PCSI
Room Redondo - Session PCSI-ThM1
Spin Dynamics for Quantum Sensing

Moderator: Christopher Palmstrom, University of California, Santa Barbara

8:30am **PCSI-ThM1-1 Theory of Spin Center Sensing of Diffusion***, **Denis Candido**,* University of Iowa **INVITED**

Defects in solids with spins (also known as spin centers) have been shown as promising room temperature solid-state qubits with the ability to be optically initialized and interrogated[1]. Additionally, they have also been demonstrate to be great non-evasive quantum sensors due to their high energy levels sensitivity to both magnetic and electric fields. In general, static electromagnetic fields can be inferred from the shift of the emitted spin center photoluminescence, while dynamical fluctuating fields (generating noise) are inferred from the change of the spin center coherence times[2].

Here we study the electric noise in spin defects due to both fluctuation of the surface charged density and the electrostatic potential at the surface of our crystal [3]. Surprisingly, we show in Fig. 1 that the depth dependence of the electric noise spectral density is strongly influenced by the two-point correlation function of both the charged particles' positions, rather than solely by the character of the charge fluctuators, e.g., point-like or dipole. Furthermore, we are able to recognize the fingerprints and signatures of diffusion phenomena of charged particles through the spin defect's T1 and T2. This is seen on both the defect spin decay and dephasing containing a crossover as function of time around the characteristic correlation time of the fluctuators, determined by the diffusion coefficients (Fig. 2). Hence, spin defects can also be used for sensing of diffusion phenomena and extraction of its corresponding correlation time and diffusion constant.

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[1] D. D. Awschalom, R. Hanson, J. Wrachtrup,and B. B. Zhou, Nature Photonics12, 516 (2018).
[2] R. Schirhagl, K. Chang, M. Loretz, and C. L. Degen, Annual Review of Physical Chemistry 65, 83 (2014).
[3] D. R. Candido and M. E. Flatté, arXiv:2112.15581 (2021).

9:10am **PCSI-ThM1-9 Probing Spin Dynamics on Diamond Surfaces Using a Single Quantum Sensor***, N. de Leon, **Jared Rovny**,* Princeton University **INVITED**

Nitrogen vacancy (NV) centers in diamond are atom-scale defects with long spin coherence times that can be used to sense magnetic fields with high sensitivity and spatial resolution. Typically, the magnetic field projection at a single point is measured by averaging many sequential measurements with a single NV center, or the magnetic field distribution is reconstructed by taking a spatial average over an ensemble of many NV centers. In averaging over many single-NV center experiments, both techniques discard information. Here we propose and implement a new sensing modality, whereby two or more NV centers are measured simultaneously, and we extract temporal and spatial correlations in their signals that would otherwise be inaccessible. We analytically derive the measurable two-point correlator in the presence of environmental noise, quantum projection noise, and readout noise. We show that optimizing the readout noise is critical for measuring correlations, and we experimentally demonstrate measurements of correlated applied noise using spin-to-charge readout of two shallow NV centers. We also implement a spectral reconstruction protocol for disentangling local and nonlocal noise sources, and demonstrate that independent control of two NV centers can be used to measure the temporal structure of correlations. Our covariance magnetometry scheme has numerous applications in studying spatiotemporal structure factors and dynamics, and opens a new frontier in nanoscale sensing.

9:50am **PCSI-ThM1-17 UPGRADED Quantum Decoherence in Superconducting Circuits: Contrasting Loss Mechanisms of Nb and Si Surface Oxides***, **D Frank Ogletree**,* Molecular Foundry, Lawrence Berkeley Lab*; V. Altoé, A. Schwartzberg, C. Song, D. Santiago,* Molecular Foundry, LBL*; I. Siddiqi,* Physics Department, UC Berkeley and Materials Sciences, LBL

The performance of quantum sensors or qubits based on superconducting circuits is limited by "two level system" (TLS) loss associated with amorphous layers at the metal and substrate interfaces [1,2]. Through selective chemical etching of niobium-on-silicon quantum resonators, correlated with millikelvin microwave loss measurements and interfacial materials analysis [3], we found clear differences in contributions of Si and Nb surface oxides. XPS and STEM analysis of resonator cross-sections were used to correlate physical and chemical changes in the surface oxides with reductions in decoherence [4,5]. Surface SiO_x hosted 70% of TLS loss, with only 24% associated with NbO_x. Although TLS loss dominated decoherence, 39% of loss did not show the characteristic TLS power dependence [1]. NbO_x hosted 68% of non-TLS losses, with only 17% associated with SiO_x. We localized 92% of all loss in the surface oxides. TEM diffraction showed an epitaxial relation between the Nb superconducting film and the Si substrate, with no evidence for the commonly-reported metal-substrate amorphous oxide layer. Post-fabrication surface oxide etching improved our median quantum-resonator quality factors from 0.93 to 5.26 million.

Author Index

Bold page numbers indicate presenter