer-controlled sputtering chamber featuring programmable shutters in front of each sputter cathode, allowing us to control the modulation sequence during the deposition. One major challenge here is to minimize the interfacial roughness during the deposition, limiting the intermixing at the interfaces. Once co-calibration of deposition rate and composition is established for both binary phases, a set of multilayer films with different modulation period and composition are characterized by X-ray reflectivity and diffraction. The morphology and the composition of the interfaces are further characterized by electron microscopy.

Functional Thin Films and Surfaces
Room Town & Country B - Session MB3-2-ThA

Nanomaterial-based Thin Films and Structures II

Moderators: Ondrej Kylian, Charles University, Prague, Czechia, **Vladimir Popok**, Aalborg University, Denmark

2:40pm MB3-2-ThA-5 AFM-SEM Imaging for TEM Grid Mounted Nanomaterials, *Kerim Arat (kerim.arat@qdusa.com), S. Spagna,* Quantum Design Inc., USA

Microscopists employing Transmission Electron Microscopy (TEM) alongside TEM-based Energy Electron Loss Spectroscopy (EELS) to study the properties of nano-materials often need to assess physical parameters like heights and cross-sectional shapes of the samples under examination. Due to the typical sub-five nanometer thickness of membranes in TEM grids, conducting Atomic Force Microscopy (AFM) measurements on grid-mounted samples is currently arduous and time-intensive. This paper introduces a fully integrated AFM and Scanning Electron Microscope (SEM) correlative workstation, facilitating direct sample imaging on a TEM grid using both techniques. This seamlessly integrated and user-friendly AFM-SEM microscopy workstation unlocks unparalleled measurement capabilities at the nanoscale, particularly for complex geometries. The AFM-SEM imaging of TEM grid-mounted samples streamlines measurement workflows, leading to enhanced data output rates. Additionally, the platform supports easy expansion of functionalities, such as elemental analysis through Energy Dispersive X-ray Spectroscopy (EDS). The diverse array of AFM modes available (including Contact, Tapping, Off-resonance, Conductive, Magnetic, and Electrostatic) enables the extraction of various physical properties from the sample.

3:00pm MB3-2-ThA-6 Sputtering onto Liquids: Towards the Synthesis of Ultra-Fine Nanoparticles, *H. Lasfargues, L. Freymann, S. Shankar, M. Momma, T. Schneider,* **Clio Azina (azina@mch.rwth-aachen.de)**, RWTH Aachen University, Germany

Physical vapour deposition approaches are highly versatile techniques which allow the deposition of a variety of material systems typically under thin film form. While thin films are the most common outcome of vapour-based deposition methods, nano-objects, such as nanoparticles, can also be produced by switching conventional solid substrates with liquid ones. Herein, the concept of sputtering onto liquids will be introduced. SoL is a technique which allows the synthesis of ultra-fine (<10 nm) nanoparticles in a vacuum-compatible liquid. While this approach has existed for more than 50 years, the mechanisms of nanoparticle formation are still not fully described. In fact, the effect of the plasma on the synthesis and stability of the suspensions is rarely discussed in the literature. Herein, we will attempt to identify the effects of the sputtered atoms kinetic energy and flux on the size of Ag nanoparticles sputtered onto polyethylene glycol and castor oil. From the systematic study it is shown that the flux and kinetic energy of the sputtered atoms have a combined effect on the nanoparticle size distribution. In addition, the functional groups of the liquids also impact the growth by stabilizing the incoming species despite their potentially elevated kinetic energies.

3:20pm MB3-2-ThA-7 Superhard Hexagonal TiB$_2$/Hf Single Crystal Superlattices for Toughness Enhancement, *Naureen Ghafoor (naureen.ghafoor@liu.se)*, Linköping University, Sweden; *N. Koutná, S. Lin,* TU Wien, Austria; *F. Angáy, M. Lorentzon, F. Eriksson, L. Hultman, J. Birch,* Linköping University, Sweden

We present combined experimental and theoretical investigations on iso-structural TiB$_2$/Hf superlattices, demonstrating the impact of individual layer thicknesses on the hardness and toughness.*Ab initio* calculations suggest that hexagonal alpha-structured TiB$_2$ and hexagonal close-packed Hf exhibit a basal-plane lattice and shear modulus mismatch of 0.16 Å (5.4%) and 200 GPa, respectively, hence providing a basis for hindering dislocation glide across interfaces. Superlattices are deposited using ion-assisted magnetron sputter deposition, designed with a modulation period of 5 nm (to allow for theoretical modeling of the structure), where the individual layer thicknesses range from 1 to 4 nm, as analyzed by XTEM, XRD, ERDA, and XPS. Superhard single crystal TiB$_2$/HfB$_2$ diboride superlattices with 40 GPa nanoindentation hardness form at lower Hf thicknesses and at high growth temperatures. Furthermore, structural characterization reveals boron diffusion from overstoichiometric TiB$_2$ into Hf layers, resulting in single crystal TiB2 and understoichiometric HfB$_2$, in response to the high negative enthalpy of Hf-B. Thanks to self-diffusion, no

strain build-up and epitaxial breakdown of superlattice layers are observed in films with period numbers as high as 375. We show that for achieving TiB$_2$/Hf superlattice, it is critical to reduce boron diffusion by controlling the TiB$_2$ stoichiometry. Consequently, nanoindentation combined with microcantilever bending testing will be presented in relation to structural and mechanical predictions by *ab initio* calculations as well as machine-learning-potential molecular dynamics, where the latter uses a moment-tensor-type potential developed and carefully validated for the purpose of this study.

4:00pm MB3-2-ThA-9 Study on Improving the Performance of Zinc Oxide Piezoelectric Pressure Sensor by Doping Vanadium, *Heng-Chi Chu (juliachu2000@gmail.com), S. Brahma, J. Huang,* National Cheng Kung University (NCKU), Taiwan

Piezoelectric effect is a phenomenon in which positive and negative ions are displaced generating electric polarization with the application of stress on the materials having non-centrosymmetric crystal structure. Zinc oxide possesses both piezoelectric and semiconductor properties. The applied pressure generates piezo-potential thereby creating a Schottky barrier at the interface of the semiconductor and the metal electrode that can be modulated by the variation of the strain. This characteristic can be applied to fabricate the piezoelectric pressure sensors devices based on ZnO/doped ZnO and investigate the stress sensitivity. However, the low piezoelectric coefficient (12.4 pC/N) of ZnO restricts further development zinc oxide based piezoelectric devices. Consequently, we doped zinc oxide with vanadium and doping of smaller ionic radius vanadium at the zinc sites enhanced electric polarization and improved the piezoelectric coefficient. Furthermore, vanadium doping induced changes in the grain size and energy band structure and influenced the performance of the piezotronic effect. We employed radio frequency magnetron co-sputtering to deposit V doped ZnO thin films by using zinc oxide and vanadium pentoxide as targets and V doping concentration was controlled by the variation of the working power of vanadium pentoxide target. Subsequently, we fabricated a pressure sensor by depositing gold electrodes to create a Schottky barrier and investigated the piezoelectric stress sensitivity. SEM results revealed that vanadium doping led to the grain size reduction. XPS analysis of the oxygen spectrum indicated that doping led to surface adsorbates and an increase in intrinsic defects. The XPS spectra of vanadium showed the presence of both V^{5+} (V^{3+}) ions at low (high) V doping concentrations. As the doping concentration increased, the proportion of V^{5+} decreased due to the redox effects, shifting to V^{3+} with a larger radius. This trend aligns with the piezoelectric coefficient. UV-vis and UPS analyses provided insights into the energy band structure. Vanadium doping shifted the Fermi level towards the conduction band, resulting in a smaller work function and band gap compared to undoped zinc oxide. This induced a more stable Schottky barrier and improved carrier transport mechanism. In the piezoelectric stress sensitivity test, vanadium doping effectively enhanced current and stress sensitivity. However, higher doping concentration decreased the sensitivity due to the lower piezoelectric coefficient. In summary, our research aims to combine the above analyses to identify optimal sputtering parameters, thereby enhancing the performance of piezoelectric pressure sensors.

4:20pm MB3-2-ThA-10 Glancing Deposited Wide Band Gap Zirconia Nanohelical Metamaterial Platforms:Unveiling Broad-Band UV-Active Chirality, *Ufuk Kilic (ufukkilic@unl.edu)*, University of Nebraska - Lincoln, USA; *M. Hilfiker,* Onto Innovation Inc., USA; *S. Wimer,* University of Nebraska - Lincoln, USA; *C. Argyropoulos,* Pennsylvania State University, USA; *E. Schubert, M. Schubert,* University of Nebraska - Lincoln, USA

Chirality is a property of asymmetry in molecules or objects that cannot be superimposed onto their mirror images. This symmetry breaking phenomenon is fundamental to various fields such as chemistry, biology, physics, and materials science. Optical manifestation of chirality known as circular dichroism is the differential absorption response of the object to the incoming left- and right- handed circularly polarized light. However, chirality found in nature is very weak, almost impossible to spectrally control, and mostly emerges in the vacuum ultraviolet (VUV) part of the spectrum [1]. Utilizing metamaterial platforms to boost chirality and to detect these chiral molecules presents challenges, as many are designed for the operation in the infrared (IR) to the visible spectral range [1,2]. The utilization of ultra-wide band gap metal oxides in nanostructure fabrication has received limited attention in the literature, particularly concerning their chiral properties [2]. In this study, we explored the fabrication of zirconia (ZrO$_2$) thin films using electron beam evaporated glancing angle deposition (GLAD) technique. This recently emerging bottom-up fabrication technique

is known for its capacity to produce various 3D nano-morphologies over wafer-scale area.

Leveraging the substrate manipulation arm, the normal incidence of the particle flux onto the surface leads to the fabrication of flat, uniform, thin films of ZrO_2. Through generalized spectroscopic ellipsometry (GSE) technique, we extracted the frequency dependent complex dielectric function and performed critical point model dielectric function analysis to identify the band-to-band transitions within near-IR to VUV spectral range. On the other hand, impinging the particle flux on the sample substrate at extremely oblique angle (85.5°) together with continuous rotation of sample (24 sec/rev) permits the fabrication spatially coherent, well-oriented nano-helices. Hence, we experimentally detected VUV-active strong circular dichroism responses from ZrO_2 nano-helical metamaterials using the Mueller matrix GSE technique. Furthermore, we employed finite element modeling (FEM) to theoretically verify these responses and observed that the chiral response can be tailored in terms of magnitude and spectral position using structural parameters of nano-helices. Furthermore, we envision a potential use of these chiral metamaterials in areas which include high power required chiroptic photonic/electric circuit designs, UV active topological insulators, chiral sensor technologies.

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Functional Thin Films and Surfaces
Room Golden State Ballroom - Session MB-ThP

Functional Thin Films and Surfaces (Symposium MB) Poster Session

MB-ThP-2 Porous Metal/Metal-Oxide Nanostructured Coatings Produced Using Gas Aggregation Sources of Nanoparticles as Recyclable SERS-Active Platforms, *A. Hanková, D. Novák, N. Khomiakova, E. Kočišová, M. Procházka, Ondřej Kylián (ondrej.kylian@matfyz.cuni.cz),* Charles University, Prague, Czech Republic

Due to their low cost, chemical and thermal stability, and unique electronic, optical or bioresponsive properties, metal-oxides (MeO) have become almost irreplaceable materials in an impressive range of modern technologies, such as (photo)catalysis, sensing, detection, or energy harvesting. In many cases, the functional properties of MeO may be enhanced by their nanostructuring that increases the specific surface and facilitates physicochemical phenomena like adsorption and diffusion of chemical species. One possibility of producing these materials relies on the deposition of highly porous transition metal (e.g. Ti, V, Nb, W) nanoparticle films by magnetron-based gas aggregation sources followed by the subsequent annealing of such formed nanoparticle films that assures their controllable oxidation and crystallization. The aim of this study is to demonstrate that further improvement of the functional properties of MeO nanoparticle-based films may be achieved if they are decorated with sputter-deposited noble metal nanostructures. In this way, different functionalities intrinsic to metal-oxide and metal components may be successfully combined or enhanced. As shown in this study, such metal/MeO nanomaterials are highly interesting as novel platforms for surface-enhanced Raman spectroscopy (SERS), in which the noble metals act as highly SERS-active component, while the transition MeO due to its photocatalytic characteristics provides the possibility of highly effective re-cycling of the platforms after cleaning them with UV light irradiation.

MB-ThP-4 A Carbon Nanotubes-Based Microwave Resonator for Ammonia Gas Sensing, *Hsuan-Ling Kao (snoopy@mail.cgu.edu.tw), Y. Tsai,* Chang Gung University, Taiwan

Carbon nanotubes (CNTs) have been used as gas-sensing material owing to their high specific surface areas and structural porosities that enable rapid responses and high sensitivity at room temperature. Fully inkjet printing technology promotes the green process using by digital controlled pattern in required location to offer fast, material saving, low cost, high substrate selectivity, and low annealing temperature. In this work, Inkjet-printed CNT films can be conferred with the appropriate resistance for embedding into transmission-type resonators for gas sensing by controlling droplet spacing (DS) and layer number. CNTs films as sensing layers and silver films as conductive layers to realize gas sensors using fully inkjet printing technology. Gas sensors, including resistive and microwave resonator sensors, were inkjet-printed on CLTE-MW to measure their response in the presence of ammonia. Gas responses of CNT films with regular electrode and interdigital electrode patterns were compared by resistive-type gas sensors. CNTs with the IDE pattern can provide large contact areas between the silver film and CNTs for the provision of more effective conductive paths, this resulting in stable sheet resistance and high response. The resistance of the sensing films embedded into the transmission-type microwave resonators should be as low as possible to avoid affecting loss. A microwave resonator consisting of two open-loop ring resonators coupled to each other by an interdigital structure was proposed as a microwave gas sensor. CNT films with the IDE pattern were embedded at the edge of the interdigital structure. The repeatability of the resonator under exposure to 700 ppm NH_3 for 20 cycles was examined. The exposure time to NH_3 gas at each step was 60 s and then, pure N_2 was injected into test chamber for 90 s at the recovery step. The average sensitivities of insertion loss and resonant frequency were 9.5 mdB and 353 kHz for 20 cycles, respectively. The results demonstrated that the CNT films with IDE pattern embedded in transmission-type microwave resonator provided two-dimensional response values in NH_3 sensing through electromagnetic transduction, thereby providing wireless sensor applications.

MB-ThP-5 Investigating 2D-Materials Using Correlative Spectroscopy & Microscopy, *T. Nunney,* Thermo Fisher Scientific, UK*; James Lallo (james.lallo@thermofisher.com),* Thermo Fisher Scientific, USA*; P. Mack, R. Simpson, H. Tseng,* Thermo Fisher Scientific, UK

Across a wide range of application areas, understanding the chemistry and structure of surfaces and interfaces is crucial. In the last fifty years, X-ray photoelectron spectroscopy (XPS) has become established as a one of the key techniques for measuring surface and interface chemistry, and advances in instrumentation have enabled it to keep pace with the requirements for both academia and industry. XPS can deliver quantified surface chemistry measurements, and by using depth profiling, an understanding of layer and interfacial chemistry, but the limit on spatial resolution for XPS can prevent it from determining how the surface structure is related to the measured chemical properties. For example, how the changing morphology of the surface during a depth profile could influence the measured composition would be challenging to determine using just XPS.

Other experimental techniques which are unable to match the surface selectivity of XPS are able to provide complementary information to extend the data from XPS. Electron microscopy can provide high resolution imaging, with elemental composition provided by energy dispersive X-ray microanalysis, but without the same surface selectivity seen with XPS or Auger electron spectroscopy (AES). This can be a perfect complement to XPS analysis, so long as the same points of interest can be identified. Molecular spectroscopy, such as FTIR or Raman, can also provide complementary information to XPS, albeit with different sampling depths, which can be extremely useful to validate measurements or confirm particular molecular structures using the wide range of spectral libraries available for those techniques.

In this poster, we will describe how a correlative approach using both surface analysis instrumentation and scanning electron microscopy can be used to characterize 2D nanomaterials. Samples of MoS_2 grown on Si substrates have been investigated using XPS, Raman and SEM to determine their composition and structure. To facilitate co-alignment of the analysis positions when moving between the instruments, special sample carriers and software alignment routines have been developed.

MB-ThP-6 CsPbI₃-Based Perovskite Thin Film Using All Vacuum Deposition Process, *HYO SIK CHANG (hschang@cnu.ac.kr), M. Jeong, j. Park,* Chungnam National University, Republic of Korea

We deposited $CsPbI_3$ films using a co-evaporation method, and optimized the film thickness and heat treatment. UV-vis and PL analysis confirmed the presence of a peak at 710nm wavelength, indicating the absorption and emission properties of the a-phase $CsPbI_3$ perovskite film. The use of vacuum co-deposition for $CsPbI_3$ deposition allows for excellent uniformity and thickness control, leading to optimized film thickness. To make inorganic $CsPbI_3$ perovskite solar cell, the phase change temperature must be lowered and a low phase change temperature of less than 200 °C is required. We have developed low phase change temperature $CsPbI_3$ with additive deposition. In this study, we manufactured a perovskite solar cell by combining the co-deposited $CsPbI_3$ perovskite with an inorganic charge transport layer using atomic layer deposition (ALD). ALD NiOx and SnO_2 films used as a hole transport layer and electron transport layer (ETL). Efforts are underway to apply vacuum co-deposition of $FAPbI_3$ and $CsPbI_3$ perovskite to tandem perovskite-Si solar cell applications.

MB-ThP-7 Synthesis and Characterization of AlCrTiZrSiW High Entropy Alloy Coating by High-Power Impulse Magnetron Sputtering, *C. Chang,* Ming Chi University of Technology, Taiwan*; J. Tang,* Lunghwa University of Science and Technology, Taiwan*; Bo-Ruei Lu (M11188027@mail2.mcut.edu.tw), J. Tsao, M. Lin,* Ming Chi University of Technology, Taiwan*; F. Yang,* National Taiwan University of Science and Technology, Taiwan

High-entropy alloy coating feature high hardness, excellent thermal stability, and corrosion resistance. They have been considered as promising candidates for next-generation surface coating material because of their advantageous properties.In recent years, the popular high power impulse magnetron sputtering (HIPIMS) surface technology has attracted considerable attention due to the ability to produce coatings with excellent properties. It is preferable to replace high entropy alloy target with a co-sputtering method involving the use of more targets(single element metal target) simultaneously, which can greatly reduce the process cost.

In this study, AlCrTiZrSiW high-entropy alloy coating deposited on the various substrates (SKH-9 high-speed steel, SUS304 stainless steel, Si wafer)

by HIPIMS technology.To obtain the Non- equimolar high-entropy alloy coatings was adjusted by varying the output power of Al and CrSi target (Zr 、TiSi、W target power was fixed). Detailed investigation was performed on the microstructure, mechanical properties and corrosion resistance of the resulting coatings. XRD and nanoindenter measurement results indicated that the coating exhibited an amorphous structure with a hardness value between 9.0 to 10.8 GPa. In addition, the coating with hydrophobic and corrosion resistance was verified via contact angle and electrochemical potentiostat test.The corrosion resistance of the AlCrTiZrSiW high-entropy alloy coating (Rp=28.3 $\Omega cm^2 \times 10^5$) is ~27 times that of the SUS304 stainless steel.

MB-ThP-9 Location-Dependent Super-amphiphobic Nano-Structured Films Deposited by Tubular Microwave Plasma, *Ta-Chin Wei (tcwei@cycu.edu.tw)*, *Y. Shen,* Chung Yuan Christian University, Taiwan
Super-hydrophobic and oleophobic surfaces have attracted much interest for both fundamental research and practical applications. In this study, Teflon-like fluorocarbon films with different nano-structures were deposited on various substrates by microwave-generated C2H2F4/CF4 plasma. The reactor was a tubular quartz tube with diameter of 5 cm and length of 80 cm. The substrates were placed in 20 different locations along the gas flow direction in upstream region, discharge region, and afterglow region. It was found that the surface morphology of the deposited film was very location dependent. The fluorocarbon films deposited in upstream and afterglow region consisted of nano-particulate structure with F/C atomic ratio of about 2.0, namely the Teflon-like structure. However, the fluorocarbon film was rough and thick with a low F/C atomic ratio when substrate was located in the discharge region. Interestingly, Teflon-like fluorocarbon films with vertical nano-wall structure could be deposited only on substrates located in the end of upstream region and in the beginning of the afterglow region. It was also found that water contact angle on the Teflon-like nanowall or nano-particulated film was above 160° and the CH2I2 contact angle was above 140°. Moreover, by using the same operating parameters, we successfully deposited transparent super-amphiphobic fluorocarbon nanowall film onto various substrates such as glass, copper, polycarbonate, and etc. Moreover, we found that Teflon-like films with nano-wall structure could also be deposited onto various porous substrates. Finally, from the time evolution of the deposited film, the growth mechanism of nano-wall structure film was realized.

MB-ThP-10 Enhancing Oxygen Evolution Reaction Performance with Sputter-Deposited High Entropy Alloy Thin Film Electrocatalysts, *Siang-Yun Li (m98l0217@gmail.com)*, *T. Nguyen, Y. Su, Y. Shen, C. Liu, J. Ruan, K. Chang, J. Ting,* National Cheng Kung University, Taiwan
Thin film catalyst, giving a different morphology, provides a significant advantage over catalyst particles for gas evolution reaction.Taking the advantages of sputter deposition, we hereby report high entropy alloy (HEA) thin film electrocatalyst for oxygen evolution reaction (OER).We investigate the catalyst characteristics not only in its as-deposited state but also during and after the OER.For comparison, unary, binary, ternary, and quaternary thin film catalysts were prepared and characterized.The surface electronic structure modification due the addition of a metal is studied experimentally and theoretically using density function theory calculation.We demonstrate that sputtered FeNiMoCrAl HEA thin film exhibits OER performance superior to all the reported HEA catalysts with robust electrocatalytic activity having a low overpotential of 220 mV at 10 mA cm^{-2}, and excellent electrochemical stability at different constant current densities of 10 and 100 mA cm^{-2} for 50 h.Furthermore, we have investigated the microstructure transformation during the OER, which is important for the understanding of the OER mechanism provided by HEA electrocatalyst.Such finding would contribute to future catalyst design.

MB-ThP-11 Transition Metal Nitride Anti-Reflective Coatings, *Barbara Schmid (barbara.schmid@tuwien.ac.at)*, *B. Hajas, N. Koutná,* TU Wien, Institute of Materials Science and Technology, Austria*; J. Blaschke,* TU Wien, Austria*; P. Polcik,* Plansee SE, Germany*; P. Mayrhofer,* TU Wien, Institute of Materials Science and Technology, Austria
Anti-reflective (AR) coatings are of high importance for our everyday lives in the field of optics, for example in visual aids and photography equipment. Lesser known, those coatings are also essential in the realm of photovoltaics like solar cells, because they are able to reduce the reflectivity of the material surface. There is a plethora of different design approaches to this topic. Within our work, we want to change the optical properties of hard TiC/TaC superlattice protective coatings without sacrificing superior mechanical properties. Using DC magnetron sputtering, we create nano-scale transition metal nitride-based (AlN and ZrN) thin films

exhibiting different material characteristics. We investigate the influence of deposition parameters and film thickness on the optical properties of our materials system. Apart from structural and morphological investigations and the determination and comparison of mechanical properties of our material systems, we conduct optical investigations using differential reflectance spectroscopy (DRS).

MB-ThP-12 Enabling Robust Chemical State Analysis of Sn-Based Perovskites *via* Auger Parameter Analysis in XPS, *A. Wieczorek, Sebastian Siol (Sebastian.Siol@empa.ch)*, Empa – Swiss Federal Laboratories for Materials Science and Technology, Switzerland
Sn-based perovskites exhibit compelling properties such as reduced toxicity and lowered band gaps over those purely based on Pb. As a result, they are of increasing interest for photovoltaic applications in single-junction and all-perovskite tandem applications.[1]

For high performances, control of the oxidation state and interfacial chemistry is paramount, which can be determined using X-Ray photoelectron spectroscopy (XPS). However, the minor chemistry related shifts of the Sn core level emission complicate the analysis, especially for semiconducting materials. Here, surface band-bending as well as differences in the work function can be particularly pronounced.

In this presentation, we demonstrate that studies based on the modified Auger parameter α' provide a robust method to resolve different chemical states in Sn-based perovskites. Using a set of reference samples, we identified a high sensitivity to the halide, resulting in a shift of up to $\Delta\alpha$ ' = 2 eV between ASnI$_3$ and ASnBr$_3$-type polycrystalline perovskite thin-films.[2] Observed dependencies of α ' on the Sn oxidation state and local chemistry provide a framework that enables reliable tracking of degradation as well as X-site composition for Sn-based perovskites and related compounds. Recently, we successfully applied this framework on Sn-based perovskite nanocrystals to ensure the absence of Sn(IV) impurities upon optimized synthesis procedures.[3]

The higher robustness and sensitivity of such studies not only enables more in-depth surface analysis of Sn-based perovskites than previously performed, but also increases reproducibility across laboratories. Due to the facile data analysis, this method is ideal for high-throughput studies that are increasingly being adopted in the development of new semiconducting materials.[4]

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MB-ThP-13 Pvd Deposition of Tin Based Antimultipacting Thin Films for Applications in Particle Accelerators, *Yanis Pisi (yanis.pisi@grenoble-inp.fr)*, CNRS, Université Paris-Sud, France
The multipactor phenomenon is a critical issue that can occur in particle accelerators. To improve the performance of components used in particle accelerators, we have chosen to develop a materials approach with innovative coatings.

The SEY is the ratio of the number of secondary electrons to the number of incident electrons (primary electrons). To avoid the multipactor effect, the ratio must be less than 1. Currently, most materials have an SEY greater than 1 [1].The investigated coatings based on nitride or carbide titanium because the SEY ratio is intrinsically low [2,3]. My work consists to elaborate based TiN (TiO$_x$N$_y$, TiN, TiN$_x$C$_y$) thin films and study their properties. Another approach concerns the investigation of thin layers consisting of alternating layers of NbN and TiN. The preferred deposition method is PVD (Physical Vapor Deposition) by cathodic pulverisation. We will present the results obtained as a function of coating nature: (i) firstly, the physical properties (such as electrical properties by 4-point measurements) and chemical characterisations (such as the layer composition determined by XPS analysis); (ii) the values of secondary

electron emission yields at the fully conditioned state (see Table, the surface was conditioned by electron bombardment). In this work, we study the SEY without the effects of roughness, which is known to significantly influence the SEY.

Reference	Layer	Substrat	Roughness (nm)	SEY
This work	TiNC	Si	0,5	1,01
This work	Multilayer NbN/TiN	Si	1	0,99
[1]	TiNC	Si	High	0,97
[2]	TiZrVC	Si	High	0,93

Table: SEY values of different thin films obtained PVD

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MB-ThP-14 Influence of Oxygen Partial Pressure and Temperature on the Optical and Electrical Properties of NiO$_x$ Thin Films obtained by r.f. Sputtering, *E. Osorio-Urquizo, Francisco David Mateos-Anzaldo (dmateos@uabc.edu.mx), M. Curiel-Alvarez, R. Nedev, O. Pérez-Landeros, B. Valdez-Salas, N. Nedev,* Instituto de Ingeniería-Universidad Autónoma de Baja California, Mexico

Nickel oxide (NiO$_x$) thin films were deposited by r.f. magnetron sputtering on n-type silicon and corning glass substrates. The deposition conditions were 60 W of power during 6 minutes, a pressure of 5 mTorr and different substrate temperatures in the range of 25-200 °C. The partial pressure between O/Ar was varied between 0 and 4 %. Prior to deposition, the substrates were cleaned in an ultrasonic bath with acetone, isopropyl alcohol and deionized water for 5 min each and dried with high-purity nitrogen after each step. Besides, the target was pre-sputtered for 15 min. MOS capacitors were fabricated by deposition of gold and aluminum as top and back contacts using thermal evaporation.The thickness and optical constants of the films were obtained by spectroscopic ellipsometry. Measurements of current-voltage (I-V) and capacitance-voltage (C-V) dependences were carried out to study the effect of temperature and oxygen partial pressure on the electrical properties of the NiO$_x$ thin films. The obtained results indicate that it is possible to obtained high quality films at low r.f. power that are viable for applications in electronic devices.

MB-ThP-17 Effect of the R.F. Power and Thermal Annealing on the Properties of NiO$_x$ Thin Films, *Roumen Nedev (roumen.nedev@uabc.edu.mx), F. Mateos-Anzaldo, M. Curiel-Alvarez, O. Pérez-Landeros, E. Osorio-Urquizo, B. Valdez-Salas, N. Nedev,* Instituto de Ingeniería-Universidad Autónoma de Baja California, Mexico

NiO$_x$ thin films were deposited by RF sputtering in Ar atmosphere on n-Si and glass substrates. During the deposition the RF power was varied between 5 W and 60 W, while the deposition time was fixed at 9 min. Three deposition temperature of 25 °C, 50 °C and 100 °C were used. The samples deposited on Si were separated in three groups. The first group was furnace annealed at 450 °C in N$_2$ atmosphere for 1 h. The second one was treated by Rapid Thermal Annealing (6 min, 550 °C), while the third group was kept as control. Metal/NiO$_x$/n–Si heterostructures were prepared by deposition of Au electrodes through a mask.

The thicknesses and optical constants of the layers were determined by spectroscopic ellipsometry. XRD measurements were used to determine the effect of deposition temperature and thermal annealing on the crystallinity of the films. The Au/NiO$_x$/c-Si structures were electrically characterized by current-voltage (I-V) and capacitance-voltage (C-V) measurements. The I-V dependences showed formation of p-n heterojunction diodes with properties, which depend on the r.f. power, deposition temperature and annealing.

MB-ThP-20 Nano Indentation Pop-in Response on Basal Plane of 4H Hexagonal SiC Surface, *Jacob C. Huang (jacobc@faculty.nsysu.edu.tw),* National Sun Yat-sen University, Taiwan

The nano-scaled mechanics for the hexagonal 4H SiC single-crystal surface (with a bandgap of 3.26 eV) is examined by using nanoindentation testing on the {0001} basal plane. The 4H SiC material was prepared by Prof. M. C. Chou's lab via the Czochralski process. The as-grown crystal surface has been examined carefully by X-Ray diffraction (XRD) to confirm the 4H hexagonal structure, with the basal plane lying on the horizon plane and the c-axis parallel to the growth direction. The (0004) peak at 2q=35.5° is the only peak appeared, ensuring the well-grown surface orientation with minimum defects. The lattice parameters, a and c, are determined to be 0.3073 and 0.1006 nm, respectively. Through the analysis of XRD rocking curves, it is confirmed that there should be minimum defects inside the as-grown SiC surface.

Nanoindentation tests were performed using the continuous stiffness method (CSM), up to a maximum depth of ~950 nm on the (0001) basal plane surface. The average elastic modulus and hardness calculated from depth ranging from 300~800 nm over nine indents were ~500 GPa and ~42.5 GPa, respectively. In addition, the first few pop-in loads and displacements are captured from the deviations from a perfect Hertizian contact curve fitted to the load-displacement curve. By using rough estimation for the yield stress from hardenss by a factor about 2.5 (Tabor's assumption), we estimate the yield stress to be about 42.5/2.5 ~ 17.0 GPa. The first pop-in loads, pop-in hardness, and pop-in stresses can all be measured. The first pop-in stress is usually termed as the incipient stress, associated with the first initiation of the activation of dislocations (nucleation or gliding of diloscations). The average incipient stress for the first dislocation activity is about 16.1 GPa, slightly below the overall yield stress. From the first pop-in displacement, about 10 nm, it is likely to be a result of the micropipe threading screw dislocations (with a Burger's vector of c-axis, namely, ~1 nm). This suggests that the first pop-in could be caused by these screw dislocations gliding for 10 Burger's vectors. The understanding of dislocation incipient pop-in as a function of applied load would give the insight for subsequent influence for various functional properties of 4H SiC.

MB-ThP-21 2D Chemical Mapping of Nanoscale Functional Material using Soft X-ray STXM, *Namdong Kim (east@postech.ac.kr),* Pohang Accelerator Laboratory, Republic of Korea

Soft x-ray nanoscopy employing the scanning transmission x-ray microscope (STXM), which can provide chemical structural information of materials at tens of nanometer scale, has become a powerful study in analytical microscopic research. The nanoscopy beamline in the Pohang Light Source is operating currently at the optimum condition in its focused beam size ~30 nm and photon energy resolution < 0.1 eV in the soft x-ray energy range (200-1650 eV).

Basically, based on different x-ray absorption contrast depending on chemical states, we have studied structural and electronic properties of nanoscale defects or domains formed on various two-dimensional (2D) materials including graphene, hBN, MoS$_2$, WSe$_2$, and topological insulators such as Bi$_2$Se$_3$ thin film as well as energy materials. We will here introduce briefly the 2D nanoscale chemical mapping of such functional materials.

Moreover, as for Li-ion batteries, we investigated in-situ annealing effect on Ni-rich NCM cathode materials from RT to high temperature by measuring Ni, Co, Mn L$_3$-, and O K-edge absorption spectra. In-situ thermal degradation is induced by annealing. And oxygen reduction is preferentially observed on the edges of smaller particles at 400 °C.

KEYWORDS: 2D chemical mapping, soft x-ray nanoscopy, STXM, 2D materials, energy materials

MB-ThP-23 Exploring HiPIMS-Deposited TixN and TixAlyN Films for Oxygen Evolution Reaction (OER) Catalysis, *Wan-Yu Wu (wywu@nuu.edu.tw),* National United University, Taiwan*; J. Ting,* National Cheng Kung University (NCKU), Taiwan*; Y. Tsai,* National United University, Taiwan*; S. Li,* National Cheng Kung University (NCKU), Taiwan*; Y. Lin,* National Chung Hsing University, Taiwan

Sustainable energy technologies are fundamentally linked to electrochemical reactions, notably the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER), which are critical in electrolysis cells. OER, characterized by its sluggish kinetics, is a bottleneck in the efficiency of molecular oxygen generation, highlighting the necessity for advanced catalyst development. While precious metals like Ir, Ru, and their oxides (IrO2, RuO2) are prevalent in current research, their scarcity, cost, and low durability limit practical applications, urging the discovery of viable alternatives. This study explores metal nitrides, specifically TixN and TixAlyN films deposited on nickel foam using High Power Impulse Magnetron Sputtering (HiPIMS), as potential OER catalysts. Despite traditionally higher OER overpotentials, these heterostructured metal nitrides demonstrate promising activity and remarkable long-term stability, even in strong alkaline electrolytes. The capability of producing these films with precise crystalline structure and stoichiometry via scalable magnetron sputtering positions them as compelling substitutes to conventional precious metal catalysts, showing lower overpotentials compared to commercial RuO2 and paving the way for their application in large-scale clean energy solutions.

MB-ThP-24 Characterization of Protective AlCrON Thin Films for Application on Sensor Thin Films in Fused Layer Modeling Processes, *W. Tillmann, Julia Urbanczyk (julia.urbanczyk@tu-dortmund.de), M. Mainz, P. Bengfort, N. Lopes Dias,* TU Dortmund University, Germany

In plastic processing, the use of sensor thin films is gaining interest for inline measurement to ensure stable process control. However, due to the corrosive and abrasive characteristics of molten plastics, the application of an appropriate protective coating becomes imperative to ensure the functionality of the sensor films. AlCrON thin films demonstrate favorable protective attributes for this purpose. The tribo-mechanical and electrical properties are inherently influenced by the oxygen content. Therefore, a systematic variation of O_2 gas flow rates (10 to 30 sccm in steps of five) during the mid-frequency magnetron sputtering process was employed resulting in the O contents rise from 12.2 at.-% for 10 mln O_2 to 57.6 at.–% for 30 mln O_2. Simultaneously, a change of a polycrystalline structure containing CrN, Cr_2N, and hexagonal AlN to an amorphous structure with increasing O content for AlCrON is observed. This affects the tribo-mechanical properties. The highest polycrystallinity was reached at 25.2 at.–% O resulting in a H/E maximum, with a maximum in hardness of (37.6 ± 2.8) GPa and an elastic modulus of (361.2 ± 20.7) GPa. Here, also the lowest coefficient of friction (CoF) at elevated temperatures was reached with 0.43 against polypropylene (PP) and 0.23 against polyamide (PA). The low CoF correlates with a lower wetting ability of the AlCrON thin film. Regarding the electrical properties AlCrON thin films show insulating characteristics dependent on the O content. The electrical resistance increases with higher O content while the dielectric stregth tends to increase with higher crystallinity.

A first attempt to apply a functional copper layer within an Al_2O_3 and AlCrON system was successful, showing promise for enhanced functionality. However, further investigation is needed to fully understand its potential and optimize its performance.

The results show that AlCrON thin films offer promising protective qualities for sensor applications in plastic processing. By adjusting the oxygen content, their tribo-mechanical properties can be optimized for reduced friction and enhanced durability, while their insulating properties are promising for maintaining the functionality of the sensors.

MB-ThP-25 Synthesis of Highly-Textured Wurtzite AlN Thin Films on Nitrogen-Terminated Metal Surfaces, *Oleksandr Pshyk (oleksandr.pshyk@empa.ch), J. Patidar, S. Zhuk, S. Siol,* EMPA (Swiss Federal Laboratories for Materials Science and Technology), Switzerland

AlN thin films in wurtzite structure are used in a broad range of piezoelectric applications such as microelectromechanical systems (MEMS) due to their high acoustic velocity, chemical resistance, thermal stability and linear piezoelectric response. Especially, for piezoelectric applications AlN thin films have to demonstrate a high crystalline quality and exhibit a pronounced out-of-plane c-axis orientation.

Typically, this necessitates the growth at elevated temperatures. It has been demonstrated that deposition on certain metallic substrates can improve the crystallinity and texture of sputter-deposited AlN [1]. However, despite the widespread application of metallic templates for the deposition of AlN, only few systematic studies of the stabilization mechanisms are reported.

In this work, we present a systematic study of AlN thin film growth on chemically and structurally different metallic seed layers. The deposition sequence used in these experiments is pre-sputter metal targets in Ar (1)/ RF magnetron sputter deposition of a metal layer (2)/ pre-sputter Al-target in Ar (3)/ pre-sputter Al target in $Ar+N_2$ (4)/ AlN deposition by reactive DCMS (5). All steps are performed at room temperature to eliminate the effects of temperature while (4) ensures metal layer exposure to N_2 for 1 min.

We demonstrate that AlN films grown on different low-work function metals show markedly improved texture and crystallinity compared to films grown on glass. To differentiate between either a chemical or a structural templating effect we vary the metal-layer thickness from 115 nm down to less than 1 nm and to tune their crystallinity and their substrate coverage. The AlN grain size strongly correlates with the glass substrate coverage by the metal layers. However, it appears much less important if the metal templates are crystalline or amorphous. It is therefore likely that the stabilization mechanism is chemical in nature.

UHV-transfer XPS studies on freshly sputtered metal layers demonstrate the formation of a thin layer of metal nitride on the surface of W and Al thin films upon short-term exposure to the N2-containing process gas, even at room temperature. The conditions were chosen equivalent to the environment in the sputter chamber leading up to the AlN deposition. We therefore assign the promotion of AlN nucleation and growth on low-work function metal substrates to the chemical effect set by a complete N2 substrate surface termination and the associated preferential c-axis polarization. The revealed mechanism extends the fundamental understanding of the AlN growth process on different metallic substrates beyond strain-driven mechanism or AlN/metal interface symmetry considerations.

MB-ThP-26 Synthesis of Epitaxial a-Ga₂O₃ Thin Films on Sapphires by Pulsed Laser Deposition, *Heungsoo Kim (heungsoo.kim.civ@us.navy.mil), M. Mastro, A. Piqué,* Naval Research Laboratory, USA

Gallium oxide (Ga_2O_3) is an emerging ultrawide-bandgap semiconductor for high power electronics and ultraviolet photonics. Among various Ga_2O_3 crystal structures, a α-Ga_2O_3 has gained a great interest because its bandgap (>5.3 eV) is far wider than that of common β-Ga_2O_3 (4.5 – 5.3eV). Thermodynamically stable β-Ga_2O_3 thin films have been successfully synthesized by various deposition techniques. However, the growth of metastable α-Ga_2O_3 thin films is more challenging process because the formation of α-Ga_2O_3 is only stable for the first few monolayers and easily converted from α-Ga_2O_3 to β-Ga_2O_3 during high temperature post growth treatment. In this work, we have explored an effective route for growing relatively thick epitaxial α-Ga_2O_3 films on *m*-plane and *a*-plane sapphire substrates by pulsed laser deposition (PLD). First, we have grown Ga_2O_3 films at various substrate temperatures (560 – 720 °C) while the background pressure was kept at 3 mTorr of oxygen. Second, the effect of oxygen background pressure was investigated in an oxygen pressure range between 1 and 50 mTorr while the substrate temperature was fixed at 720 °C. The crystal structure and film quality of all Ga_2O_3 thin films were then investigated by high-resolution X-ray diffraction (XRD). For films grown on *a*-plane sapphires, pure α-Ga_2O_3 films can be obtained at only high growth temperatures (> 720°C) while the β-Ga_2O_3peaks are appeared as the growth temperature is lowered below 720 °C. For films grown on *m*-plane sapphires, pure α-Ga_2O_3 film can be obtained at all temperature ranges (560 – 720 °C) while the film crystallinity improved as the growth temperature increases. We will present details of optimization processes to grow pure α-Ga_2O_3 films along with structural and optical properties of Ga_2O_3 films.

MB-ThP-27 High Responsivity GaS Nanobelt Metal-Semiconductor-Metal Photodetector with Ni Contact, *Chun-Yi Lin (gary12305112@gmail.com), C. Wang,* National Taiwan University of Science and Technology, Taiwan

Two-dimensional GaS is an important member of group III_A–VI_A semiconductors possessing exceptional optoelectronic properties. In this work, 2D GaS nanobelts (NBs) were successfully synthesized via the vaper-liquid-solid (VLS) method and the structure, morphology, and chemical composition of the as-prepared nanobelts are extensively investigated. Furthermore, GaS nanobelts are fabricated into photodetector with Ni contacts through electron beam lithography (EBL), electron beam evaporation and lift-off processes. The photodetector determines the photodetectors exhibited a dark current smaller than 500 fA while demonstrating remarkably high responsivity, external quantum efficiency (EQE) and detectivity is tens mAW^{-1}, ~10^4 % and ~10^{13} Jones, respectively. Moreover, they displayed repeatable ON−OFF switching behavior, which with a fast response time is ~60 ms under the 405 nm excitation. Given the very low dark current, the GaS nanobelts were characterized as p-type semiconductors via MOSFET measurements under 405 nm excitation, with a measured mobility of ~10^{-3} $cm^2 V^{-1} s^{-1}$.

To further enhance the performance of the devices,GaS/Ni heterostructure devices were formed through rapid thermal annealing (RTA). Post-annealing,the devices exhibited metallic behavior with a conductivity of ~10^3 $\Omega^{-1}cm^{-1}$ with high annealing temperature. On the other hand, low-temperature annealing resulted in the formation of Ni_xGaS/GaS heterostructures. These findings present a novel approach to enhancing the responsivity of GaS photodetectors with Ni contacts, offering promise for future high-performance optoelectronic systems.

MB-ThP-29 The Effect of the Precursors and Chemical Vapor Deposition Process on the Synthesis of Two-Dimensional Molybdenum Nitride Nanomaterials, C. Peng, B. Lin, H. Chen, L. Chen, **Sheng-Kuei Chiu (skuechiu@o365.fcu.edu.tw)**, Feng Chia University, Taiwan

Transition metal nitrides (TMNs) are crucial in influencing a wide range of physical and chemical characteristics due to their layered structure. They find applications in energy storage, sensors, electronics, spintronics, and catalysis. TMNs have a 2D structure that contains several active sites on the surface or edge, which contribute to their exceptional catalytic activity. Ongoing research is increasingly focused on developing methods to synthesize 2D TMNs. There are several defects in the structure of 2D TMN created using solution-based chemical synthesis, such as the hydrothermal technique. When fluorine, hydroxyl, or other oxygen-containing groups are on the surface of 2D TMNs, they become less reactive than they were before. Obtaining the desired effect from the use of TMNs synthesized by the hydrothermal process is challenging. The chemical vapor deposition (CVD) method has recently been approved as a way to make high-quality 2D transition metal nitrides (TMNs) that do not have any functional groups on the surface. We present a novel technique for producing an extremely thin, two-dimensional molybdenum nitride nanomaterial via chemical vapor deposition. Molybdenum nitride can be synthesized on a SiO2/Si wafer by the CVD process. It undergoes an ammoniation reaction with the transition metal disulfide (MoS2) and substitutes it with the transition metal nitride (MoN). By using a range of material testing devices, the precise composition and structure of the material are verified. This verification process aims to synthesize exceptionally reactive TMNs by carefully manipulating experimental conditions. The ultimate goal is to further the use of 2D TMNs in nanoelectronic components in the future.

MB-ThP-30 Optical Properties of Nanoscale Multi-Layered Ti/taC Thin Films, K. Oh, **JiWon Park (pjw000605@naver.com)**, Korea Aerospace University, Republic of Korea; J. Kim, KIMS, Republic of Korea; Y. Kim, Yonsei University, Republic of Korea; S. Lee, Korea Aerospace University, Republic of Korea

For the decade, it has been shown that diamond-like carbon (DLC) coatings are very promising anti-reflection (AR) and protective coatings for solar cell. However, tetrahedral amorphous carbon (ta-C) coatings with extremely high hardness, smooth surface, excellent wear resistance, and better thermal stability than DLC have been paid much attention to an alternative protective coating materials. Additionally, optical properties of the taC coating could be improved by various metals doping. In this study, various contents of Si were doped in the taC coating to improve the mechanical and optical properties of tacC coatings. A filtered cathodic vacuum arc (FCVA) and magnetron sputter hybrid system was used to synthesize the metal doped taC coating. As the Ti concentration increased, the mechanical properties of the coatings decreased. The hardness and elastic modulus of the taC coating (50 and 435 GPa)decrease down to 14 and ~223 GPa. Xray photoelectron spectroscopy (XPS) C 1 s spectra showed that both the Ti atomic percent and TiC bond percent increased with sputtering power. In addition, Tidoped taCcoatings showed an improved transmittance in all wavelength ranges when the sputtering powers were relatively low, comparing with undoped taC coating. Tribological behaviors of the Tidoped taC coatings were ubvestigagted and the results showed that with increasing sliding distance, the CoF and the wear rate increased regadless of the Ti and Ti-C contendt in the Ti-doped taC coatings. Experimental details and further results will be presented.

MB-ThP-31 Vernier Ellipsometry Sensing with Ultralow Limit-of-Detection and Large Dynamic Range by Tuning of Zero-Reflection Points, Y. Zhang, M. Thawda Phoo, F. Yishu, X. Li, Y. Lam, **Juan Antonio Zapien (apjazs@cityu.edu.hk)**, City University of Hong Kong

Optical sensors using zero-reflection points (ZRPs) enable excellent sensitivity due to accompanying phase singularities and the steepest slope of the reflectivity curve. Reflection zeros have been demonstrated at different spectral regions under very specific conditions in the angle of incidence (AoI) and polarization state. However, manipulation of the darkness points for multiple spectral positions and polarizations has not been achieved yet. Here, we report the collaborative and synergic operation of three ZRPs in a simple platform formed by a lithography-free, three-layer, metal-dielectric-metal structure where careful design and efficient manipulation of these ZRPs results in an optical sensor with unsurpassed, experimentally demonstrated, limit of detection ~2×10^{-8} RIU. The synergic operation of the proposed sensor relies on: i) strong coupling between p-pol surface plasmon polariton and p-pol photonic waveguide modes with experimentally demonstrated reflection suppression, Rabi splitting and phase singularities; ii) simultaneous implementation of two orthogonally polarized ZRPs and wavelength-interrogation mode of operation leads to spectral overlap of s-pol photonic modes with the coupled, p-pol resonances; and iii) ellipsometry-based sensing where the relatively insensitive s-pol ZRPs provide internal references to boost the sensor performance in terms of the amplitude ratio (ψ) and phase difference (Δ) of the s- and p-polarized reflectance thereby naturally forming a refinement measuring scale akin to a Vernier scale. Remarkably, the precise manipulation of the double dark points via the AoI control enables a second metric that yields ultrahigh sensitivity and can be reset to the original spot over a large dynamic range, thereby avoiding the trade-off between sensitivity and dynamic range. This occurs because the AoI acts an additional degree of freedom to tune and reset the sensor to its original ZRPs while keeping track of the total accumulated change. The strength of these capabilities has been demonstrated for a biosensor of SARS-CoV-2 spike (S2) protein that can track the full functionalization process of the chip surface and then reset to its best sensing conditions to perform real-time dose-dependent detection of the S2 spike protein. Our work provides a new and powerful strategy for the development of optical sensors, perfect light absorbers, pyroelectric detectors, and phase modulators.

MB-ThP-32 Optical and Protective Coatings Synthesized by Magnetron Sputtering, E. Aubry, FEMTO-ST (UMR CNRS6174)/UTBM, France; **Pascal Briois (pascal.briois@utbm.fr)**, FEMTO-ST (UMR CNRS 6174)/UTBM, France

The consortium of Opti-Reve project is composed by Surcotec and He-arc for the Swiss part and Gaggionne and UTBM for the French part. This project aims to develop a new technological solution (optical and protective coatings) in order to improve the quality of optical polymer components thanks to new functionalities brought to the surface by PVD technology, notably the corrosion resistance and the wear, as well as the brightness.

As part of this study, we first theoretically defined the material presenting the best reflection for the application but also its thickness. Based on the theoretical results, an adequate protective coating is determined. From the experimental point of view, the films were sputtered by magnetron sputtering from metallic targets in a neutral argon atmosphere for the reflective layer, then in a reactive atmosphere for the protective layer. The thin films were characterized by SEM, XRD for the morphological and structural parameters, the optical properties were determined by spectrophotometry. The first results obtained will be presented as well as future work.

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