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 $H_3PMo_{12}O_{40}$. 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 (Tc) 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/NbOx 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 (Tc) 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 inPerpendicularly Magnetized Ta/Cu/Pt/Co/Pt System**, *Saikat Maji, Soubhik Kayal, 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 isrealized 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) ofthe HM. However, the magnetization reversal in these systems requires an in-plane bias magnetic field (H_x) inaddition to the in-plane charge current (J_x). Field-free switching in PMA systems at a lower current densityis crucial for storage device applications. To investigate the magnetisation reversal, Ta(3 nm)/Cu(t nm)/Pt(3nm)/Co(0.4 nm)/Pt(1 nm) multilayers with PMA were prepared for t = 0, 1, 2 and 4. The Cu layer has beenintroduced 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

reduced upto 16%, 35% and 55% compared to the Ta/Pt/Co/Pt systemin 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 (= -1.20×10^{11} A/m^2) 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 fromz polarized spin current in addition to the conventional SOT resulting from −y polarized spin current producedby 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 $D^*_{shot} \approx 5.0 \times 10^{13}$ 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 $D^*_{shot} = 4.2 \times 10^{13}$ 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.

Author Index

Bold page numbers indicate presenter