Electronic Materials and Photonics
Room 318 - Session EM-TuM

Advanced Devices and Materials for Photonic, Sensing, and Quantum Applications

Moderators: Dr. Erica Douglas, Sandia National Laboratories, **Dr. Seth King**, University of Wisconsin - La Crosse, **Prof. Leland Nordin**, University of Central Florida, **Somil Rathi**, Arizona State University

11:00am **EM-TuM-13 Low-Loss Single Mode AlN-Based CMOS-Compatible Platform for Quantum Photonic Integrated Circuits***, **Bogdan Dryzhakov,** John Serafini, Bernadeta Srijanto, Steven Randolph, Kyle Kelley,* Oak Ridge Natinal Laboratory

Quantum photonic technologies require scalable integrated platforms that combine low-loss routing from the UV to IR, controlled modal confinement, nonlinear optical functionality, and fabrication compatibility. Single-mode photonic circuit operation is critical for quantum applications, requiring waveguide geometries that suppress parasitic higher-order modes; however, the reduced dimensions and tighter tolerances needed for modal confinement amplify sensitivity to sidewall roughness, etch damage, dimensional nonuniformity, and scattering loss. Aluminum nitride (AlN) offers a promising CMOS-compatible material platform, combining wide-bandgap transparency, environmental robustness, ferroelectric functionality, and intrinsic χ(2) nonlinearity. We present an end-to-end AlN quantum photonic integrated circuit platform, targeting $\chi^{(2)}$ nonlinear processes for on-chip quantum light generation. Building a suitable fabrication stack required studies spanning lithography across organic, metal, and dielectric masking strategies, reactive ion etching optimization, and modeled design principles. The demonstrated nonlinear photonic platform achieves single-mode operation at 1550 nm with propagation losses as low as ~1 dB cm^{-1} and Q-factors exceeding 10^5. These results establish ferroelectric AlN as a viable platform for scalable quantum interconnects and integrated quantum technologies.

11:15am **EM-TuM-14 Elvamide Nylon as a Versatile and Tunable Alignment Layer in Liquid Crystal Devices***, **Joshua Levy,*** National Academies of Sciences, Engineering, and Medicine*; Zoey Davidson, Jakub Kolacz, Christopher Green, Christopher Spillmann,* US Naval Research Laboratory

Liquid crystal (LC) alignment layers are essential for uniform molecular orientation in LC devices, governing anchoring strength, pretilt angle, and optical performance. Polyimide (PI), the most widely used alignment layer material, requires aggressive solvents (NMP) and curing temperatures >200°C, precluding integration with thermochemically sensitive photonic substrates. Furthermore, PI exhibits significant absorption in the blue-UV spectral ranges, limiting its utility in broadband LC-tunable photonic devices like phase shifters, tunable filters, ring resonators, and variable optical attenuators. Nylon Elvamide 8023R is a methanol soluble, room-temperature-processable alternative that has been used in LC devices for decades, yet no systematic characterization relating processing parameters to alignment layer performance has been reported. This work presents the first thickness-correlated characterization of spin-coated Elvamide 8023R on ITO glass using liquid crystal E7. Elvamide films were spin coated across a range of concentrations (Figure 1(a)), and atomic force microscopy confirmed uniform, continuous film formation at both the microscale (Figure 1(b)) and nanoscale, where individual nylon fibrils are resolved prior to rubbing (Figure 1(c)). Following unidirectional rubbing (Figure 2(a)), orientation mapping and histograms reveal a dramatic shift from randomly oriented fibrils (Figure 2(b)) to strongly aligned fibrils (Figure 2(c)), with the nematic order parameter increasing 12-fold from S=0.066 to S=0.828. Film thickness scales approximately linearly with spin concentration (Figure 3(a)), with continuous films formed down to ~1.7 nm with high film uniformity, below that achievable using polyimide. Polar anchoring energy, measured using the Yokoyama-van Sprang high-field method, remains approximately constant across all concentrations (Figure 3(b)), with a mean value of $E_a=1.58\times10^{-4}$ J/m^2, exceeding the strong anchoring threshold by 10-fold. Pretilt angle, measured via the Scheffer-Nehring crystal rotation method, exhibits concentration-dependent behavior below 0.0625%, then saturates at α=1.19°±0.10° (Figure 3(c)), revealing a mechanism for tuning LC pretilt through coating thickness without compromising anchoring strength. FTIR and UV-Vis spectroscopy further confirmed high optical transmissivity from UVB through IR, addressing PI's UV absorption limitations. These findings make Elvamide 8023R a compelling alignment layer material for LC-tunable photonic devices operating over a wide range of the electromagnetic spectrum, particularly where low processing temperatures, minimal optical loss, and ultra-thin films are required.

11:30am **EM-TuM-15 Rolled-up metamaterials (RUMMS) for infrared imaging***, **Gokul Nanda Gopakumar,** Stephanie Law,* Pennsylvania State University

Subwavelength information about an object is carried by waves with large wavevectors. The diffraction limit is caused by the rapid evanescent decay of these large wavevector modes at the surface of a material. Hyperbolic materials allow light with large wave vectors to propagate within the material without decaying exponentially close to the surface. These materials have a negative real part of the permittivity tensor along at least one direction and a positive permittivity along at least one other direction, leading to an open isofrequency surface, in contrast to the closed isofrequency surface of normal materials. In a flat hyperbolic material, the sub-diffractional information will still exponentially decay once it leaves the hyperbolic medium. However, in a rolled-up hyperbolic material, the wavevector of the light decreases as it propagates radially, and the image is magnified, enabling propagation beyond the surface.

In this work, we present rolled up semiconductor-based infrared hyperbolic metamaterials. We fabricate these structures by using a strained bilayer that can be released from the substrate. The strained bilayer is grown using III-V semiconductors in a molecular beam epitaxy system. It comprises of a compressively strained bottom layer and tensile strained top layer grown on top of a sacrificial layer. A heavily doped III-V semiconductor is grown on top and this layer acts as an optical metal in the IR. Fabrication of rectangular mesas is done using standard lithographic and wet etching techniques. Finally, a wet etch that selectively removes the sacrificial layer is used to gradually release the strained bilayer, causing it to roll up. By changing the alloy composition, we tune the stress in the bilayers to change the diameter of the rolled-up tube. The number of turns in the rolled-up tube can also be increased by increasing the etching time. The result is a RUMM that has alternating layers of dielectric and metal in the radial direction.

The growth of the strained bilayer and determination of the strain are evaluated using high resolution X-ray diffraction. Scanning electron microscopy is used to image the rolled-up tubes and correlate their diameter to the bilayer strain. Finally, infrared spectroscopy will be used to measure the optical properties of the RUMMs. This is the first step in creating a fully semiconductor-based curved hyperbolic metamaterial that can be used in subdiffractional imaging in the IR wavelength range.

11:45am **EM-TuM-16 Optical Data Storage Materials***, Yuanbing Mao, **Venkata Daggupati,*** Illinois Institute of Technology

To satisfy the demand for further data growth and low energy consumption storage, the exploration of new optical data storage (ODS) recording materials has drawn intensive attention. However, the lack of suitable persistent and optically stimulated luminescence materials with deep-level traps is still the bottleneck of such applications. We have recently explored solid-state optical materials and tuned their optical properties, and ultimately engineering their desirable trap characteristics, for such applications. Particularly, by tailoring their trap depth, density and distribution, we have improved their optical information storage performance. Moreover, synergistic stimulation of these phosphors has been demonstrated as multimode storage media for ODS applications. Hence, other than demonstrating trap engineering as an effective way to tune luminescence properties of solid-state optical materials for ODS application, this talk will offer deep insights into their fundamental trapping and recombination processes and lay a strong foundation for multi-functional optical materials in future innovations.

12:00pm **EM-TuM-17 High-Mobility Electron Transport and Mid-Infrared Optical Properties of Sputter-Deposited InN***, **Ryan Spangler,*** Pennsylvania State University*; Jacob Shusterman,* Oak Ridge National Laboratory*; Josh Nordlander,* Pennsylvania State University*; Anton Ievlev,* Oak Ridge National Laboratory*; Jon-Paul Maria,* Pennsylvania State University

InN is a wurtzite group-III nitride that strongly favors high unintentional *n*-type conductivity, especially when grown by sputter deposition. This capacity for high carrier concentrations (>10^{19} cm^{-3}), when combined with the high mobilities allowed by the low electron effective mass of InN, makes this material a promising candidate for semiconductor plasmonics in the mid- to near-infrared. In this work, we demonstrate a sputter-deposition process that uses high working gas pressures (>100 mTorr) to achieve favorable transport properties of heteroepitaxial InN on AlN-buffered C-plane sapphire. Within this processing space, we find the Hall mobility increases significantly with film thickness, achieving a value of 840 $cm^2/V\cdot s$ at a thickness of 240 nm, significantly higher than other reports of sputtered InN.[1-3] We perform X-ray diffraction and atomic force microscopy to characterize the high film quality. We also use time-of-flight secondary ion mass spectrometry (ToF-SIMS) depth profiles to assess whether impurities such as O, H, and C can account for the high background carrier concentrations ($>10^{19}$ cm^{-3}) of the unintentionally doped material. We further dope the InN films with Ge to control the infrared optical properties, increasing the carrier concentration to nearly 10^{22} cm^{-3} to induce plasma frequencies ranging from 5.5 µm to 1.6 µm as measured by infrared variable angle spectroscopic ellipsometry (IR-VASE). As expected, however, the Hall mobility begins to fall at high Ge doping levels, which could increase optical losses at near-infrared frequencies. This work showcases the potential for tunable, high-mobility sputter-deposited InN and Ge:InN in IR plasmonic and optoelectronic applications.

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2. Bashir, U., Hassan, Z., Ahmed, N. M., Oglat, A., & Yusof, A. S. (2017). Sputtered growth of high mobility InN thin films on different substrates using Cu-ZnO buffer layer. *Materials Science in Semiconductor Processing*, *71*, 166–173. https://doi.org/10.1016/j.mssp.2017.07.025
3. Sakamoto, M., Kobayashi, A., Fukai, Y. K., Ueno, K., Tokumoto, Y., & Fujioka, H. (2019). Improving the electron mobility of polycrystalline InN grown on glass substrates using AlN crystalline orientation layers. *Journal of Applied Physics*, *126*(7), 075701. https://doi.org/10.1063/1.5117307

Author Index

Bold page numbers indicate presenter