Materials and Device Technologies for Quantum Information Sciences

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Modern information and communication technologies relies on hardware that is based on Silicon, Germanium and other supporting electronic materials such as III-V semiconductors, oxides and metals. While the electronic structure and properties of all our semiconductor materials and devices are dictated by quantum mechanics, the operating principles for computation are classical and rooted in digital 0 and 1 states of various devices. Quantum information sciences (QIS) (which includes computation, sensing, communication and other information processing modlaities) on the other hand relies on individual quantum states of electrons, ions or photons and entanglement between them which is fundamentally different from the classical 0 and 1s discussed above. Over the past several years, many transformative advances have been made in materials and devices which has enabled scaling quantum mechanical bits (qubit) to several interacting qubits and even two-dimensional arrays of qubits. In this talk, I will introduce and present the broad classes of quantum information technologies that are relevant to semiconductor materials and solid-state devices. I will discuss superconducting qubits, quantum dot qubits as well as photonic qubits and identify the most promising materials and architectures for their accession into a scalable technology. I will also highlight the shortcomings in each class of qubits and roadblocks towards enabling a scalable and commercial technology. If time permits I will also show our recent results on hybrid light-matter states that are formed in excitonic materials couple with plasmonic substrates. Finally, I will also elude to designs and concepts for on-chip quantum information processing using low-dimensional materials. I will conclude by giving a broad perspective on the future of quantum electronics and photonics hardware and where semiconductor materials and device engineers who lie at the core of EDS community; have a role to play in these emerging research areas.