AVS Quantum Science Workshop
Room Redondo - Session AQS-ThA2

AVS Quantum Science Workshop: Color Centers for Quantum Sensing

Moderator: Tongcang Li, Purdue University

3:50pm **AQS-ThA2-24 Engineering Diamond for Quantum Sensing*,* *Jennifer M. Schloss**, J. Mallek, D. deQuilettes, E. Price, L. Pham, J. Barry, M. Steinecker, D. Phillips, D. Braje,* Massachusetts Institute of Technology Lincoln Laboratory **INVITED**

Diamond hosts a wide array of color centers, several of which demonstrate outstanding optical and spin properties. Among these defects, the nitrogen vacancy center in its negatively charged state (NV-) has emerged as a promising emitter for quantum sensing, owing to its unique combination of characteristics including: (1) robust operation over wide-ranging conditions; (2) optical and microwave control of the NV- quantum states without need for narrow-band lasers or cryogens, and (3) capability for vector magnetic field sensing and high-resolution imaging.

Harnessing the potential of these centers requires tailoring their density and charge state distribution as well as the surrounding environment. Plasma enhanced chemical vapor deposition (PECVD) has become a key enabling technology for this optimization. NVdense layers of engineered material may be created through in-situ doping into highcrystalline-quality diamond lattice. Tailored material is fashioned through a combination of PECVD growth together with post-growth processing such as electron irradiation and high temperature annealing.

We will show how diamond is optimized for quantum sensors through a supervised machine-learning based feedback approach. Through highlighting some recent optimized diamonds, we will demonstrate how critical properties such as N-doping density and strain differ for bulk magnetometry [1, 2] and magnetic imagers.

[1] E. Eisenach et al. Nature Communications 12 1357 (2021)

[2] S. Alsid et al. arXiv:2206.15440 (2022)

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4:30pm **AQS-ThA2-32 Quantum Diamond Sensors — Best of Both Worlds*,* *Ron Walsworth*,** University of Maryland **INVITED**

The nitrogen–vacancy (NV) quantum defect in diamond is a leading modality for magnetic, electrical, temperature, and pressure sensing and imaging with high spatial resolution and wide field-of-view under ambient and extreme conditions. This quantum sensing technology has diverse applications across the physical and life sciences — from probing magnetic materials to biomedical diagnostics. I will provide an overview of quantum diamond sensors and their many applications, with a focus on the enabling material properties and future challenges for improved performance.

5:10pm **AQS-ThA2-40 Spin-Carrying Quantum Centers in Wide-Band Gap Semiconductors as Magnetometry Sensors for Space Applications*,* *Hannes Kraus*,** *A. Gottscholl, C. Cochrane,* Jet Propulsion Laboratory **INVITED**

There are various forms of magnetometers currently in development and each significantly vary in terms of their size, cost, complexity, and performance. However, only a small subset of them can be used in the remote and harsh environment of space due to the heavy requirements levied on the instrument prior to flight. These space bound magnetometers should be reliable, simple, and robust. With over 60 years of development heritage, Fluxgate and optically pumped atomic gas-based magnetometers are the most commonly used instruments for missions in space.

However, recent trends in spaceflight towards smaller and cheaper spacecraft (e.g. CubeSats) necessitate also downscaling size and complexity of scientific instruments. Here, solid-state quantum effect-based magnetometer instruments enter the spotlight. The wide band-gap nature of materials like silicon carbide (SiC), diamond or hexagonal boron nitride (hBN) allows application in harsh environments, while sub-gap defects carrying spins, which can be addressed optically and electrically, contribute magnetic field sensitivity through magnetic resonance response.

The *SiCMAG* electrically detected magnetometer sensor leverages an increased spindependent recombination (SDR) current furnished through sub-gap silicon vacancy (VSi) defects in SiC. Quantum singlet-multiplet mixing effects close to zero field make those devices sensitive to minuscule modulation of the magnetic field around zero. Under electron paramagnetic resonance (EPR) conditions under a bias field, the sensor becomes an EPR spectrometer, allowing detection of electron-nuclear hyperfine interaction (HFI), and thus enabling an in-situ absolute magnetic field calibration to the physically constant HFI.

Current sensitivities of unoptimized sensors reach the order of 1µT/√Hz. The *OPuS-MAGNM* optically pumped solid state quantum magnetometer operates on a similar approach, with addressing and readout of the magnetically sensitive quantum centers happening through optical excitation and detection. Lab-scale instruments using diamond NV centers have already shown sensitivities below 100pT/√Hz. We show progress building an integrated sensor using the SiC VSi center, and an outlook on how this sensor is easily adaptable to the other mentioned quantum solid state material systems, i.e. diamond NV centers and hBN.

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