Functional Thin Films and Surfaces
Room Palm 1-2 - Session MB1-WeA

Thin Films and Surfaces for Optical Applications

Moderators: Rajiv Pethe, Vital Chemicals, Juan Antonio Zapien, City University of Hong Kong

2:00pm **MB1-WeA-1 Experimental and Theoretical Insights into UV-Active Chirality in Glancing Angle Deposited Zirconia Nano-Helical Metamaterial Platforms**, ***Ufuk Kilic***, *Matthew Hilfiker,* University of Nebraska-Lincoln, USA*; Shawn Wimer, Raymond Smith,* University of Nebraska - Lincoln, USA*; Christos Argyropoulos,* Pennsylvania State University, USA*; Eva Schubert, Mathias Schubert,* University of Nebraska - Lincoln, USA **INVITED**

Chirality, the property of handedness in molecules or objects that prevents them from being superimposed on their mirror images, is optically manifested as circular dichroism (CD)—the differential absorption of left- and right-handed circularly polarized light. However, chirality found in nature is inherently weak, challenging to spectrally control, and primarily active in the ultraviolet (UV) region of the spectrum [1-3]. Enhancing UV-active chirality, crafting UV-active photonic wave-guide systems and also detecting chiral molecules through metamaterial platforms remains a challenge, as most designs are optimized for the infrared (IR) to visible spectral ranges [3].

In this study, we fabricated ultra-wide bandgap (~5 eV) zirconia (ZrO_2) thin films using the glancing angle deposition (GLAD) method with electron beam evaporation. When the particle flux was directed at normal incidence (0°), uniform coating of flat ZrO_2 thin films were successfully fabricated. In contrast, directing the flux at an oblique angle (85.5°) with continuous substrate rotation (24 seconds per revolution) yielded spatially coherent, super-lattice nano-helices. Generalized spectroscopic ellipsometry (GSE) technique was used to extract frequency-dependent complex dielectric functions and identify band-to-band transitions spanning the near-IR to vacuum-UV (VUV) spectrum. Strong VUV-active CD responses were experimentally observed in ZrO_2 nano-helical metamaterials using Mueller matrix GSE. Additionally, visualization of both near- and far-field characteristics induced by circularly polarized illumination, along with the theoretical validation of the VUV-active chiroptical response, were investigated using finite element modeling (FEM) based full wave simulations. The systematic FEM calculations also revealed that the chiral properties could be tuned by (i) adjusting the structural parameters of the nano-helices and (ii) incorporating plasmonic subsegments into the helical structure.

Our research outputs suggest that the proposed metamaterial design holds significant potential for applications such as high-power chiro-optic photonic and electronic circuits, quantum information systems, UV-active topological insulators, and chiral sensing technologies.

[1] Kilic, U., *et al.*, *Nat. Commun.* 15, 3757 (2024).

[2] Kilic, U. *et al.*, Adv. Funct. Mater. 31.20: 2010329,(2021).

[3] Sarkar, S. *et al.,* Nano letters 19.11: 8089-8096,(2019).

2:40pm **MB1-WeA-3 Optical and Electrical Properties of Thermochromic W-Doped VO_2 Films Prepared at a Reduced Temperature (350 °C) on Glass Substrates with YSZ Interlayers**, ***Sadoon Farrukh***, *Jaroslav Vlček, Jiří Rezek, Radomír Čerstvý, Jiří Houška, Tomáš Kozák,* University of West Bohemia - NTIS, Czechia

Vanadium dioxide (VO_2) is an extremely interesting and increasingly investigated coating material due to its reversible first-order transition between a low-temperature monoclinic VO_2(M1) semiconducting phase and a high-temperature tetragonal VO_2(R) metallic phase relatively near room temperature (approximately 68 °C for the bulk material). High modulation of the infrared transmittance, and electrical and thermal conductivity makes VO_2-based films a suitable candidate for numerous applications, such as electronic and optical switches, thermal sensors, smart thermal radiator devices for spacecraft, adaptive thermal camouflage, and energy-saving smart windows with automatically varied solar energy transmittance.

The application potential of these films depends on the ability to achieve not only the VO_2 stoichiometry but also the crystallization of the VO_2(M1/R) phase under as industry-friendly process conditions as possible, i.e., at a deposition temperature close to 300 °C (usually used temperatures are higher than 450 °C) and without any substrate bias voltage in case of usually used magnetron sputter techniques. Moreover, the transition temperature needs to be reduced down to 25 °C for many applications (e.g., smart windows). Besides the optical transmittance in the visible range, the characteristics of the semiconductor-metal transition, such as phase-transition amplitude, hysteresis width, and phase-transition sharpness, are of key importance.

The paper deals with crystal structure, optical and electrical properties, and semiconductor-metal transition characteristics of strongly thermochromic W-doped VO_2 films with a reduced transition temperature (24-33 °C). They were deposited at a reduced temperature(350 °C) onto glass substrates with two versions of Y-stabilized ZrO_2 (YSZ) interlayers (serving also as a highly optically transparent bottom antireflection layer) possessing different crystal orientations, and onto bare glass and monocrystalline YSZ andAl_2O_3 substrates for comparison.The W-doped VO_2 films were deposited using a controlled reactive deep oscillation magnetron sputtering (DOMS) of a single V-W (3.0 wt.%) target. The DOMS is a modified version of HiPIMS with packages (macropulses) of short high-power micropulses.

3:00pm **MB1-WeA-4 Enhancing Optical Properties and Photocatalytic Performance withNanopatterned Anodized Aluminum Oxide on transparent substrate**, ***Fu-Gi Zhong***, *Shih-Hsun Chen,* National Yang Ming Chiao Tung University (NYCU), Taiwan

In recent years, the rapid advancement of nanotechnology has driven an increasing demand for high-performance nanostructured materials. Among various fabrication techniques, anodic aluminum oxide (AAO) films have attracted significant attention due to their excellent chemical and thermal

stability, transparency, and tunable nanoporous structure. AAO features highly ordered nanopore arrays, making it an ideal template for functional thin films, especially in applications requiring high surface area and aspect ratios. By integrating functional ceramic or semiconductor coatings, materials

deposited on AAO can self-assemble into nanostructures, further enhancing their optical and chemical reactivity and making them highly suitable for applications in sensors, photocatalysis, and other fields requiring heightened sensitivity and resolution.

This study focuses on the fabrication of AAO structures on transparent substrates, followed using Atomic Layer Deposition (ALD) to coat these structures with ZnO thin films, aiming to produce transparent, nanostructured porous films on both sides of the substrate. By integrating ZnO coatings

with AAO structures, we plan to investigate light transmission and surface interaction properties, thereby enhancing optical performance and photocatalytic efficiency and making the films more suitable for high-sensitivity, multifunctional sensor and photocatalytic applications.

3:20pm **MB1-WeA-5 A Comparative Study: The Structural and Optoelectronic Properties of Al- and Ga-Doped ZnO Films Deposited by Atmospheric Pressure Plasma Jet**, ***Chih-Yun Chou***, National Taiwan University, Taiwan

Aluminum-doped zinc oxide (AZO) and gallium-doped zinc oxide (GZO) are leading transparent conductive oxides (TCOs) for optoelectronic applications, valued for high transparency and conductivity. GZO provides superior carrier mobility and lower resistivity, while AZO is more cost-effective and less toxic.This study compares AZO and GZO films prepared via atmospheric pressure plasma jet (APPJ) deposition, allowing for precise parameter control to evaluate Al and Ga's effects on ZnO film properties and their suitability in advanced optoelectronics.

Structural analysis using X-ray diffraction (XRD) and scanning electron microscopy (SEM) reveals both AZO and GZO films exhibit a hexagonal wurtzite structure with a *c*-axis orientation. The broader full-width at half maximum (FWHM) at (002) peak and higher strain in GZO films suggest more pronounced lattice distortion, likely due to Ga's higher doping efficiency. Further, reducing the working distance, thereby increasing processing temperature, effectively eliminates surface particles in GZO films but not in AZO films. This temperature-driven improvement enhances the mobility of Ga atoms on the substrate surface, leading to a more cohesive and uniform film morphology in GZO.

Optoelectronic properties assessed via UV-Vis spectroscopy and Hall effect measurements indicate that GZO films maintain high visible-range transparency (>80%) compared to AZO films (>70%). In the near-infrared range, GZO transparency decreases significantly (<40% at 1400 nm) due to its higher carrier concentration. Overall, AZO films show lower electronic performance, likely due to complex defect formation and increased impurity scattering, evidenced by higher Urbach energy (E_U) values (0.28-0.29 eV for AZO films and 0.26 eV for GZO). Decreased APPJ working

distance enhances carrier mobility, improving the figure of merit at 550 nm for GZO from 11 × 10^{-3} Ω^{-1} to 26.4 × 10^{-3} Ω^{-1} and for AZO films from 0.4 × 10^{-3} Ω^{-1} to 0.8 × 10^{-3} Ω^{-1}.

In conclusion, while AZO and GZO films both possess favorable characteristics for TCOs, their electronic behaviors diverge markedly under APPJ processing. Al doping tends to introduce complex defects that limit carrier mobility and concentration, making AZO less suitable where high conductivity is essential. In contrast, GZO films achieve higher carrier concentration and mobility, making them more appropriate for applications where efficient charge transport is critical. The findings also emphasize the significance of the APPJ working distance parameter and underscore the importance of selecting appropriate dopants and understanding defect dynamics to optimize ZnO-based TCO performance.

3:40pm **MB1-WeA-6 Unveiling the Interplay of Structural, Optical, and Hydrophobic Properties of Sputtered Grown PTFE@AlSiN Thin Films**, *Raman Devi, Somdatta Singh,* ***Ramesh Chandra,*** IIT Roorkee, India

Radio frequency (RF) magnetron sputtering technique was used to develop PTFE@AlSiN thin films on glass substrates at temperatures ranging from 250ºC to 450ºC. Methods like X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), UV-Vis Spectroscopy, water contact angle (CA) measurements, and nanoindentation were used to examine the structural, morphological, optical, hydrophobic, and mechanical properties of PTFE@AlSiN at various substrate temperatures (250ºC-450ºC). XRD studies showed that the coating deposited with an Ar:N_2 ratio of 20:6 at various substrate temperatures formed a hexagonal phase, demonstrating its polycrystalline nature. A nanocomposite with microstructure has been formed by embedding AlN nanocrystallites in a soft amorphous matrix of Si_3N_4 provides better mechanical properties. The contact angle measurement method displayed an excellent contact angle of around ~118º (good hydrophobicity). According to optical transparency measurements, all coatings exhibited > 90% transparency in the visible spectrum. The PTFE@AlSiN coated at 450ºC had the highest hardness value greater than 25 GPa.

Keywords: optical transparency, magnetron sputtering, thin film, hydrophobicity; nanoindentation, hardness

4:00pm **MB1-WeA-7 High-Entropy Oxide Thin Film as Absorber Layer for Near Infrared Photodetectors**, ***Shao-Chun Chao****, Tai-An Chen, Jyh-Ming Ting,*** National Cheng Kung University (NCKU), Taiwan

A novel light-absorbing material of high-entropy oxide (HEO) was synthesized using the sol-gel method. The sol-gel method offers advantages such as low cost, high uniformity, flexible material preparation, and suitability for large-scale production. In this study, a streamlined process was used to produce uniform, controllable nanostructured thin films. By leveraging the properties of HEO, the film properties were adjusted, making it an excellent absorber layer in photodetectors. The HEO material demonstrated an unparalleled ability to absorb a broad spectrum of light, ranging from 300 to 1400 nm. We measured the performance of a photodetector with an Ag/HEO/n-Si structure. Under near-infrared illumination, this photodetector exhibited an impressive high photoresponse, generating a high photocurrent density of approximately 10 mA/cm^2 at an incident light wavelength of 1050 nm, with a peak responsivity of 1.545 A/W, and an external quantum efficiency (EQE) exceeding 182%, surpassing most oxide-based photodetectors reported in the literature. The outstanding performance of this device is attributed to the high concentration of oxygen vacancies in the HEO compound, resulting in significant light absorption and high EQE. Furthermore, this study is the first to use the sol-gel method to prepare HEO thin-film absorber layers, demonstrating the material's excellent potential in the field of photodetectors.

4:20pm **MB1-WeA-8 Effective Ways to Enhance the Performance of N-MoS_2/P-Cuo Heterojunction Based Self-Powered Photodetectors**, ***Davinder Kaur,*** Indian Institute of Technology Roorkee, India

The present study investigated two effective routes to improve the response time and the detection range for the n-MoS_2/p-CuO heterostructure (a conventional p-n heterojunction). In the first rectification, an insulating aluminium nitride (AlN) layer was inserted in between the molybdenum disulfide (MoS_2)and cupric Oxide (CuO) layer, which eventually converted the conventional p-n heterojunction to Semiconductor-Insulator-Semiconductor (SIS) with a superior carrier tunneling mechanism. Interestingly, the fabricated heterostructure exhibits self-powered and broad-range photoresponse. The response time (rise time and fall time) of the fabricated n-MoS_2/p-CuO heterojunction decreases from 93.35 ms and 102.68 ms to 11.31 ms and 12.73 ms with the insertion of ultrathin insulating AlN Layer. The higher responsivity and ultrafast photoresponse in n-MoS_2/AlN/p-CuO (SIS) heterojunction can be ascribed to the carrier tunneling mechanism through the ultrathin-insulating AlN layer. Moreover, the detection range can be enhanced up to the UV region by adding a layer of MoS_2 quantum dots (QDs) on the surface of the MoS_2 layer in the fabricated heterostructure. The fabricated n-MoS_2 QDs/n-MoS_2-/AlN/p-CuO heterostructure shows photoresponse in a broad range from UV to NIR radiations. The obtained results demonstrate the n-MoS_2-/AlN/p-CuO (SIS) heterostructure with the addition of MoS_2 QDs shows excellent potential for next-generation ultrafast optoelectronics applications.

4:40pm **MB1-WeA-9 Influence of SHI irradiation on the Photoluminescence and Dielectric properties of bilayer structured Au/GeO2 thin films for Optoelectronics applications**, ***Mahendra Singh Rathore****, Anand Y. Joshi,*** Parul University, India*; Srinivasa Rao N.,* MNIT Jaipur, India

Abstract

In the present work, the effects of swift heavy ion beam irradiation on the engineering the physical, optical, photoluminescence and dielectric properties of bilayer structured Au/GeO_2 thin films have been investigated. GeO_2 and Au thin films have been grown onto silicon substrate using electron beam evaporation. Eventually the prepared Au/GeO_2/Si thin films were irradiated with 100 MeV Ag ions at different ion fluences ranging from 1×10^{12} to 1×10^{13} ions/cm^2. The pristine and irradiated samples were characterized using XRD, RBS, SEM, AFM, UV-Vis reflectance and photoluminescence Spectroscopy. The dielectric properties, AC conductivity, dielectric and tangent loss were analyzed of the pristine and irradiated samples. The results reveal that the nucleation of Au NCs was observed with increase in fluence. The elemental composition and film thickness observed using RBS measurements. The surface morphology and topography results reveal that the nucleation of particles with increase in ion fluences. Broad PL band observed in visible region which corresponding to the green light emission due to the presence of Au NCs. The CIE curve plotted from the PL data. The oxygen vacancy related defect states as well as surface Plasmon resonance (SPR) induced absorption and subsequent electron injection from Au NPs to conduction band of GeO_2. The dielectric properties varied with irradiation. The variation in electronic transition of wide band gap GeO_2 NC's by nucleation of gold NP's are considered to practical application in optoelectronics devices such as wavelength detection and optical switching devices and have been discussed in details.

Keywords: Au/GeO_2 thin films, ion beam irradiation, XRD, RBS, Photoluminescence, Dielectric properties.

Author Index

Bold page numbers indicate presenter

— A —
Argyropoulos, Christos: MB1-WeA-1, 1
— C —
Čerstvý, Radomír: MB1-WeA-3, 1
Chandra, Ramesh: MB1-WeA-6, **2**
Chao, Shao-Chun: MB1-WeA-7, **2**
Chen, Shih-Hsun: MB1-WeA-4, 1
Chen, Tai-An: MB1-WeA-7, 2
Chou, Chih-Yun: MB1-WeA-5, **1**
— D —
Devi, Raman: MB1-WeA-6, 2
— F —
Farrukh, Sadoon: MB1-WeA-3, **1**
— H —
Hilfiker, Matthew: MB1-WeA-1, 1
Houška, Jiří: MB1-WeA-3, 1
— J —
Joshi, Anand Y.: MB1-WeA-9, 2
— K —
Kaur, Davinder: MB1-WeA-8, **2**
Kilic, Ufuk: MB1-WeA-1, **1**
Kozák, Tomáš: MB1-WeA-3, 1
— N —
N., Srinivasa Rao: MB1-WeA-9, 2
— R —
Rathore, Mahendra Singh: MB1-WeA-9, **2**
Rezek, Jiří: MB1-WeA-3, 1
— S —
Schubert, Eva: MB1-WeA-1, 1
Schubert, Mathias: MB1-WeA-1, 1
Singh, Somdatta: MB1-WeA-6, 2
Smith, Raymond: MB1-WeA-1, 1
— T —
Ting, Jyh-Ming: MB1-WeA-7, 2
— V —
Vlček, Jaroslav: MB1-WeA-3, 1
— W —
Wimer, Shawn: MB1-WeA-1, 1
— Z —
Zhong, Fu-Gi: MB1-WeA-4, **1**