Monday Afternoon, November 4, 2024

Quantum Science and Technology Mini-Symposium
Room 123 - Session QS1+EM+MN+PS-MoA

Materials + Devices for Quantum Systems

Moderators: Somil Rathi, Arizona State University, **Jaesung Lee**, University of Central Florida

1:30pm **QS1+EM+MN+PS-MoA-1 Elastic Layered Quantum Materials***, Jiun-Haw Chu,* University of Washington **INVITED**

Recently elastic strain has emerged as a powerful tool for probing and controlling quantum materials. By changing chemical bond lengths, elastic strain can modulate electronic structure up to very high energy scale. Additionally, as a second rank tensor, strain enables access to various instabilities associated with different symmetry channels. In this talk, I will discuss several examples of the application of strain to unconventional electronic orderings in van der Waals layered materials, including zigzag antiferromagnetism, charge density waves and excitonic insulators.

2:00pm **QS1+EM+MN+PS-MoA-3 Controllable Extended Defect States in Topological Insulators and Weyl Semimetals***, **Eklavya Thareja**, J. Gayles,* University of South Florida*; I. Vekhter,* Louisiana State University

Over the past decade study of topological materials has emerged as one of the most active areas in condensed matter physics, owing to a wide range of their proposed applications ranging from quantum computing to spintronics. What sets them apart from the materials currently used to build information technology is their robustness to disorder. However, in addition to the immunity of their electronic states against disorder, one needs ways to control the properties of these electronic states in these materials. We show that extended defects such as line defects and planar defects host localized states in Topological Insulators and Weyl Semimetals, which are two common topological materials. These localized states can be manipulated by controlling the scattering at the defects, for example, by using an external magnetic field. This leads to controllable spin accumulation and non-dissipative currents near the defects, due spin-momentum locking. These results bring us closer to functional applications.

2:15pm **QS1+EM+MN+PS-MoA-4 Topological Interfacial State in One-Dimensional h-BN Phononic Waveguide***, Y. Wang, **Sanchaya Pandit**,* University of Nebraska - Lincoln

Artificial topological structures have gained considerable research attention in the fields of photonics, electronics, mechanics, acoustics, and many others, as they promise robust propagation without loss along the edges and interfaces. In this work, we explored the topological states in one-dimensional (1D) phononic waveguides empowered by hexagonal boron nitride (h-BN), a hallmark two-dimensional (2D) material with robust mechanical properties that can support phonon propagation in high frequency regime. First, degenerate trivial and nontrivial topological structures were designed based on the Su-Schrieffer-Heeger (SSH) model. The dispersion engineering was then performed to match the passbands and bandgaps for these two topological structures through optimizing the geometric parameters of the unit cells. An interfacial state emerged when connecting these two sets of unit cells together and forming the 1D waveguide. The topological nature of this interfacial state, immune to structural and material parameter perturbation, was verified with the variation of strain and thickness in the waveguide. The phononic topological state studied here can be further coupled with defect-related quantum emitters in h-BN, opening the door for next-generation hybrid optomechanical circuits.

2:30pm **QS1+EM+MN+PS-MoA-5 Scanning Nano-Optical Imaging of Quantum Materials***, **Guangxin Ni**,* Florida State University

Scanning near-field Nano-Optical imaging is an invaluable resource for exploring new physics of novel quantum materials. Surface plasmon polaritons and other forms of hybrid light-matter polaritons provide new opportunities for advancing this line of inquiry. In particular, nano-polaritonic images obtained with modern scanning nano-infrared tools grant us access into regions of the dispersion relations of various excitations beyond what is attainable with conventional optics. I will discuss this emerging direction of research with two examples from 2D layered quantum materials.

2:45pm **QS1+EM+MN+PS-MoA-6 Engineering of Erbium-Implanted Lithium Niobate Films for Integrated Quantum Applications***, **Souryaya Dutta**,* College of Nanotechnology, Science, and Engineering (CNSE), University at Albany*; A. Kaloyeros, S. Gallis,* College of Nanotechnology, Science, and Engineering (CNSE), University at Albany (UAlbany)

Rare-earth-doped materials have garnered significant attention as material platforms in emerging quantum information and integrated photonic technologies. Concurrently, advances in its nanofabrication processes have unleashed thin film lithium niobate (LN), $LiNbO_3$, as a leading force of research in these technologies, encompassing many outstanding properties in a single material. Leveraging the scalability of ion implantation to integrate rare-earth erbium (Er^{3+}), which emits at 1532 nm, into thin film lithium niobate can enable a plethora of exciting photonic and quantum technologies operating in the telecom C-band. Many of these technologies also rely on coupling via polarization-sensitive photonic structures such as waveguides and optical nanocavities, necessitating fundamental material studies.

Toward this goal, we have conducted an extensive study on the role of implantation and post-implantation processing in minimizing implantation-induced defectivity in *x*-cut thin film LN. By leveraging this, we have demonstrated an ensemble optical linewidth of ~140 GHz of the Er emission at 77 K. Our demonstration showcases the effectiveness of our ion implantation engineering in producing cutting-edge Er emission linewidth in thin film LN at higher temperatures compared to values reported for diffusion-doped bulk materials at liquid helium temperatures (~3 K). Furthermore, we show that the Er photoluminescence (PL) is highly polarized perpendicular to the *x*-cut LN *c*-axis through a systematic and combinational PL and high-resolution transmission electron microscopy (HRTEM) study. These results indicate that using Er rare-earth emitters in thin film LN, along with their polarization characteristics and related ion implantation engineering, presents a promising opportunity to produce highly luminescent Er-doped LN integrated photonic devices for nanophotonic and quantum applications at telecom wavelengths.

3:00pm **QS1+EM+MN+PS-MoA-7 MBE Grown InAs/GaAs Quantum Dot Platforms with Spatial and Spectral Control for Quantum Devices***, **Nazifa Tasnim Arony**,* University of Delaware*; L. McCabe,* University of Delaware-Now at Yale University*; J. Rajagopal, L. Mai, L. Murray, P. Ramesh, T. Long, M. Doty, J. Zide,* University of Delaware

Epitaxially grown semiconductor quantum dots (QDs) have been well studied in the past few decades and have shown great promise as single photon emitters, and as a basis for potential qubits. These features of quantum dots grown on a semiconductor matrix make it a desirable platform/building block for quantum devices which has a wide-range of applications in quantum information, quantum sensing and quantum computing. For a complete epitaxially grown quantum device, spatial, spectral and structural homogeneity, optical tunability, and scalability are the key requirements. Recent work from our group has shown a method for site controlled QD growth where InAs QDs are grown on site-templated GaAs substrates with arrays of nano-pits.[1] However, achieving spectral homogeneity and good optical quality to ensure scalability is still a big challenge due to the size distribution of the QDs during growth, and impurities introduced in the regrowth surface from the fabrication processes respectively. This work addresses these challenges and explores three different objectives, first one being the domain of quantum dot columns (QDCs) as a buffer layer for the top QD-arrays of interest while burying defects/impurities underneath the QDCs. Additionally, initial experiments on spectral control of InAs/GaAs QDs by an in-situ method called 'cap and flush' are discussed, and the concept of quantum dot molecules (QDMs) is introduced for optical tunability in site-templated scalable device platforms.

[1] J. Vac. Sci. Technol. B 38, 022803 (2020).

3:15pm **QS1+EM+MN+PS-MoA-8 High Bandwidth Al-Based Single Electron Transistors for Silicon Quantum Dot Charge Sensing***, **Runze Li**,* University of Maryland, College Park*; P. Namboodiri, J. Pomeroy,* NIST-Gaithersburg

We have reduced the resistance of all-metal-based single electron transistors (SETs) for a 10 to 15 times higher operation current. This will provide more bandwidth and less noise to the SETs for eventual use as quantum dot charge sensors. People want to use the gate layer integrated all-metal-based SETs as charge sensors for quantum computing, but the long-remaining problem was the instability of readout due to the charge offset drift. Our group has developed stable aluminum-based SETs using plasma oxidation techniques, solving the instability problem. However, the devices we made are limited by the output current, typically <10 pA level when working in the single electron regime. The limitation on the current is due to the AlOx tunnel junctions' high resistance. Our goal is to bring up the output current up to ~100 pA level. We have been working on reducing the resistance of the AlOx thin film by reducing the plasma oxidation time and increasing the thin film area. We have seen a 10 to 15 times reduction in the resistance by varying plasma parameters. And we have also seen an obvious decrease in the resistance when increasing the tunnel junction area. We are continuing to develop data to study the quantitative relationship between the oxidation time/area and resistance. We are expecting to report the results of the reduced resistance in this talk.

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