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

Thin Films for Electronic Devices II

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

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

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

KEYWORDS

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

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

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

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

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

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

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

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

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

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

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

3:40pm **MB2-2-WeA-6 Growth of Nanostructured Molybdenum Disulfide (Mos_2) Thin Film for the Application of Electronic Materials***, I. Giwa, K. Qian, F. Sanchez, E. Mawire, S. Dong, E. Smith, Q. Yuan, **Zhigang Xiao (zhigang.xiao@aamu.edu)**,* Alabama A&M University, USA

We report the fabrication of molybdenum disulfide (MoS_2) thin films–based electronic devices. Nanostructured molybdenum disulfide (MoS_2) thin films are grown as the active semiconducting channel material for the fabrication of MoS_2-based field-effect transistors using plasma-enhanced atomic layer deposition (ALD). MoS_2–based electronic devices such as MoS_2 field-effect transistors, inverters, and ring-oscillators are fabricated with the ALD-grown MoS_2 film using the clean room-based micro- and nano-fabrication techniques. Hydrogen sulfide (H_2S) gas is used as the S source in the growth of molybdenum disulfide (MoS_2) while molybdenum (V) chloride ($MoCl_5$) powder is used as the Mo source. The MoS_2 film will be analyzed by the high-resolution tunnel electron micrograph (HRTEM), scanning electron micrograph (SEM), X-ray photoelectron spectroscopy (XPS) analysis and Raman spectrum analysis. The fabricated MoS_2 device wafer will be annealed at high-temperatures (800 – 900 ^oC), and the electrical property of the MoS_2–based electronic devices will be measured before and after the high-temperature annealing and will be compared. The characterization results of the nanostructured molybdenum disulfide (MoS_2) thin films and the measurement results on the fabricated MoS_2–based electronic devices will be reported in the ICMCTF 2024 Conference.

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4:00pm **MB2-2-WeA-7 $BaTiO_3$ Epitaxial Thin Films Integrated on Si by Pulsed Laser Deposition for Electro-Optic Modulators**, ***Heungsoo Kim (heungsoo.kim.civ@us.navy.mil)***, *S. Mathews,* Naval Research Laboratory, USA; *A. Posadas, A. Demkov,* The University of Texas at Austin, USA; *A. Piqué,* Naval Research Laboratory, USA

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

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