Electronic Materials and Photonics
Room 207 A W - Session EM3+TF-WeA

Materials and Devices for Advanced Photonics and Plasmonics

Moderator: Erin Cleveland, Laboratory of Physical Sciences

4:15pm **EM3+TF-WeA-9 Writable and Spectrally Tunable Cadmium Oxide Plasmonics via Gallium-Ion Implantation**, ***Maxwell Tolchin*** [1], The Pennsylvania State University; *Bhaveshkumar Kamaliya,* McMaster University, Canada; *Angela Cleri,* The Pennsylvania State University; *Youngji Kim,* Vanderbilt University; *Morvarid Ghorbani,* McMaster University, Canada; *Anton Ievlev,* Center for Nanophase Materials Sciences, Oak Ridge National Laboratory; *Nabil Bassim,* McMaster University, Canadian Centre for Electron Microscopy, Canada; *Joshua D. Caldwell,* Vanderbilt University, Sensorium Technological Laboratories; *Jon-Paul Maria,* The Pennsylvania State University

Ion beam engineering is a promising field to advance plasmonic and nanophotonic technologies. At high (1s to 10s MeV) and low (10s to 100s keV) ion beam energies, semiconductor chemistries can be modified and constructed into spatially and spectrally coherent devices. A direct beneficiary to ion beam engineering is cadmium oxide (CdO) thin film plasmonics. High-throughput CdO thin films grown by high-power impulse magnetron sputtering (HiPIMS) have an intrinsic affinity for oxygen vacancy formation. Thereby, achieving carrier concentrations of 1.6 to 3.5 x 10^{19} cm^{-3} while maintaining mobilities of 235 to 290 $cm^2V^{-1}s^{-1}$. By the carrier concentration to plasma frequency relation using Drude formalism, spectral ranges can span the mid-wave infrared (MWIR) spectrum. This is evident by reactively co-sputtering HiPIMS CdO with extrinsic dopants (i.e., Y, In, F) to extend carrier concentrations and mobilities to 5 x 10^{20} cm^{-3} and 470 $cm^2V^{-1}s^{-1}$, respectively. These capabilities realize CdO as a highly programmable, low-loss material system with a chemical bandwidth to sustain high crystallinity and structural resilience. Herein, and enabled by the chemical flexibility of CdO and need for localized and wavelength-tunable plasmonics, 30 keV gallium-ion (Ga^+) implantation is employed. Using a focused ion beam scanning electron microscope (FIB-SEM), thermally activated Ga^+ implants facilitate shallow, donor-doped CdO at ion doses ranging from 1 x 10^{14} to 1 x 10^{16} ions/cm^2. Beam tilting techniques and iterative thermal activation conditions achieve site-specific and spectrally defined architectures. Microscopy and spectrometry support high-homogeneity Ga^+ distribution and characteristic morphology in CdO. Near- and far-field spectroscopy show observable changes to phonon and plasmon resonances affiliated with Ga-doping behavior. An innovative beam-stitching process affords larger pattern designs to demonstrate Hall Effect transport properties of 1.3 x 10^{20} cm^{-3} and 372 $cm^2V^{-1}s^{-1}$. In summary, spectral tunability by Ga^+ implantation is on-par with optoelectronic properties seen in extrinsically doped-CdO thin films with an added dimensionality of spatially-controlled dopant writability. And, this work acknowledges the reliability of ion implantation doping for next generation plasmonics and nanophotonics by ion beam engineering.

4:30pm **EM3+TF-WeA-10 Potential-Modulated Sers Profiling via Glad-Fabricated Ag Nanorod Arrays for Ultrasensitive andLabel-Free Spectroelectrochemical Sensing**, ***Lakshay Bhardwaj***, *JP Singh,* Indian Institute of Technology Delhi, India

Routine analysis of food adulterants and pharmaceutical additives at the point of care is crucial for food safety and environmental protection. Surface-enhanced Raman spectroscopy (SERS)-based sensing has gained significant importance in various scientific and technological domains, including analytical chemistry, biomedical diagnostics, forensic science, drug discovery, environmental monitoring, and food safety. Electrochemical SERS (EC-SERS) enhances the technique by regulating surface charge, adsorption, desorption dynamics, and redox processes, improving signal intensity and selectivity. Despite having advantages, developing EC-SERS sensors for field applications remains constrained by the limited availability of robust and reproducible SERS-active electrochemical substrates. This study introduces a cutting-edge portable EC-SERS platform, leveraging silver (Ag) nanorods engineered onto screen-printed electrodes *via* a thermal evaporation-based glancing angle deposition (GLAD) technique. This innovative approach ensures exceptional signal enhancement, outstanding sensitivity, and remarkable reproducibility, making it a powerful tool for high-precision molecular detection. Potential-modulated SERS profiling of *p*-aminothiophenol, 1,2-bis-(4-pyridyl)ethylene, and melamine was carried out at various electrochemical potentials. Additionally, the maximum signal enhancement was achieved at an optimized potential (*V*max), enabling the detection of melamine with a remarkable limit of 10 pM, surpassing previously reported substrates. The results highlight the promise of GLAD-fabricated AgNRs@SPE as a sensitive, label-free, reusable, and portable EC-SERS platform. This platform will present significant improvements in detecting analytes relevant to analytical chemistry, the pharmaceutical industry, and drug control.

4:45pm **EM3+TF-WeA-11 Nano-Plasmonics for Hybrid, Far IR Photodetection: Simulation and Fabrication**, ***Basil Vanderbie***, *Samuel Fedorka, Charles Dickerson, John McElearney,* Tufts University; *Corey Shemelya,* Government; *Thomas Vandervelde,* Tufts University

Far infrared avalanche photodetectors are typically cryogenically cooled to negate thermally excited carriers from being generated in the absorption region which limits potential applications.To remove the need for cryogenic equipment a possible option is the removal of the absorption region and replacement with plasmonic nano-antennas and direct carrier injection. In this work we explore novel methods, materials, and geometries to promote direct injection and anisotropic progression of carriers into the avalanche region of a III-V PIN diode.Our proposed designs were verified by simulation with CST Microwave Studio for electromagnetics and COMSOL Multiphysics for carrier dynamics. Additionally, we have developed a unique fabrication plan for both the multi-axis junction and plasmonic resonator, as well as structures resonant in the RF regime for the purposes of a feasibility study.

5:00pm **EM3+TF-WeA-12 ML-Based Optimization of a Subwavelength Grating Polarization Filter Using Simulated and Experimental Data**, ***Patrick Flanigan***, *Manuj Mishra,* North Carolina Central University

A polarization filter is a photonic integrated circuit component that can block one type of polarization (TE or TM) while allowing the other to pass; one such example of this is a periodic (Bragg) grating with subwavelength elements. The purpose of this project is to find the conditions of the grating that will optimize the relevant figure of merit, the extinction ratio (ER), which is defined as the ratio of the passed mode transmission to the blocked mode transmission. This can be done through Monte Carlo simulations or non-linear optimization algorithms -- the method here is to sweep the available parameter space in two variables and construct a Machine Learning (ML) model to predict where the ER maximum lies within the existing data points. Both simulated and experimental data will be considered to develop the most accurate picture of the underlying physics. The simulations are based on the Finite Difference Time Domain (FDTD) method and were obtained by running the nearly-identical simulations in parallel to save time. The experimental data was obtained via the SiEPIC multi-project wafer project. In both cases, the data needs to be collected for both broadband TE and TM incident light. For the ML optimization, the initial choice of algorithm will be the random forest method, due to its successful track record and suitability to the specifics of this problem.

Figure 1 shows a schematic of the system, with the key variable parameters being the grating's period (a) and tooth thickness (d); the simulations were fully three-dimensions. Figure 2 shows the simulated data that will be used for training the ML model; the experimental counterpart will be smaller in scope due to the limitations of working on a communal wafer.

[1] **JVST Highlighted Talk**

Author Index

Bold page numbers indicate presenter