ENGINEERING NEW SOLID STATE QUANTUM SYSTEMS

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Abstract: Engineering coherent systems is a central goal of quantum science and quantum information processing. Point defects in diamond known as color centers are a promising physical platform. As atom-like systems, they can exhibit excellent spin coherence and can be manipulated with light. As solid-state defects, they can be produced at high densities and incorporated into scalable devices. and quantum computers, and has been demonstrated to be a highly sensitive, non-invasive magnetic probe capable of resolving the magnetic field of a single electron spin with nanometer spatial resolution. However, realizing the full potential of these systems requires the ability to both understand and manipulate diamond as a material. I will present two recent results that demonstrate how carefully tailoring the diamond host can open new opportunities in quantum science. First, currently-known color centers either exhibit long spin coherence times or efficient, coherent optical transitions, but not both. We have developed new methods to control the diamond Fermi level in order to stabilize a new color center, the neutral charge state of the silicon vacancy (SiV) center. This center exhibits both the excellent optical properties of the negatively charged SiV center and the long spin coherence times of the NV center, making it a promising candidate for applications as a single atom quantum memory for long distance quantum communication. Second, color centers placed close to the diamond surface can have strong interactions with molecules and materials external to the diamond, which makes them promising for nanoscale sensing and imaging. However, uncontrolled surface termination and contamination can degrade the color center properties and give rise to noise that obscures the signal of interest. I will describe our recent efforts to stabilize shallow NV centers within 5 nm of the surface using new surface processing and termination techniques. These highly coherent, shallow NV centers will provide a platform for sensing and imaging down to the scale of single atoms. In fact, many platforms for quantum technologies are limited by noise and loss arising from uncontrolled defects at surfaces and interfaces, including superconducting qubits, trapped ions, and semiconductor quantum dots. Our approach for correlating surface spectroscopy techniques with single qubit measurements to realize directed improvements is generally applicable to many systems, and I will describe our recent efforts to tackle noise and microwave losses in superconducting qubits.

Bio: Nathalie de Leon is an assistant professor in the Department of Electrical and Computer Engineering at Princeton University, where she started in 2016. Her group focuses on building quantum technologies with solid state defects and new material systems for superconducting qubits. She received the Air Force Office for Scientific Research Young Investigator Award in 2016, the Sloan Research Fellowship in 2017, the NSF CAREER Award in 2018, the DARPA Young Faculty Award in 2018, and the DOE Early Career Award in 2018. She is also on the leadership team of the Co-design Center for Quantum Advantage, a DOE National Quantum Information Science Center. She was previously a postdoctoral fellow in the Harvard physics department, jointly supervised by Mikhail Lukin and Hongkun Park, working on cavity QED with diamond nitrogen vacancy (NV) centers integrated with diamond-based nanophotonics, with the goal of realizing scalable solid-state quantum networks. She received her Bachelor of Science degree in chemistry in 2004 from Stanford, where she worked under Richard Zare, and she earned her Ph.D. in chemical physics in 2011 from Harvard in the lab of Hongkun Park.