

Functional Thin Films and Surfaces Room Palm 5-6 - Session MB3-MoM

Low-dimensional Materials and Structures

Moderators: Vladimir Popok, FOM Technologies, Denmark, Kostas Sarakinos, University of Helsinki, Finland

10:00am **MB3-MoM-1 Shape and Symmetry Engineering in Transition Metal Dichalcogenide Nanoribbons for Light Harvesting**, Ganesh Ghimire, Stela Canulescu [stec@dtu.dk], Technical University of Denmark, Denmark
INVITED

In this talk, I will discuss how controlling shape and symmetry at the nanoscale can fundamentally change how transition-metal dichalcogenides (TMDs) interact with light. By tailoring these materials into nanoribbon architectures, we can induce local symmetry breaking, tune excitonic behavior, and open new pathways for light harvesting and nonlinear optical response.

I will begin by introducing our alkali-assisted CVD approach for growing highly crystalline MoS₂ nanoribbons.^{1,2} These nanoribbons can extend to tens of microns in length and naturally form monolayer-multilayer junctions within a single structure. This built-in structural gradient creates regions that either preserve or break inversion symmetry. As a result, we observe strong second harmonic generation and distinct excitonic emission localized at the nanoribbon edges. These symmetry-driven optical characteristics directly translate into improved device performance: individual nanoribbon photodetectors exhibit responsivities among the highest reported for TMD-based nanoscale photodetectors.

I will then expand the discussion to the bulk photovoltaic effect (BPVE), a mechanism that enables photocurrent generation in non-centrosymmetric crystals without the need for p-n junctions. I will show how engineered asymmetry in 3R-stacked MoS₂ and lithographically defined WS₂ nanoribbons leads to strong nonlinear optical response and shift-current generation. The resulting devices display large short-circuit current densities and measurable open-circuit voltages, underscoring the potential of symmetry-driven photovoltaic operation.

Overall, I will highlight how **nanoscale shape and symmetry engineering** serve as powerful design principles for next-generation optoelectronic and energy-conversion technologies. By deliberately breaking symmetry—through strain, stacking control, and dimensional confinement—we can create TMD architectures that harvest light more efficiently and exhibit enhanced nonlinear optical behavior. These findings position TMD nanoribbons as versatile building blocks for future light conversion, sensing, and photovoltaic applications.

References:

1. Ghimire, G. *et al.* Molybdenum Disulfide Nanoribbons with Enhanced Edge Nonlinear Response and Photoresponsivity. *Adv. Mat.* 35, (2023).
2. Miakota, D. I., Ghimire, G., Ulaganathan, R., Rodriguez, M. & Canulescu, S. A novel two-step route to unidirectional growth of multilayer MoS₂ nanoribbons. *Appl Surf Sci.* 619, (2023)

10:40am **MB3-MoM-3 Discovery of Goldene Comprising Single-atom Layer Gold; Prospects for Novel Noble Metallenes**, Lars Hultman [lars.hultman@strategiska.se], Linköping University, IFM, Thin Film Physics Division, Sweden
INVITED

The quest to make monolayer gold has hitherto been limited to a few atomic layers stabilized on or inside another material. The bonding nature of metals is the root cause to gold's tendency to take 3D shapes during all kinds of synthesis, like vapor-phase deposition or precipitation from solutions.

Through an innovative scheme, single-atom-thick 2D gold¹⁾, named *goldene*, has been exfoliated by wet-chemically etching away Ti₃C₂ layers from Ti₃AuC₂ nano-laminated MAX-phase^{2), 3)} ceramic initially formed by substituting the Si layer in Ti₃SiC₂ thin films with Au³⁾. The driving force for such exchange substitution lies in the eutectic nature of the Au-Si phase diagram. Etching-free the goldene sheets is made using a diluted form of the Murakami's reagent⁵⁾. Surfactant schemes are applied to hinder *goldene* sheets from coalescing with each other in water suspension.

Goldene is observed by scanning transmission electron microscopy. A tendency for curling and agglomeration of *goldene* is observed, whereas *ab initio* molecular dynamics simulation shows that flat atomic layers are inherently stable. X-ray photoelectron spectroscopy reveals an Au 4f binding energy increase of 0.88 eV. Prospects for preparing *goldene* from a series of carbide and nitride MAX phases are also presented. Proposed applications for *goldene* include sensors and photocatalyst for water splitting during solar energy harvesting. The use of Au resources would be minimized due to the ultimate surface-area-to-volume ratio for *goldene*.

Isolated three-atomic-layer Au sheets – trilayer *goldene* – was recently reported by us by selectively removing the Ti₄C₃ sheets from Ti₄Au₃C₃, formed by Au-intercalated Ti₄SiC₃ thin films.⁶⁾ Finally, this presentation will discuss ways to realize other noble-metal *metallenes*⁷⁾ from thin-film or bulk-powder templates.

1. *Nature Synthesis*, **3** (April 16, 2024) 744-751
2. *MAX phases* are inherently nanolaminated hexagonal ternary metal carbides and/or nitrides with a general formula M_{n+1}AX_n, where M is a transition metal, A is a group 13-16 element, X is carbon and/or nitrogen, and n = 1, 2, 3,...
3. Review: M. Dahlqvist, M.W. Barsoum, J. Rosen, *Materials Today* **72** (2024) Jan/Feb, p. 1
<https://doi.org/10.1016/j.mattod.2023.11.010>
4. H. Fashandi, M. Dahlqvist, J. Lu, J. Palisaitis, S. Simak, I. Abrikosov, J. Rosen, L. Hultman, M. Andersson, A. Lloyd-Spetz, P. Eklund *Nature Materials* **16** (2017) 814
5. Potassium ferricyanide is combined with potassium hydroxide (or sodium hydroxide) and water to formulate Murakami's etchant.
6. Y. Shi, [...], L. Hultman *Sci. Advances* **11**, eadt7999 (2025) 28 March 2025
7. Kashiwaya, Y. Shi, J. Rosen, L. Hultman, *2D Materials* **12** (2025) 033001

11:20am **MB3-MoM-5 Nanoporous TiO₂ Thin Films by Helium-Assisted Sputtering for Noble-Metal-Free Hydrogen Sensing**, Stanislav Haviar [haviar@ntis.zcu.cz], Akash Kumar, Tomáš Kozák, Petr Zeman, University of West Bohemia in Pilsen, Czechia

A large portion of magnetron-sputtered film applications targets the fabrication of highly compact, dense films. Textbook knowledge of thin-film growth delineates process windows that lead to “low-quality,” non-compact morphologies. However, there are use cases where higher porosity or other forms of nanostructuring are advantageous—for example, when a large reactive surface area is desired. In this work, we discuss a modification of classical reactive sputtering in an Ar/O₂ mixture by introducing helium gas. Subsequently, we evaluate the resulting materials assembled as conductometric hydrogen gas sensors.

Titanium oxide films were deposited by conventional DC reactive sputtering, where helium replaced part of the Ar/O₂ working-gas mixture. The stoichiometric as-deposited films were post-annealed to achieve stable TiO₂. The introduction of helium promotes the formation of distinctive morphological features, which increase film porosity, as observed by electron microscopy.

We analyze the mechanisms involving reflected fast neutrals underpinning the emergence of nanoporous structures, supported by SEM imaging as well as structural characterization via XRD and Raman spectroscopy. We describe the evolution of the microstructure with annealing temperature and identify key processing parameters required to obtain porous yet stable films.

The application potential is then assessed by employing the films as conductometric hydrogen sensors. Films prepared by He-assisted sputtering show a several-fold increase in sensitivity to hydrogen without the addition of any noble metals.

Overall, controlled nanostructuring of thin films represents a promising route to engineer novel materials for gas sensing, and He-assisted deposition is one such approach.

Monday Morning, April 20, 2026

11:40am **MB3-MoM-6 Large-Area Single-Crystals of Borophene on Square and Triangular Copper Surfaces: Synthesis and Characterization**, **Adrian Gozar** [agzar@fairfield.edu], Fairfield University and Yale University, USA; *Ivan Bozovic*, Yale University and Shanghai Advanced Research in Physical Sciences, USA **INVITED**

The materials-by-design paradigm is based on synergistic efforts involving synthesis, characterization and advanced computation to ensure materials meet technological needs within a cost-effective framework. Borophene, a crystalline monolayer sheet, is envisaged to play an important role in this area because of its extraordinarily rich polymorphism. The multitude of potentially stable structures singles out borophene from all other two-dimensional materials and fuels hopes for obtaining on-demand structures with applications in flexible electronics, energy storage or catalysis.

We have used a unique ultra-high vacuum system for synthesis, by Molecular Beam Epitaxy, and in-situ characterization, by Low Energy Electron Microscopy, of micron-size borophene crystals on Cu(111) and Cu(100) substrates. Our real-time imaging capabilities provide information about the growth of faceted borophene islands up full monolayer coverage and also about phase-stability, evaporation and sub-surface dissolution. Combining low energy electron diffraction with scanning tunneling microscopy and ab initio theory allows us to resolve the crystal structures as triangular networks with vacancy ratios $\eta = 1/5$ for Cu(111) and $\eta = 1/6$ for Cu(100) surfaces. First-principles calculations indicate that charge transfer rather than covalent bonding, couples borophene to the underling Cu surfaces. The calculated electronic band structures host multiple anisotropic Dirac cones. Ex-situ scanning near-field optical microscopy data reveal dielectric contrast between borophene and substrates, showing that nano-optical tools provide new ways to access intrinsic electronic properties of these novel structures.

[1] R. Wu et al., J. Vacuum Sci. Tech. A 43, 042703 (2025)

[2] J. Zhao et al., Rev. Sci. Instrum. 96, 023907 (2025)

[3] A. Gozar et al., Nano Today 50, 101856 (2023)

[4] R. Wu et al., Nature Chemistry 14, 377 (2022)

[5] I. Bozovic, Nature Materials 21, 11 (2022)

[6] R. Wu et al., Nature Nanotechnology 14, 44 (2019)

Functional Thin Films and Surfaces

Room Palm 5-6 - Session MB2-1-MoA

Thin Films for Emerging Electronic and Quantum Photonic Devices I

Moderators: Shirley Espinoza, ELI Beamlines, ELI ERIC, Czechia, Jaroslav Vlcek, University of West Bohemia, Czechia

2:00pm MB2-1-MoA-2 Optical and Electrical Properties of Nitrogen-doped p-type Cu₂O Thin Films Prepared by Reactive HiPIMS, Jan Koloros [koloros@ntis.zcu], Jiří Rezek, Pavel Baroch, University of West Bohemia in Pilsen, Czechia

One of today's challenging scientific topics is finding a suitable p-type TCO that would at least approach the optoelectronic properties of the n-type counterpart [1]. Finding such p-type material is a necessary condition for further sustainable technological development of society. The realization of p-n junctions using transparent conductive materials will enable the development of a new generation of invisible electronics, contribute to reducing the energy requirements of various optoelectronic devices or lead to the production of more efficient solar cells. Transparent conductive materials based on Cu₂O appear to be among the most promising. This is mainly due to the abundance of elements used, their non-toxicity and interesting optoelectronic properties. One of the limiting factors in Cu₂O layers is the low mobility of holes. In our previous work [2], we demonstrated that post-deposition laser annealing can effectively enhance hole mobility.

In our work, we systematically investigated the role of nitrogen incorporated into Cu₂O thin films, with a primary focus on their optical and electrical properties, including the optical band gap and electrical resistivity. The Cu₂O:N films were prepared by reactive HiPIMS of Cu circular target (100 mm in diameter) in Ar+O₂+N₂ atmosphere. The pulse-averaged target power density (S_{av}) was varied from ≈ 100 -1300 Wcm⁻², and the fraction of N₂ in (Ar+N₂) mass flow was 0–90 %. A decreasing trend in resistivity has been observed with increasing nitrogen content. The prepared p-type Cu₂O:N films with the highest value of a nitrogen fraction of 90% exhibited a very low resistivity about 5x10⁻² Ωcm exceeding the current state of the art [3].

[1] J. Singh, P. Bhardwaj, R. Kumar, V. Verma, Progress in Developing Highly Efficient p-type TCOs for Transparent Electronics: A Comprehensive Review, J Electron Mater (2024).

[2] J. Rezek, M. Kučera, T. Kozák, R. Čerstvý, A. Franc, P. Baroch, Enhancement of hole mobility in high-rate reactively sputtered Cu₂O thin films induced by laser thermal annealing, Applied Surface Science, (2024).

[3] J. Rezek, J. Koloros, J. Houška, R. Čerstvý, S. Haviar, D. Kolenatý, J. Y. Damte, P. Baroch, Ultra-low-resistivity nitrogen-doped p-type Cu₂O thin films fabricated by reactive HiPIMS, Applied Surface Science, (2025).

2:20pm MB2-1-MoA-3 Fabrication and Manipulation of Weakly-Interacting Interfaces for Optoelectronic Applications, Kostas Sarakinos [kostas.sarakinos@helsinki.fi], University of Helsinki, Finland INVITED

A key challenge in the materials science community is to understand the correlation among nanoscale atomic arrangement, structure-forming mechanisms, and mesoscale morphology during material synthesis. Addressing this challenge will herald a new epoch in which tailor-made materials and devices with unprecedented macroscopic behavior will be created by controlling mesoscale structure via nanoscale manipulation. The present talk demonstrates the implementation of the above-outlined concept of multiscale materials design during the vapor-based synthesis of thin noble-metal films (and nanostructures) on weakly-interacting substrates, including oxides and van der Waals crystals. Such film/substrate systems exhibit a pronounced and uncontrolled three-dimensional (3D) morphology, which is a major obstacle toward fabricating high-quality multifunctional metal contacts in a wide array of devices. Using growth of silver (Ag) on silicon dioxide (SiO₂) as a model system—along with a combination of in situ film growth monitoring, ex situ microstructure and chemical characterization, and modelling—it is shown that the tendency for 3D growth morphology can be effectively reversed, without compromising key physical properties of the film and the substrate, when miniscule amounts of minority gaseous [1,2,3] and metal species [4,5] (surfactants) are deployed with high temporal precision at the film growth front, such that atomic-scale processes that govern key film-formation stages are selectively targeted and affected. The talk concludes with a discussion with

regards to the implications and possibilities that this strategy opens for tuning macroscopic performance of devices in the areas of energy saving and generation.

[1] A. Jamnig et al., "3D-to-2D morphology manipulation of sputter-deposited nanoscale silver films on weakly-interacting substrates via selective nitrogen deployment for multifunctional metal contacts", ACS Applied Nano Materials 3 (2020) 4728.

[2] N. Pliatsikas et al., "Manipulation of thin silver film growth on weakly-interacting silicon dioxide substrates using oxygen as a surfactant", J. Vac. Sci. Technol. A 38 (2020) 043406.

[3] K. Sarakinos et al., "Unravelling the effect of nitrogen on the morphological evolution of thin silver films on weakly-interacting substrates", App. Surf. Sci. 649 (2021) 159209.

[4] A. Jamnig et al. "On the effect of copper as wetting agent during growth of thin silver films on silicon dioxide substrates", App. Surf. Sci. 538 (2021) 148056.

[5] A. Jamnig et al., "Manipulation of thin metal film morphology on weakly-interacting substrates via selective surfactant deployment", J. Vac. Sci. Technol. A. 40 (2022) 033407.

3:00pm MB2-1-MoA-5 Stability and Interlayer Formation at Epitaxial P-Type Oxides and Ga₂O₃ Interfaces, Anna Sacchi [anna.sacchi@nrel.gov], Andriy Zakutayev, Brooks Tellekamp, Michelle Smeaton, Steven Spurgeon, National Renewable Energy Laboratory, USA; Shivashree Shivamade Gowda, Patrick Hopkins, University of Virginia, USA

Research in power electronics is increasingly directed toward ultra-wide bandgap (UWBG) oxides such as Ga₂O₃, valued for its wide bandgap (≈ 4.5 eV), high breakdown field (≈ 8 MV/cm), as well as thermal and chemical stability. However, the impossibility to achieve p-type doping in Ga₂O₃ has motivated the exploration of heterojunctions based on different p-type oxides, among which NiO and Cr₂O₃ are considered the most promising.^{1,2} To date, most studies on Ga₂O₃ based heterojunctions have focused primarily on device optimization rather than on the fundamental understanding of interface dynamics and long-term stability, except for a recent study³ where the formation of a NiGa₂O₄ interlayer at the NiO/Ga₂O₃ interface after prolonged thermal cycling was found responsible for device performances degradation.

This work aims to provide a deeper understanding of NiO/Ga₂O₃ and Cr₂O₃/Ga₂O₃ interfaces. Pulsed laser deposition growth technique is exploited to run a detailed growth campaign for NiO and Cr₂O₃ on top of Ga₂O₃ substrates with various orientations, i.e., (100), (001), and ($\bar{2}01$). X-ray diffraction evaluated material quality and epitaxial relationships, revealing ($\bar{2}01$) substrate orientation as common epitaxial match for both oxides. Transmission electron microscopy is used to examine interface stability and possible interlayer formation when thermal treatments are applied, simulating long-term high-temperature operations. Additionally, thermoreflectance measurements are performed to investigate heat dynamics at the interfaces, both with and without the interlayer presence.

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(1) Kokubun, Y.; Kubo, S.; Nakagomi, S. All-Oxide p-n Heterojunction Diodes Comprising p-Type NiO and n-Type β -Ga₂O₃. *Appl. Phys. Express* **2016**, *9* (9), 091101. <https://doi.org/10.7567/APEX.9.091101>.

(2) Callahan, W. A.; Egbo, K.; Lee, C.-W.; Ginley, D.; O'Hayre, R.; Zakutayev, A. Reliable Operation of Cr₂O₃:Mg/ β -Ga₂O₃ p-n Heterojunction Diodes at 600 °C. *Appl. Phys. Lett.* **2024**, *124* (15), 153504. <https://doi.org/10.1063/5.0185566>.

(3) Egbo, K.; Garrity, E. M.; Callahan, W. A.; Chae, C.; Lee, C.-W.; Tellekamp, B.; Hwang, J.; Stevanovic, V.; Zakutayev, A. NiGa₂O₄ Interfacial Layers in NiO/Ga₂O₃ Heterojunction Diodes at High Temperature. *Appl. Phys. Lett.* **2024**, *124* (17), 173512. <https://doi.org/10.1063/5.0194540>.

Monday Afternoon, April 20, 2026

3:20pm **MB2-1-MoA-6 Investigation of High-temperature Morphology and Electrical Performance of YZr-alloyed Amorphous Al_2O_3 Thin Films**, *Norma Salvadores Farran* [norma.salvadores@tuwien.ac.at], Florentine Scholz, Tomasz Wojcik, TU Wien, Austria; Astrid Gies, Jürgen Ramm, Klaus Böbel, Oerlikon Balzers, Liechtenstein; Szilard Kolozsvári, Peter Polcik, Plansee Composite Materials, Austria; Tobias Huber, Jürgen Fleig, Helmut Riedl, TU Wien, Austria

Aluminium oxide (Al_2O_3) is a widely used insulating material, particularly in thin-film applications. In addition to its various polymorphs, Al_2O_3 can also exist in an amorphous phase, which is characterized by excellent oxidation resistance and high thermal conductivity. A key advantage of the amorphous form is its uniform structure, free from pinholes. Owing to these properties, amorphous Al_2O_3 being investigated as a dielectric material in electronic and semiconductor devices, as well as in energy storage technologies. Therefore, identifying cost-effective and sustainable deposition methods for the fabrication of high-quality Al_2O_3 insulating thin films is of great importance.

Amorphous Al_2O_3 films were synthesized using a reactive Modulated Pulse Power (MPP) sputtering process. All depositions were carried out in an in-house developed sputtering system equipped with a 3-inch aluminium target and operated in a mixed Ar/O_2 atmosphere. The primary aim of this study was to examine the influence of yttrium–zirconium (YZr) alloying on the thermal stability of the amorphous Al_2O_3 phase, with the goal of preventing phase transitions into crystalline states up to 1200 °C. To achieve this, varying amounts of YZr were incorporated into the aluminium targets. The effects of these YZr additions and their concentrations on process stability, as well as on the resulting film properties – including morphology, structure, and electrical resistivity – were analysed using advanced high-resolution characterization techniques.

Phase formation and evolution were investigated using X-ray diffraction (XRD) over a temperature range from room temperature up to 1200 °C. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) were employed to assess the deposition rate and surface morphology of the coatings. The chemical composition of the films was analysed using X-ray photoelectron spectroscopy (XPS), which was also utilized to examine the bonding states of the constituent elements. Additionally, in-situ impedance spectroscopy was used to study variations in the electrical properties as a function of temperature. For electrical characterization, Ti/Pt electrode pads were fabricated via photolithography.

4:00pm **MB2-1-MoA-8 Ion-Beam Assisted Deposition of P-Type Oxide Semiconductor Thin Films in Room Temperature**, *Tsung-Yu Huang* [huang.tsungyu@mail.mcut.edu.tw], Ming Chi University of Technology, Taiwan

INVITED

Transparent semiconductor oxides are an important class of materials in materials science, including SnO_2 , In_2O_3 , ZnO , and dozens of doped transparent semiconductor oxides. These materials have been widely used in various electronic and optoelectronic devices. Tin monoxide (SnO), due to the overlap between its 5s orbital and the oxygen 2p orbital, exhibits unique characteristics that enable hole transport. This makes it one of the most promising candidates for p-type oxide semiconductors. In this study, our p-type SnO thin film achieved a mobility of $4.52 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$.

4:40pm **MB2-1-MoA-10 Influence of Bonding Temperature on Electromigration Suppression in Cu-Doped Ag Bumps**, *Chien-Cheng Chiang* [johnson10678@gmail.com], Peng-Hsiang Hsu, Fan-Yi Ouyang, National Tsing Hua University, Taiwan

The continuous advancement of technology has driven the demand for higher-performance electronic devices, leading to progressive miniaturization of device dimensions. However, further device scaling is fundamentally constrained by physical limits. To overcome these challenges, three-dimensional integrated circuits (3D ICs) have emerged as a promising alternative for enhancing device performance. Compared with conventional flip-chip solder joints, direct metal bonding (DMB) provides higher interconnect density, lower electrical resistance, and improved reliability, making it an attractive technique for advanced packaging. Nevertheless, as interconnect dimensions decrease, reliability issues become increasingly critical, with electromigration (EM) being one of the primary failure mechanisms.

In this study, Ag alloyed with 3.2 at.% Cu was employed as the interconnect material, and a nanotwinned structure was introduced to enhance EM resistance. Thermal compression bonding was performed at various temperatures to investigate the influence of bonding temperature on electromigration behavior and microstructural evolution. Compared with pure silver, Ag doped with 3.2 at.% Cu exhibits not only a better bonding

interface at higher bonding temperatures but also retains a larger amount of twin structures, thereby achieving superior electromigration resistance. The results provide valuable insights into the relationship between bonding parameters and EM performance, offering practical strategies to improve the reliability of next-generation advanced packaging technologies.

Functional Thin Films and Surfaces

Room Palm 5-6 - Session MB2-2-TuM

Thin Films for Emerging Electronic and Quantum Photonic Devices II

Moderators: **Ufuk Kilic**, University of Nebraska - Lincoln, USA, **Ulrich Schmid**, TU Wien, Austria

8:00am MB2-2-TuM-1 Polyoxometalate Thin Film Heterostructures and Blends with Neuromorphic Computing Capabilities, Dimitra Georgiadou [D.Georgiadou@soton.ac.uk], University of Southampton, UK **INVITED**

Neuromorphic computing holds promise for lowering power consumption and increasing the computation speed of Artificial Intelligence (AI) applications, as it is emulating the parallel manner of memorising and processing information in the brain. Although machine learning algorithms inspired by the spiking neural networks in the brain have recently made gigantic leaps into the field of neuromorphic computing, scalability and power efficiency remain a challenge. There is, therefore, a clear need for redesigning the neuromorphic hardware systems using radically novel materials and architectures that can better emulate the chemical processes in the mammalian brain and lead to efficient computation with added functionalities.

Polyoxometalates (POMs), a class of redox active molecular metal oxides, have emerged as promising candidates for next generation neuromorphic devices. Their discrete molecular structure, tunable electronic properties, and compatibility with silicon-based platforms have made them attractive materials for advanced memory applications with tunable long- and short-term memory characteristics. POMs can accept multiple electrons without compromising their structural integrity, notably acting as “electron reservoirs” or “electron sponges”, while the highly tunable surface chemistry of these metal oxide clusters offers many routes for electronic device optimisation.

In this talk, I will present a two-terminal redox-based resistive switching memory using the Keggin phosphomolybdate POM $\text{H}_3\text{PMo}_{12}\text{O}_{40}$. By combining this Mo-POM with nanogap coplanar metal electrodes, we create nanoelectronic devices that offer significant advantages, such as low power consumption and fast switching times. Emphasis will be placed on the diverse strategies used to integrate POMs with different metal substrates and functional layers, such as dielectric and conjugated polymers. I will also discuss the influence of counterions and encapsulating layers in resistive switching mechanisms.

This combination of redox active nanomaterials and nanogap architecture holds great potential for advancing electronic technologies, while being also fully compatible with large area manufacturing and flexible substrates. Overall, this work introduces POM-based systems as a viable alternative to the limitations of conventional CMOS memory, offering a blueprint for future developments in molecular electronics.

8:40am MB2-2-TuM-3 Yttrium-Doped Aluminum Nitride Memristors to Enhance the Pattern Recognition Accuracy of Unsupervised Spiking Neural Network, Jer-Chyi Wang [jcwang@mail.cgu.edu.tw], Chang Gung University, Taiwan **INVITED**

Recently, an increasing requirement for pattern recognition and decision-making in computing systems has led to the development of artificial neural network (ANN). Although ANN is inspired by the working principle of the biological nervous system, the learning rule and computing architecture are still inconsistent with nervous behaviors, making it difficult to realize the functionalities of the human brain. To overcome these issues, spiking neural network (SNN) with high biological plausibility has been proposed for next-generation neuromorphic computing systems. SNN performed with the spike-timing-dependent plasticity (STDP) learning rule can mimic the learning behaviors of living beings. Hence, the design of electronic devices with STDP behavior, such as synaptic transistors, memristors, and ferroelectric memories, has become a crucial task. Among them, memristors have been considered as the most promising candidates because of their synapse-like morphology, high scaling ability, and low power consumption. Nitride-based memristors, such as AlN, Si_3N_4 , WN, and CuN memristors, have been reported to exhibit superior memory characteristics; however, most of the devices require specific operation

methodologies to mimic the synaptic properties. Thus far, no studies have focused on the process-related influences on the STDP behavior of memristors and further implementation of the devices in the SNN system. In this study, yttrium (Y)-doped AlN memristors are proposed to investigate the dependence between the Y-doping concentration and SNN performance. With an increase in the Y-doping concentration, both the memory characteristics and synaptic behaviors of the AlN memristors significantly improved. In addition, the STDP parameters of the memristors were extracted and fed into the SNN to simulate the pattern recognition capability. The optimized pattern recognition accuracies of 75.89 and 60.21% for the MNIST and ETH-80 datasets, respectively, were achieved for the AlN memristors with a Y-doping concentration of 3.4%, which is promising for implementation in future neuromorphic computing system and artificial intelligence.

9:20am MB2-2-TuM-5 Room-Temperature Sputtered Niobium Thin Films: Synchrotron-Based Hard X-ray Photoelectron Spectroscopy of Interfacial Oxidation for Superconducting Applications, Ananya Chattaraj [achattara@bnl.gov], Center for Functional Nanomaterials, BNL, USA; **Aswin kumar Anbalagan**, National Synchrotron Light Source II, Brookhaven National Laboratory, USA; **Mingzhao Liu**, Center for Functional Nanomaterials, BNL, USA

Niobium (Nb) thin films are critical materials for superconducting quantum circuits due to their high superconducting transition temperature (T_c) and compatibility with microfabrication processes. However, device performance is often limited by dielectric losses originating from interfacial oxides, where two-level systems (TLS) act as parasitic energy dissipation centers. Understanding the structural and chemical evolution of Nb oxides and their depth distribution is therefore essential for improving thin film quality and device coherence. In this study, Nb thin films were deposited by DC magnetron sputtering at room temperature, without post-deposition annealing or thermal treatment. This low-temperature approach enables CMOS-compatible multilayer integration while preserving the integrity of previously fabricated qubit or dielectric layers. X-ray diffraction (XRD) revealed a preferential Nb(110) texture, in contrast to the Nb(111)/(222) orientations commonly obtained under elevated growth temperatures. X-ray reflectivity (XRR) confirmed smooth surface morphology and sharp interfaces. The oxidation behavior and interfacial chemistry were investigated using both laboratory-based X-ray photoelectron spectroscopy (XPS) and variable photon energy Hard X-ray Photoelectron Spectroscopy (HAXPES) at the NSLS-II synchrotron, Brookhaven National Laboratory. HAXPES measurements performed over the 2000–5500 eV photon energy range enabled non-destructive, depth-resolved chemical analysis from the surface oxide to the metallic Nb bulk. Quantitative fitting of Nb 3d and O 1s spectra revealed multiple suboxide species (Nb_2O_5 , NbO_2 , and NbO_x) and their gradual evolution across the Nb/NbO_x interface. The variable-energy HAXPES approach provided nanometric insight into oxidation gradients and interfacial structures inaccessible to conventional XPS, highlighting the power of synchrotron-based depth profiling for complex thin films. Electrical transport measurements confirmed a superconducting transition temperature (T_c) of ~9 K, demonstrating that high-quality superconducting properties can be retained under room-temperature growth conditions. The integrated structural, spectroscopic, and transport characterization establishes a framework for understanding interfacial oxidation in Nb thin films and provides critical guidance for mitigating oxide-related losses in superconducting and quantum device technologies.

9:40am MB2-2-TuM-6 Orbital Hall Effect and Spin-Orbit Torque Mediated Field-Free Switching at Reduced Current Density in Perpendicularly Magnetized Ta/Cu/Pt/Co/Pt System, Saikat Maji, Soubhik Kaya, Ankan Mukhopadhyay, Anil Kumar Parameswaran Sarala [anil@iisc.ac.in], Indian Institute of Science, India

The current-induced magnetization reversal (CIMR) in a perpendicular magnetic anisotropy (PMA) system is realized through the Néel wall motion enabled by the spin-orbit torque (SOT). In heavy metal (HM)/Ferromagnet(FM) based PMA systems, the SOT emerges from the spin current generated by the spin Hall effect (SHE) of the HM. However, the magnetization reversal in these systems requires an in-plane bias magnetic field (H_x) in addition to the in-plane charge current (J_x). Field-free switching in PMA systems at a lower current density is crucial for storage device applications. To investigate the magnetisation reversal, Ta(3 nm)/Cu(t nm)/Pt(3 nm)/Co(0.4 nm)/Pt(1 nm) multilayers with PMA were prepared for $t = 0, 1, 2$ and 4. The Cu layer has been introduced to enhance the SHE of the Pt layer with the assistance of the orbital Hall effect offered by the Culayer. As a result, the current density for magnetization reversal (J_c) reduces with the introduction of the Culayer. At $H_x = 5$ mT, the J_c has been

Tuesday Morning, April 21, 2026

reduced upto 16%, 35% and 55% compared to the Ta/Pt/Co/Pt system in multilayers with $t = 1, 2$, and 4 nm, respectively. Additionally, deterministic switching has been observed

in the multilayers with $t = 2$ and 4 nm for $H_x = 0$ and is described as field-free switching. The minimum

J_c ($= -1.20 \times 10^{11}$ A/m²) has been obtained for field-free switching from $+M_z$ to $-M_z$ state in the multilayer

with $t = 4$ nm. The field-free switching has been explained by introducing the unconventional SOT arising from z polarized spin current in addition to the conventional SOT resulting from $-y$ polarized spin current produced by the J_x in the micromagnetic simulation framework.

10:00am **MB2-2-TuM-7 Impact of Interlayers on the Electrical and Microstructural Stability of Cu Films Deposited on SiC Substrates, Jui-Wei Hsu [michaelhsu33@gmail.com]**, College of Semiconductor Research, National Tsing Hua University, Hsinchu, Taiwan; *Fan-Yi Ouyang*, Department of Engineering and System Science, National Tsing Hua University, Hsinchu, Taiwan

Silicon carbide (SiC) has become a key substrate material for high-voltage and high-temperature power devices due to its wide bandgap, high breakdown field, and excellent thermal conductivity. However, its distinct surface chemistry and higher thermal budget pose challenges for metallization. In conventional Si-based systems, interlayers such as TiN, Ta, and TaN are widely used as Cu diffusion barriers and adhesion layers. Yet, their effectiveness on SiC substrates remains insufficiently understood. Establishing a stable, low-resistance Cu film stack on SiC is therefore critical for ensuring both electrical performance and reliability under high-temperature operation.

In this study, TiN, Ta, and TaN interlayers were deposited on SiC substrates using a sputtering system, followed by a 5000 Å Cu overlayer. This configuration enables direct comparison of how each interlayer affects Cu texture, interfacial stability, and diffusion behavior during subsequent thermal processing. The as-deposited Cu/TiN structure exhibited the lowest sheet resistance, followed by Cu/TaN and Cu/Ta. After annealing at 200–300 °C, the Cu/Ta stack demonstrated the best stability, while Cu/TaN maintained a slightly higher but stable value around 2.0 Ω/sq. TiN showed more pronounced resistance variation with temperature. The temperature-dependent evolution of resistivity and interfacial structure, along with the underlying diffusion mechanisms, will be discussed in detail. These findings contribute to a deeper understanding of Cu/interlayer/SiC interfaces, providing design guidance for reliable metallization schemes in next-generation power electronics.

Keywords: SiC, TiN/Ta/TaN interlayer, diffusion barrier, Cu metallization, thermal stability

10:20am **MB2-2-TuM-8 Ternary-Blending Energetics and 3d Packing in Thin Films Enable Ultralow-Noise Nir Opds and Thermally Durable All-Polymer Opvs, Chih-Ping Chen [cpchen@mail.mcut.edu.tw]**, Ming Chi University of Technology, Taiwan **INVITED**

We report complementary molecular- and ternary blend-control thin-film strategies that concurrently suppress non-radiative loss and dark current in near-infrared (NIR) organic photodetectors (OPDs) and deliver record-level thermal durability in all-polymer organic photovoltaics (OPVs). (i) In OPDs, introducing PTQ10 into PM6:PY-IT forms a ternary film that suppresses unfavorable molecular packing and tunes interfacial energetics, thereby mitigating thermally activated carrier generation/leakage. A ternary OPD incorporating PTQ10 into PM6:PY-IT suppresses unfavorable packing and optimizes energy-level alignment, thereby mitigating thermally activated carrier generation and leakage. The devices achieve $J_d < 1.0 \times 10^{-9}$ A cm⁻² at -2 V and shot-noise-limited detectivity $D^*_{\text{shot}} \approx 5.0 \times 10^{13}$ Jones (830 nm, -2 V) without sacrificing responsivity. In the case of donor D18 paired with Y-series acceptors of varied surface energies and frontier orbitals identifies D18:Y18 blends with optimized 3D packing (GIWAXS), reduced trap density, and minimized non-radiative recombination, yielding $D^*_{\text{shot}} = 4.2 \times 10^{13}$ Jones at -2 V, with superior linear dynamic range, cutoff frequency, and response time. For OPVs, blending the polymer donor PBQx-TF with high-crystallinity D18 followed by sequential deposition of PY-IT tunes morphology and balances carrier mobilities while minimizing energy losses. The ternary all-polymer OPV attains PCE = 16.07%, surpassing the corresponding binaries (15.26% for PBQx-TF:PY-IT; 14.39% for D18:PY-IT), and exhibits outstanding durability, retaining 80% of its initial PCE after 1500 h at 120 °C, with intact layer structure. Together, these results establish clear design rules—ternary-blend energetics and controlled 3D

packing—for achieving ultralow dark current in NIR OPDs and unprecedented thermal stability in all-polymer OPVs.

Functional Thin Films and Surfaces

Room Palm 1-2 - Session MB1-WeA

Optical Materials and Thin Films

Moderators: Tsung-Yu Huang, Ming Chi University of Technology, Taiwan ,
Juan Antonio Zapien, City University of Hong Kong

2:00pm MB1-WeA-1 Ultrafast Phenomena in Optical Materials with fs–ns Time-Resolved Spectroscopic Ellipsometry, Shirly Espinoza [shirly.espinoza@eli-beams.eu], ELI Beamlines, ELI ERIC, Czechia **INVITED**

Static, imaging, and time-resolved ellipsometry link microstructure and optical function in thin films. Using time-resolved spectroscopic ellipsometry (TRSE), we access amplitude and phase simultaneously (angles Ψ and Δ) to recover the complex dielectric function (ϵ) with femtosecond resolution, a capability that conventional transient probes do not provide directly and that is key to disentangling overlapping ultrafast processes. As complementary techniques, time-resolved X-ray diffraction (TR-XRD) correlates lattice strain and structural pathways with the optical response, while imaging ellipsometry maps, with spatial resolution, thickness and optical constants (n , k), assessing uniformity and device-level variability.

In ZnO thin films, TRSE separates bleaching by Pauli blocking, band-gap renormalization, and intra-valence-band absorption, together with the evolution of excitonic features under strong photoexcitation; this yields the full-time evolution (real and imaginary parts) of $\epsilon(\omega, t)$ and clarifies electron–electron and electron–phonon coupling on sub-ps time scales.

In LaCoO₃ thin films, TRSE reveals a photoinduced insulator-to-metal transition with spectral-weight transfer to low energies, followed by an ultrafast relaxation and, between 1–30 ps, a second maximum whose kinetics and thickness dependence evidence coherent acoustic phonons that transiently modulate the optical constants.

Complementarily, imaging ellipsometry applied to spin-coated oxides demonstrates its utility for metrology and function: thickness/optical-constant mapping and fabrication of Co₃O₄/CeO₂ diodes with reproducible rectification, all within a low-cost deposition platform.

Finally, for layered chalcogenides, recent results obtained outside our TRSE setup show that GaS acts as a reconfigurable optical material: laser-induced structural modification persistently tunes the band structure and refractive index with low loss, enabling sub-wavelength patterning and programmable optical elements.

Taken together, TRSE, TR-XRD, and imaging ellipsometry form a quantitative toolbox to read and design ultrafast optical functionalities in oxides and chalcogenides, from fundamental dynamics to scalable device integration.

2:40pm MB1-WeA-3 The Role of Contaminants in the Microstructural Evolution of Defects in Low-Emissivity Glazing at High Temperatures, Phillip Rumsby [phillip.rumsby@etud.polymtl.ca], Bill Baloukas, Oleg Zabeida, Ludvik Martinu, Polytechnique Montréal, Canada

Silver-based coatings present exceptional optical and electrical properties, garnering them significant interest in applications requiring multifunctional optical filters. Amongst these are low-emissivity (low-E) windows. These dramatically reduce radiative heat transfer, improving the energy efficiency of window units while simultaneously providing highly transparent and aesthetically pleasing glass facades. However, Ag films present specific challenges in terms of their chemical and high-temperature stability, which must be managed with an appropriate combination of protective layers (hard coatings, diffusion barriers, metallic interface layers).

In this work, we investigate the processes by which minor mechanical defects in said protective layers evolve during glass tempering. This process, in which coated glass is heated at temperatures in excess of 650 °C, can cause small, practically invisible scratches, formed during glass cutting and handling, to develop into highly visible features. This can lead to entire panes of glass being rejected late in the fabrication process.

First, the multiple mechanisms participating in coating degradation are isolated and their interplay is analyzed: indeed, in addition to purely microstructural changes, disruption of the protective films allows diffusion of both atmospheric and substrate contaminants to the Ag layer, such as O₂, H₂O, and Na. The effect of different combinations of contaminants is thus evaluated by annealing partial stacks with various barrier layer configurations in controlled environments and on substrates of different composition, allowing one to control contaminant availability. Subsequent optical, electrical and microstructural analyses reveal key differences in the Ag dewetting behavior induced by O₂ and Na exposure.

Defects with repeatable morphological features are then generated using a microscratch tester with a diamond tip indenter. The effect of defect types and tempering conditions on scratch visibility is then compared quantitatively by image analysis of dark-field photographs. This reveals that atmospheric contaminants play a dominant role in scratch intensification. Investigation of the coating microstructural features leading to this increase in visibility is performed by both scanning and transmission electron microscopies; this indicates that large Ag particles ($\approx 1 \mu\text{m}$) formed at the scratched surfaces are not the main contributor. Rather, particles formed inside the coating, with restricted sizes ($\approx 100 \text{ nm}$) contribute to scattering much more strongly, as evidenced by Mie scattering calculations.

3:00pm MB1-WeA-4 Thermochromic VO₂-Based Coating for Energy-Saving Smart Windows: Design and Scalable Synthesis, Jaroslav Vlcek [vlcek@kfj.zcu.cz], University of West Bohemia, Czechia **INVITED**

Vanadium dioxide (VO₂) exhibits a reversible phase transition from a low-temperature monoclinic VO₂(M1) semiconducting phase to a high-temperature tetragonal VO₂(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 with almost the same luminous transmittance at the transition into the metallic state make VO₂-based coatings a promising candidate for thermochromic smart windows reducing the energy consumption of buildings.

We report two different types of high-performance thermochromic coatings synthesized on standard soda-lime glass at a low substrate temperature of 320–350 °C: three-layer YSZ/V_{0.85}W_{0.018}Sr_{0.127}O₂/SiO₂ coatings, where YSZ is yttria-stabilized zirconia, prepared using a scalable (proved by a successful transfer to a large-scale roll-to-roll deposition device with ultrathin flexible glass substrate) sputter deposition technique, and even higher-performing coatings with four layers of subwavelength W-doped VO₂ nanoparticles dispersed in SiO₂ matrix prepared using a two-step process, combining magnetron sputter deposition and postannealing in oxygen. The coatings exhibit a transition temperature of 22–33 °C with an integral luminous transmittance $T_{\text{lum}} > 60\%$ and a modulation of the solar energy transmittance $\Delta T_{\text{sol}} > 10\%$. Such a combination of properties, together with the low substrate temperature in both cases, fulfill the requirements for large-scale implementation on building glass (glass panes, or flexible glass and polymer foils laminated to glass panes) and have not yet been reported in the literature.

We present and explain the fundamental principles of both developed low-temperature (usually used temperatures are higher than 450 °C) preparation techniques and the design of these thermochromic coatings. Moreover, we explain the effect of Sr in the W and Sr co-doped VO₂ on the electronic structure and the enhanced thermochromic properties of the three-layer YSZ/V_{0.85}W_{0.018}Sr_{0.127}O₂/SiO₂ coatings, and the effect of the discontinuous W-doped VO₂ microstructure on the very promising thermochromic properties ($\Delta T_{\text{sol}} > 15\%$) of the coatings with four layers of W-doped VO₂ nanoparticles dispersed in SiO₂ matrix.

3:40pm MB1-WeA-6 Designing Light-Active Thin Film Heterojunctions: Band Alignment and Layer Engineering for Efficient Photocatalysis, Monserrat Bizarro [monserrat@materiales.unam.mx], UNAM, Mexico **INVITED**

The design of functional thin films capable of harvesting visible light for photocatalytic processes relies critically on controlling charge transport and interfacial phenomena. While the formation of semiconductor heterojunctions in nanoparticles or powdered materials has proven to be a powerful approach to improve carrier separation and extend light absorption, the actual mechanisms that govern the performance of *thin-film* heterostructures—where photocatalysis is inherently surface-dominated—remain poorly understood.

In this work, we explore how stacking order and interfacial electric fields define the photocatalytic response in two representative systems: ZnO/Bi₂O₃ and BiOBr/BiOI thin-film heterojunctions prepared by spray pyrolysis. Each semiconductor was first deposited as an individual layer to establish its structural, optical, and electronic properties, and then combined in two configurations (A/B and B/A) to evaluate the influence of layer sequence. Detailed microstructural analyses confirmed the formation of well-defined physical junctions and excluded the presence of new ternary phases. Band positions, carrier concentrations, mobilities, and Fermi levels were determined to construct energy band diagrams that explain the observed photocatalytic trends.

Under blue or simulated sunlight irradiation, the heterostructures exhibited a pronounced dependence of activity on stacking order. Configurations in

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which the semiconductor with the wider band gap and less negative conduction band (ZnO or BiOBr) occupied the surface achieved superior photocatalytic efficiency toward dye degradation, attributed to favorable band alignment, internal electric fields that drive charge migration, and reduced recombination at the interface. Conversely, reversing the stacking sequence quenched the photocatalytic response, highlighting the delicate interplay between layer order, thickness, and interfacial charge transfer.

These findings demonstrate that thin-film heterojunctions can be rationally designed to enhance surface photocatalytic activity through precise control of band alignment and interface fields. Beyond their relevance for environmental photodegradation, such insights are broadly applicable to solar energy conversion, photoelectrochemical devices, and other light-assisted surface reactions, positioning thin-film heterostructures as a versatile platform for functional materials engineering.

Functional Thin Films and Surfaces Room Palm 3-4 - Session MB2-3-ThM

Thin Films for Emerging Electronic and Quantum Photonic Devices III

Moderators: Jiri Houska, University of West Bohemia, Czechia, Spyros Kassavetis, Aristotle University of Thessaloniki, Greece

8:00am **MB2-3-ThM-1 Piezoelectric MEMS – from Advanced Material Systems to Novel Device Architectures, Ulrich Schmid [ulrich.e366.schmid@tuwien.ac.at], Daniel Platz, Michael Schneider, TU Wien, Austria** **INVITED**

In a compact introduction, I will motivate the benefits of piezoelectric thin films for MEMS and will give a short overview to state of art device applications.

Next, I will highlight latest results on the electrical, mechanical and piezoelectrical characterization of sputter-deposited aluminium nitride (AlN) including the impact of *e.g.*, substrate pre-conditioning. I will present test structures for determining piezoelectric coefficients (d_{33} , d_{31}) down to an accuracy of about 0.1 pm/V on wafer level. The impact of AlN doping with yttrium which leads to an increase of the moderate piezoelectric coefficient of pure AlN, as known with scandium, will complete the material-related part of my talk.

Next, these films are integrated into fabrication processes of silicon MEMS devices. In combination with a tailored electrode design, cantilever-type resonators are realized featuring Q-factors up to about 350 in water (@1-2 MHz). This enables the precise determination of the viscosity and density of fluids up to dynamic viscosity values of about 300 mPas. Besides this application, such high Q-factors are most essential when targeting mass-sensitive sensors, thus paving the way to *e.g.*, nanosized particle detection even in such highly viscous media like oil. In addition, the characterization of bitumen with dynamic viscosities up to the 10.000 mPas range is demonstrated with these piezoelectric MEMS resonators.

Besides sensing, the field of MEMS actuators is covered. I will present some selected results on buckled, bistable plate-type MEMS devices that allow continuous switching between the two stable states by integrated piezoelectric thin film actuators for realizing *e.g.*, compact ultrasound emitters. Specific features of this device architecture will be discussed.

8:40am **MB2-3-ThM-3 MEMS Magnetoelectric Resonators: Pushing the Limits of Magnetic Field Detection., Davinder Kaur [davinder.kaur@ph.iitr.ac.in], Pradeep Kumar, Indian Institute of Technology Roorkee, India**

Nowadays, flexible magnetoelectric (ME) heterostructures comprising lead-free piezoelectric are of considerable interest for commercializing wearable electronic devices such as energy harvesters, nonvolatile memory, implantable medical diagnostics, and sensors. Here, we fabricate a highly flexible, cost-effective, nanostructured magnetic field sensor comprising an AlN/Ni-Mn-In ME heterostructure over Ni foils. The functionality of the AlN/Ni-Mn-In/Ni heterostructure has been investigated by measuring the magnetodielectric MD (%) and magnetoelectric coupling (α_{ME}) coefficient with Ni-Mn-In thickness, anisotropy, and flexibility. The thickness ratio of piezoelectric AlN (~400 nm) and magnetostrictive Ni-Mn-In (~385 nm) layers has been optimized to achieve the high performance of the magnetic sensor. The encapsulation of the Ni-Mn-In layer drastically enhances the performance of the fabricated heterostructure. The highest MD ~ 2.95% and α_{ME} ~ 3.2 V/cm·Oe have been recorded with an equal thickness ratio of AlN and Ni-Mn-In layers. It could be ascribed to the large magnetostrictive strain transferred to the AlN piezoelectric layer, which enhances the induced ME voltage. Moreover, the nonzero value of α_{ME} at zero bias magnetic field has been observed and related to the piezomagnetic coefficient (q) grading in the Ni-Mn-In(+q)/Ni(-q) ferromagnetic system, which enhances the strength of magnetoelectric coupling. The fabricated device has easily detected the ultralow magnetic field of up to or less than ~1 μ T. In addition, the anisotropic functionality of the device has been explained by measuring the magnetodielectric and magnetoelectric characteristics in parallel and perpendicular dc bias fields. Further the surface acoustic wave (SAW) delay line-based piezo resonator has been fabricated over highly flexible AlN/Ni-Mn-In/Kapton for flexible MEMS application. The fabricated device resonates at ~1.40 GHz. The effect of the external magnetic field on the resonance frequency (f_R) of the device has

been investigated and tunability ($\Delta f_R/f_R$) ~9% was observed. The device displays high sensitivity of ~0.94 Hz/nT at room temperature.

Keywords: Ferromagnetic shape memory alloys, flexible magnetic sensor, lead-free piezoelectric, magnetostrictive effect, surface acoustic waves (SAW).

9:00am **MB2-3-ThM-4 Synthesis and Piezoelectric Properties of Wurtzite $Al_{1-x-y}Sc_xGd_yN$ Heterostructural Alloys, Julia Martin [jmartin6@nrel.gov], National Renewable Energy Laboratory, USA; Cheng-Wei Lee, Nate S.P. Bernstein, Colorado School of Mines, USA; Thi Nguyen, Rensselaer Polytechnic Institute, USA; Ande Bryan, Eli Cooper, John S. Mangum, Colorado School of Mines, USA; Sage R. Bauers, Andriy Zakutayev, Keisuke Kazawa, National Renewable Energy Laboratory, USA; Prashun Gorai, Rensselaer Polytechnic Institute, USA; Rebecca W. Smaha, National Renewable Energy Laboratory, USA**

Wurtzite AlN-based ternary nitride alloys are a promising platform to realize functional materials, particularly ferroelectrics and optical emitters, that can smoothly integrate with conventional microelectronics. Here, we explore substitution of multiple elements into AlN forming quaternary nitride alloys as a strategy for enabling new multifunctional materials. Through a computationally-guided approach, we successfully predict the phase diagram of these pseudo-ternary heterostructural AlN-ScN-GdN alloys as a function of effective temperature and experimentally grow $Al_{1-x-y}Sc_xGd_yN$ thin films via combinatorial sputter synthesis for the first time. We find that for $x + y \lesssim 0.35$, $Al_{1-x-y}Sc_xGd_yN$ crystallizes into a wurtzite structure which is consistent with the calculated phase diagram. Further, we computationally probe whether co-substitution induces cooperative effects on these alloys' piezoelectric and ferroelectric properties, finding that it is beneficial for reducing the polarization switching barrier. We also calculate that $Al_{1-x-y}Sc_xGd_yN$ thin films should display ferroelectric switching that could be realized experimentally in the future. This is supported by our experimental measurements of a high optical band gap, enhanced piezoelectric coefficient, and a change in the calculated polarization switching mechanism. Overall, our work sets the foundation toward quaternary wurtzite-nitride-based multifunctional materials, including piezoelectrics, ferroelectrics, and possibly multiferroics.

9:20am **MB2-3-ThM-5 Sputter Coating of High-Quality VO_2 Metal-Insulator Transition Films for Flexible Electronics, Juan Andres Hofer [juhofer@ucsd.edu], University of California San Diego, USA; Ali C. Basaran, General Atomics, USA; Tianxing Damir Wang, Ivan K. Schuller, University of California San Diego, USA**

The metal-insulator transition (MIT) in vanadium dioxide (VO_2) thin films is a topic of great interest for applications in smart windows, memristors, and neuromorphic computing applications. VO_2 thin films are accompanied by substantial changes in the electronic and optical properties across the MIT, and these changes can be induced by external stimuli such as voltage, strain, or temperature. While several studies have shown that flexible and freestanding VO_2 films can be achieved, complex pre- or post-growth processing is required. In this work, we show that direct sputter deposition of VO_2 on flexible Kapton substrates results in a straightforward methodology to achieve flexible MIT films. A pre-deposited Al_2O_3 layer on Kapton enhances film adhesion, and the resulting flexible VO_2 films show up to 4 decades of change in resistance across the MIT. Temperature and substrate-induced strain during growth affect substantially the quality of the films. The resulting VO_2 flexible devices show ultra-low power consumption for resistive switching, up to two orders of magnitude lower than in samples grown on traditional substrates. We also demonstrate that the VO_2 MIT characteristics can be governed by mechanical deformation, resulting in a novel method to induce resistive switching and decrease power consumption. This study reveals a straightforward approach for direct growth of high-quality flexible VO_2 films exhibiting robust MIT, with promising applications in tactile sensors and electromechanical devices.

Funding Acknowledgment: This material is based upon work supported by the Air Force Office of Scientific Research under award number FA9550-22-1-0135.

9:40am **MB2-3-ThM-6 Glancing Angle Deposition of WO_x and Cu-doped TiO_2 Thin Films for Improved Conductometric Gas Sensing, Akash Kumar [akashkumarneutronics@gmail.com], University of West Bohemia, NTIS, India; Stanislav Haviar, University of West Bohemia, NTIS, Czechia; Nirmal Kumar, University of West Bohemia, NTIS, India**

The emerging hydrogen industry is stimulating efforts in developing new materials for various purposes, including the quest for efficient, sustainable, and low-power hydrogen detectors. Many such devices rely on metal oxide

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semiconductor materials, which are easily integrable into devices and relatively cheap but suffer from some challenges, such as low sensitivity and selectivity.

This study explores the possibility of exploiting a Glancing Angle (GLAD) sputter deposition of Cu-doped TiO_2 and WO_x films, targeting the enhancement of active surface area and, therefore, sensor sensitivity improvements.

Cu-doped TiO_2 and WO_3 films were deposited using conventional reactive DC magnetron sputtering, employing circular titanium and tungsten targets in a mixture of argon and oxygen. Cu-doping was achieved by using a composite target. Films were post-annealed prior to sensing characterization. The Glancing Angle Deposition (GLAD) technique was employed to induce a characteristic columnar nanostructure, thereby increasing the films' porosity and so leading to a desired increase in active surface area. Multiple parameters were tuned to enhance the sensing response, including the angle of deposition (80° , 85° , 88°), thickness (50–300 nm), and reactive sputtering parameters.

Synthesized films were thoroughly analyzed by SEM and XRD. Sensing response measurements revealed an interesting fact: that neither the surface roughness nor the surface area improves the response to the sensing gas monotonically. In the presented paper, we discuss the geometrical reasons as well as the synthesis parameters that influence the sensing characteristic. The comparison of the two materials, WO_3 and TiO_2 , is also given.

Functional Thin Films and Surfaces

Room Golden State Ballroom - Session MB-ThP

Functional Thin Films and Surfaces Poster Session

MB-ThP-1 Improved Energy Storage Features in Atomic Layer Deposition Tailored Nickel Oxide on Phosphorous Doped MnO₂ Core-Shell Configuration, *Sangeeta Adhikari*, Vellore Institute of Technology, India; **Do Heyoung kim** [kdhh@chonnam.ac.kr], Chonnam National University, Republic of Korea

An innovative method was employed to synthesize ultrathin NiO on phosphorus-doped MnO₂ nanosheets, utilizing a straightforward hydrothermal process to produce a Mn precursor on Ni-foam, subsequently enhanced by phosphorus doping through a basic solid-state annealing procedure and ALD technique. The effect of phosphorus doping was examined by varying the annealing temperature, resulting in a significant increase in oxygen vacancies and electrochemical performance. Furthermore, the atomic layer deposition of NiO improved electrochemical performance while ensuring cycling stability without disturbing the system. Modifying the thickness of NiO thin films on phosphorus-doped MnO₂ led to a notable enhancement in electrochemical performance, as shown by the performance of the solid-state asymmetric device. This integrated approach is expected to aid in creating novel electrode materials for high-performance supercapacitors through the application of electroactive metal oxides using ALD coating.

MB-ThP-2 Scalable Surface Engineering of PDMS for Uniform Inkjet-Printed Silver Patterns, *Hsuan-Ling Kao* [snoopy@mail.cgu.edu.tw], Chang Gung University, Taiwan; *Li-Chun Chang*, Ming Chi University of Technology, Taiwan; *Min-Hsuan Lu*, Chang Gung University, Taiwan

The advancement of flexible and wearable electronics has increased the demand for materials compatible with the human body. Polydimethylsiloxane (PDMS) stands out due to its biocompatibility, transparency, chemical stability, and skin-like mechanical properties, making it suitable for bio-integrated devices. Its elastomeric nature also allows conformal contact with curved surfaces, making it suitable for epidermal and implantable electronics. Despite these advantages, achieving reliable inkjet printing of conductive traces on PDMS remains challenging due to poor ink adhesion and inconsistent droplet behavior. This study introduces a scalable surface modification approach using dielectric barrier discharge (DBD) plasma to improve PDMS wettability for inkjet printing of silver nanoparticle films. The DBD plasma treatment was performed under ambient conditions, and the discharge parameters were tuned to ensure uniform activation across the entire surface. The optimized argon flow rate and electrode gap facilitated consistent plasma exposure, resulting in reproducible surface energy enhancement. By optimizing argon flow and electrode-substrate distance, the treated area was expanded to 5 × 5 cm². Water contact angle (WCA) measurements across nine points confirmed uniformity, averaging 50° ± 1.8°, and white-light interferometry verified the surface remained undamaged. Substrate temperature was also found to play a role comparable to WCA in determining film quality, particularly in relation to printed pattern dimensions. At 50 °C, 200 μm-wide lines printed with three layers exhibited slight wrinkling or cracking, while 300 μm-wide lines showed minor edge spreading. Four-layer prints at this temperature led to bulging. At 60 °C, three- and four-layer 200 μm-wide lines suffered from severe wrinkling and cracking, while 300 μm-wide lines showed edge drying or bulging in three layers, and slight bulging in four layers. An appropriate substrate temperature was identified as essential, enabling both 200 μm and 300 μm-wide silver lines to maintain structural integrity and electrical performance across three to four printed layers. Under these optimized conditions, 300 μm-wide, 4 cm-long silver transmission lines exhibited excellent conductivity with low insertion loss. These results demonstrate the effectiveness of the proposed surface engineering and printing strategy for enabling high-quality, large-area conductive patterns on PDMS, supporting the development of next-generation bio-integrated electronic systems.

MB-ThP-3 Hydrogen-Induced Defect Formation in Yttrium-Based Coatings for Dry Etching Processes, *Jiyeon Baek* [jy.baek@samsung.com], Jinsoo Jung, Taeyoon Park, Jinho Jo, Jaebum Sung, Yongjoon Cheong, Youngjune Park, Woohyung Kim, Seokmin Yoon, Samsung Electronics, Republic of Korea

As the critical dimensions of semiconductor devices shrink, especially for the sub-3nm node, dry etching processes increasingly employ complex

hydrogen-containing plasma mixtures to achieve precise pattern control. Hydrogen plasma exposure can induce degradation of chamber coatings and the formation of yttrium-based particle defects, resulting in significant yield loss. This study investigates the material properties and microstructural design strategies of yttrium-based coatings to enhance hydrogen resistance and process stability. Hydrogen-induced defect formation was modeled as a function of materials phase and deposition conditions, and correlations between microstructural characteristics and plasma-induced degradation were evaluated. From a materials perspective, Y₂O₃ and Y₃Al₅O₁₂ (YAG) coatings were experimentally assessed. Regarding deposition methods, commonly employed plasma-resistant coating techniques, including plasma spraying, aerosol deposition (AD), and physical vapor deposition (PVD), were systematically reviewed. Exposure to hydrogen-rich plasma revealed hydroxide formation, approximately 20nm in thickness, on Y₂O₃ grains, while no transformation to a new crystalline phase was observed on YAG grains, as confirmed by crystallographic analysis. Concurrently, microstructural evaluation demonstrated that PVD coatings minimize pores and reactive species diffusion paths, effectively mitigating plasma-induced degradation. These observations confirm that PVD YAG is a promising candidate for suppressing hydrogen-induced particle formation and enhancing the durability of etch chamber components in sub-3nm node dry etching processes. The results provide a mechanistic understanding of hydrogen plasma-coating interactions and strategies for the optimized design of plasma-resistant chamber coatings.

MB-ThP-4 Spatially Resolved Molecular Arrangement on the Surface of PEDOT:PSS Film via Laser Scanning, *Chanwoo Kim*, *Habeom Lee* [hblee@pusan.ac.kr], Pusan National University, Republic of Korea

Conjugated polymers, particularly poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS), are extensively studied for their intriguing electronic and optical properties, making them promising candidates for various functional applications. Precise and spatially resolved control over their molecular organization and morphology is one of challenging things for the tailored innovations. Here, we present a comprehensive investigation into the localized and spatially precise surface structural reorganization of PEDOT:PSS films, achieved through Laser-induced photo thermal effect without any chemical agents. Our focus is on delineating the intricate morphological and molecular changes and understanding the underlying mechanism that enables this spatial control.

Our study delineates the morphological evolution on surface of PEDOT:PSS films (~ 10 μm thickness) under varying laser doses (wavelength: 532 nm, spot size: 7 μm, continuous wave). Notably, a moderate laser dose induces significant morphological transformations, including undulating and dome-like micro-scale surface features with color change. Critically, the moving continuous laser induces a localized thermal distribution. This consistent thermal propagation, coupled with the kinetic state of the laser, induces a rearrangement within the PEDOT:PSS molecular system. The evidenced AFM phase images exhibit a distinct geometry, providing direct visual evidence of spatially controlled molecular reorganization on the surface. These observations promise a powerful approach for achieving spatially resolved control over molecular arrangement, enabling precise patterning and local property tuning.

Further characterization using XPS, UV-Vis, AFM, XRD, Raman, and FT-IR spectroscopy provides insights into the mechanisms driving these changes. This comprehensive study not only significantly elucidates fundamental understanding of laser-PEDOT:PSS interactions for functional film design but also suggests the intricate potential of this technique for creating advanced functional surfaces with tailored properties through precisely engineered molecular architectures.

MB-ThP-5 Influence of the Si Alloying on the Growth Stability and Electrical Properties of Aln Thin Films, *Norma Salvadores Farran* [norma.salvadores@tuwien.ac.at], *Tomasz Wojcik*, TU Wien, Austria; *Astrid Gies*, *Jürgen Ramm*, *Klaus Böbel*, Oerlikon Balzers, Liechtenstein; *Szilard Kolozsvári*, *Peter Polcik*, Plansee Composite Materials, Austria; *Tobias Huber*, *Jürgen Fleig*, *Helmut Riedl*, TU Wien, Austria

Aluminum nitride-based ceramics are well known for their insulating properties combined with high thermal conductivity. Their range of applications is wide, in both structural components and thin films. However, the electrical conductivity of these materials is highly temperature-dependent. As the temperature increases, the mobility of charge carriers also rises, which poses significant challenges to their insulating performance.

This study investigates the growth of insulating AlSiN thin films using physical vapor deposition (PVD) and evaluates their electrical insulation at temperatures up to 750 °C. Various reactive PVD techniques were explored, including high-power impulse magnetron sputtering (HiPIMS) and bipolar pulsed sputtering. All depositions utilized a 3-inch aluminum target with varying silicon concentrations in an Argon/Nitrogen (Ar/N₂) atmosphere. Depending on the silicon content, either hexagonal AlN films containing an amorphous Si₃N₄ phase or fully amorphous AlSiN films were produced. The target's alloying concept was designed to enhance deposition stability during sputtering. Within this framework, we also investigated the formation of a fully nitride film at lower reactive gas ratios while maintaining excellent electrical insulating properties.

Phase formation has been examined using X-ray diffraction (XRD), while the deposition rate and film morphology were characterized by scanning electron microscopy (SEM). The insulating behavior of the coatings was evaluated via in-situ impedance spectroscopy across a temperature range from 300°C to 750°C, using Ti/Pt lithography pads as electrodes.

The electrical properties are related to the morphology of the films, particularly whether the films were crystalline or amorphous. Additionally, the influence of impurities, such as O₂, plays a significant role in reducing the insulating properties of the films.

MB-ThP-6 Ag-Modified Bi₂Se₃ Nanoplatelets with Enhanced UV-Visible Photodetection, Chih-Chiang Wang [wilbur0913@gmail.com], National Yunlin University of Science and Technology, Taiwan; An-Ya Lo, National Taiwan Normal University, Taiwan

Bi₂Se₃ has emerged as a promising candidate for photodetector applications due to its narrow band gap (~0.35 eV), conductive surface states, and insulating bulk properties. In this study, Bi₂Se₃ nanoplatelets were synthesized on Al₂O₃(100) substrates via thermal evaporation, followed by Ag deposition using the magnetron sputtering technique. The rhombohedral crystal structure of Bi₂Se₃ was confirmed by XRD, HRTEM, Raman spectroscopy, and XPS analyses. The presence and distribution of Ag on the Bi₂Se₃ surface were further verified by FESEM-EDS, XPS, and HRTEM. Optical measurements revealed that the UV-visible absorbance of Bi₂Se₃ nanoplatelets decreased when the Ag content exceeded 7.1 at.%. However, photocurrent responses under zero bias were significantly enhanced by the introduction of Ag. Specifically, the Bi₂Se₃ nanoplatelets containing 7.1 at.% Ag exhibited photocurrents approximately 4.3 and 4.6 times higher than those of pristine Bi₂Se₃ under UV and visible light, respectively. This enhancement is attributed to (i) the intrinsic narrow band gap of Bi₂Se₃, (ii) the formation of a Schottky field at the Ag/Bi₂Se₃ interface, (iii) the LSPR effect of Ag, and (iv) the improved surface conductivity at the heterointerface. These findings demonstrate that optimized Ag deposition can effectively enhance the photosensitivity of Bi₂Se₃ nanoplatelets, highlighting their potential for broadband photodetector applications.

MB-ThP-7 Tailoring Nanometric Vanadium Dioxide Morphology to Tune Thermochromic Optical Properties, Asma Banshamlan [asma.banshamlan@univ-st-etienne.fr], Hai Hoang Thi Thanh, Florent Bourquard, Anne-Sophie Loir, Yannick Bleu, Yaya Lefkir, Christophe Donnet, Florence Garrelle, Lilian Bosuett, Université Jean Monnet Saint-Étienne, CNRS, Institut d'Optique Graduate School, Laboratoire Hubert Curien, UMR 5516, F-42023 Saint-Etienne, France

Vanadium dioxide (VO₂) thin films are highly attractive for optical coatings and photonic devices due to their reversible metal-insulator transition (MIT) near 68 °C, which produces a sharp change in optical properties. Controlling the MIT through thin-film processing and morphology is critical for achieving tunable infrared functionality.

Amorphous VO_x layers with thicknesses of 50 - 200 nm were deposited by pulsed laser deposition (PLD) from a V₂O₅ target onto glass substrates, followed by rapid thermal annealing (RTA) at 400 °C for 15 - 120 s in oxygen. Structural and optical responses were characterized using grazing-incidence XRD, Raman spectroscopy, SEM, and UV-Vis spectroscopy.

All films exhibited dewetting, with morphology strongly dependent on initial thickness. Thinner films formed dense, uniform nanoparticles, while thicker films developed larger, less homogeneous features. These differences directly affected the MIT-driven optical response: plasmonic resonances red-shifted with increasing feature size, enabling selective infrared modulation. In contrast to more complex nanoparticle fabrication methods, this simple approach provides precise control over mean particle size, and the plasmonic response is highly sensitive even without monodispersity or long-range ordering.

These results demonstrate that thickness-dependent dewetting can be harnessed to design VO₂ thin-film coatings with tunable, wavelength-selective optical properties.

MB-ThP-8 Different Morphologies of Gallium Oxide Thin Films Fabricated by Liquid-Target Reactive DC-Pulsed Magnetron Sputtering, Jan Koloros [koloros@ntis.zcu.cz], Petr Novák, Sayed Alireza Ataie, Jiří Rezek, Radomír Čerstvý, Pavel Baroch, University of West Bohemia in Pilsen, Czechia

Gallium oxide (Ga₂O₃) remains a focus of research due to its outstanding optoelectronic properties, including an ultra-wide bandgap of approximately 4.8 eV, a high electron saturation velocity, and its ability to withstand a high breakdown electric field of about 8 MV/cm. Although Ga₂O₃ is typically prepared using methods such as MBE, MOCVD, or ALD, it would be advantageous to find a viable method for preparing this material using magnetron sputtering as well. This is because this method is known for its high deposition and ease of up-scaling the process. Despite some published work in this area, it has not yet been possible to find conditions that lead to layers with satisfactory electrical properties.

In this work, we focus on reactive magnetron sputtering of Ga₂O₃ films using a liquid gallium metal target on different substrates and under various conditions (oxygen and argon partial pressures, substrate temperature, and pulse-averaged target power density). The resulting films exhibit a broad range of morphologies, from compact solid thin films to wire-like microstructures. We present the optical, electrical, and microstructural properties of the films and suggest their correlations with the discharge parameters as well as the substrate used. We found that the crystalline quality of Ga₂O₃ films and their preferential orientation play a crucial role in achieving improved electrical properties. The optimal crystal structure can be obtained primarily by selecting an appropriate temperature and substrate that promotes the crystalline growth of the film.

MB-ThP-9 Electrochromic Rearview Mirror Utilizing Poly(3,4-Propylenedioxythiophene) Derivative for Advanced Automotive Applications, Sindhu Sukumaran Nair [sindhunair@pilani.bits-pilani.ac.in], Birla Institute of Technology and Science, Pilani, India

We report the fabrication of single-type electrochromic windows (ECWs) and rearview mirrors (ECMs) using a novel di-4-isopropylbenzyl-substituted propylenedioxythiophene film as the electrochromic active layer. The spectroelectrochemical properties and electrochromic performance of these devices were systematically characterized. The electrochromic devices (ECDs) exhibited a color change between violet in the reduced state and transparent in the oxidized state at redox potentials. Key performance metrics of the ECDs include fast switching times, high coloration efficiency, low switching voltages (±2.0 V), excellent switching stability, and outstanding optical memory retention.

MB-ThP-10 3-Layer Polymer Film Composites Based on PE Recyclates, Marcin Bilewicz [marcin.bilewicz@polsl.pl], Tomasz Tanski, SILESIA UNIVERSITY OF TECHNOLOGY, Poland; Tomasz Glinski, Sinoma, Poland

Keywords: n-layer films; blow molding; polymer composites; recycling; hot-tack

Multilayered films are used recently for many applications like packaging, materials with special barrier properties or with resistance for specific liquids or radiation, e.g. UV. The investigation aimed to obtain the composite in form of 3-layer polymer film and next to perform the analysis of the structure and properties of newly developed composite produced using 20 meter high blow moulding technology supported by a precision gravimetric dispensing system. To keep better control, the process was supported by advanced, rotating basket and precise sensors. The film samples were prepared, including a reference film labelled as PE pure and made from standard material, and films with a modified middle layer B, containing regrunulate and calcium carbonate in specified proportions. The mechanical strength tests of the sealed films were conducted to verify strength of films in aim to be used for FFS (Form-Fill-Seal) packaging lines and are very promising comparing to single layer films. 3-layer packaging films based on PE recyclates and calcium carbonate in the middle layer, retain their required mechanical properties.

MB-ThP-11 Plasma-Polymer Fluorocarbon Based High Sensitivity Surface Enhanced Raman Spectroscopy Application, Sang-Jin Lee [leesj@cbnu.ac.kr], Chungbuk National University, Republic of Korea

Surface-enhanced Raman spectroscopy (SERS) provides a powerful analytical tool for molecular identification through the amplification of Raman scattering signals from target analytes on plasmonic nanostructures. In this study, we present a plasma-polymer-fluorocarbon (PPFC)-based nanocomposite thin-film platform designed to achieve high SERS sensitivity

via controlled nanoparticle formation. By tuning the sputtering power density during mid-frequency magnetron sputtering, the distribution and ratio of Ag and Cu nanoparticles embedded in the PPFC matrix were precisely modulated, as confirmed by X-ray photoelectron spectroscopy (XPS) and ultraviolet–visible–near infrared (UV–Vis–NIR) spectroscopy. The optimized Ag–Cu PPFC (CAP) thin films exhibited distinct localized surface plasmon resonance (LSPR) absorption peaks and demonstrated an enhancement factor (EF) of up to 10^8 for rhodamine 6G, supported by finite-difference time-domain (FDTD) simulations showing strong electromagnetic localization at the metal–metal nanogaps. Furthermore, a simplified fabrication approach employing a single composite target of Cu, carbon nanotube (CNT), and PTFE powders (5:60–80:35–15 wt.%) was developed to produce Cu–PPFC nanocomposite films with moderate SERS sensitivity ($EF \approx 2.18 \times 10^4$). The prepared CAP and Cu–PPFC nanocomposite films successfully detected rhodamine 6G on flexible polyethylene terephthalate substrates, maintaining distinguishable Raman signals even with reduced optical transmittance. These results demonstrate that plasma–polymer fluorocarbon nanocomposites incorporating Cu and Ag nanoparticles offer a scalable, flexible, and cost-effective route toward high-performance SERS-active substrates suitable for on-site and point-of-care molecular detection applications.

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