Quantum Science and Technology Mini-Symposium
Room 208 W - Session QS1-TuA

Interdisciplinary Quantum Applications

Moderators: Yi-Ting Lee, University of Illinois at Urbana Champaign, **Kasra Sardashti**, University of Maryland College Park

2:15pm **QS1-TuA-1 A Study of Superconducting Behavior in Ruthenium Thin Films**, ***Bernardo Langa Jr.,*** University of Maryland*; Brooke Henry,* Clemson University*; Ivan Lainez,* University of Maryland*; Richard Haight,* IBM*; Kasra Sardashti,* University of Maryland

Ruthenium (Ru) is a promising candidate for next-generation electronic interconnects due to its low resistivity, small mean free path, and superior electromigration reliability at nanometer scales. In addition, Ru exhibits resistance to oxidation, low diffusivity, and most importantly, superconductivity below 1 K. These qualities make Ru an attractive material for superconducting qubits where its stability may help mitigate two-level system defects. Here, we investigate the superconducting behavior of Ru thin films (11.9–108.5 nm thick), observing transition temperatures from 657.9 mK to 557 mK. A weak thickness dependence appears in the thinnest films, followed by a conventional inverse thickness dependence in thicker films. Magnetotransport studies reveal type-II superconductivity in the dirty limit ($\xi >> l$), with coherence lengths ranging from 13.5 nm to 27 nm. Finally, oxidation resistance studies confirm minimal RuOx growth after seven weeks of air exposure. Our findings provide key insights for integrating Ru into superconducting electronic devices and explore its potential in advancing scalable, high-coherence quantum devices.

2:30pm **QS1-TuA-2 Realizing Epitaxial Trilayer Josephson Junctions Grown with Molecular Beam Epitaxy**, ***Colin Myers,*** University of Maryland, College Park*; Kasra Sardashti,* Laboratory for Physical Sciences*; Christopher Richardson,* Laboratory for Physical Sciences, College Park

The Al/AlOx/Al Josephson Junction (JJ) remains the primary choice for superconducting qubit design. Reducing the potential loss mechanisms and two-level systems (TLS) in these junctions is a major priority for quantum computation and design. Hence, many alternatives to the traditional JJ are being explored, with NbTiN posing as a possible substitute for aluminum. Alloyed NbTiN possesses a Tc near 17 K, allowing for far higher operating temperatures compared to aluminum. Utilizing plasma-assisted molecular beam epitaxy (PAMBE), we grow epitaxial trilayer stacks of NbTiN/AlN/NbTiN, where AlN serves as the insulating barrier layer of the JJ. This allows for an oxygen-free system, in addition to employing the precise thickness and compositional control associated with traditional MBE growth. Assembling a JJ from this trilayer architecture now presents unique patterning and lithography challenges. We present a novel approach to JJ design and fabrication, as well as epitaxial NbTiN as an emergent material for quantum information science.

2:45pm **QS1-TuA-3 Enabling Quantum Information Science with DNA-Templated Quantum Materials**, ***Xin Luo***[1]*, Jeffrey Gorman, Mark Bathe,* Massachusetts Institute of Technology

Quantum information science is limited by the lack of materials that enable precise, rational control over quantum photonic, excitonic, and spin states and other properties of the quantum materials. While DNA nanotechnology offers in principle such control via spatial templating of chromophores, quantum dots, and molecular spin centers with nanometer-scale precision, this capability requires interfacing with silicon-based 2D devices to enable quantum information science with translational impact on devices. Toward this end, we previously demonstrated that programmable DNA templates can position quantum materials such as colloidal quantum dots and rods with nanometer-scale precision for integration with photonic devices through top-down electron beam lithography [1]. Here, we apply this approach to fabricate photonic cavities to control single-photon emissive properties and photonic waveguides for photonic quantum circuits. We additionally demonstrate pathways towards controlling molecular spins and excitons with DNA templates for quantum information science and technology. This scalable approach to templating quantum materials opens new applications to quantum sensing, networking, and simulation, with potential impact on secure communications, medical diagnostics, computing, and beyond.

[1] Luo, X. *et al.* DNA origami directed nanometer-scale integration of colloidal quantum emitters with silicon photonics. *bioRxiv*, doi: 10.1101/2025.01.23.634416 (2025).

3:00pm **QS1-TuA-4 Enhanced Readout Contrast of V2 Ensembles in 4H-SiC Through Resonant Optical Excitation**, ***Infiter Tathfif,*** University of Maryland College Park*; Charity Burgess, Brenda VanMil,* Army Research Laboratory*; Samuel G. Carter,* Laboratory for Physical Sciences

Favorable optical and spin properties of the V2 silicon vacancy defect in 4H-SiC have made it a promising candidate for quantum technologies. For quantum sensing with defect spins, the contrast in optically-detected magnetic resonance (ODMR) is an important metric, which tends to be rather low (<1%) for V2 ensembles using off-resonant laser excitation. To improve contrast, we resonantly excite the V2 ensembles at low temperatures and compare our findings with off-resonant excitation. Our measurements show a ~90 times improvement for ODMR contrast over the off-resonant case for fairly low resonant excitation. We hypothesize that for a particular wavelength, the resonant laser excites a subset of defects within the ensemble and drives only one of the spin-selective optical transitions for each defect. This leads to a strong spin polarization, contributing to the high readout contrast. To test our hypothesis and further characterize the behavior, we examine the dependence of the contrast on the laser linewidth and the sample temperature. Modulating the resonant laser linewidth up to 1 GHz, corresponding to the splitting of the two optical transitions, results in the contrast decreasing by 50%. As the temperature is increased to 60 K, the contrast decreases and reaches the off-resonant value, presumably due to linewidth broadening. Although the PL signal is 50 times weaker than the off-resonant excitation due to the participation of the defect sub-ensemble, the sensing figure of merit (FoM) is 10 times higher, making the resonant approach still the best choice for sensing at low temperatures. Due to the high readout contrast and reduced laser power requirements, we plan to utilize this resonant technique for wide-field magnetic imaging of quantum materials and devices at low temperatures.

3:15pm **QS1-TuA-5 Enhancement of Superconductivity in Cryogenically Grown Ultra Thin Al Films**, ***Teun van Schijndel****, Yu Wu, Wilson Yánez-Parreño, Tawshia Chowdhury, Christopher Palmstrom,* University of California at Santa Barbara

Superconductivity in thin films can deviate significantly from bulk behavior, especially as dimensionality and disorder come into play. This is particularly true for aluminum, where critical temperature (Tc) and film morphology are highly sensitive to thickness and growth conditions. Here, we present an *in-situ* scanning tunneling microscopy (STM) study, performed at 78 K, of Al thin films grown on atomically clean Si(111) substrates by molecular beam epitaxy at cryogenic temperatures down to 6 K. The morphology is characterized across a wide range of coverages, from sub-monolayer up to 20 monolayers (ML). Cryogenic growth results in oriented hexagonal islands that begin to coalesce into a continuous film around 5 ML, with a typical roughness of a few monolayers. This roughness is constant up to 20 ML. Upon annealing to room temperature, the surface becomes nearly atomically smooth, though grain boundaries remain visible in STM. In contrast, room temperature growth produces significantly rougher films with large, disconnected islands of varying shape and orientation. We also investigated the superconducting properties of cryogenically grown films after exposure to atmospheric conditions, as required for ex-situ transport measurements. To stabilize the films, we used different post-growth treatments, including low temperature capping, cold oxidation, and room temperature oxidation. The films show critical temperatures approaching 3 K, which is significantly above the bulk value of 1.2 K.

[1] **JVST Highlighted Talk**

Author Index

Bold page numbers indicate presenter