

PCSI

Room Keahou I - Session PCSI-WeM2

Point Defects (for Quantum Information Applications) II

Moderator: Gregory Fuchs, Cornell University

11:00am PCSI-WeM2-31 Quantum Point Defects in Wide Band Gap Semiconductors: Donor Properties in ZnO and Charge States of Diamond, X. Wang, E. Hansen, V. Niaouris, C. Pederson, N. Yama, University of Washington; L. Vines, University of Oslo, Norway; Kai-Mei Fu, University of Washington

INVITED

Quantum point defects which exhibit both spin and optically active states are attractive qubit candidates for quantum sensing and network technologies. Here we present progress on two qubit systems: shallow donors in ZnO and deep vacancy-related defects in diamond.

In direct band-gap semiconductors, the bound-electron spin states of shallow donors forming the qubit states can be optically accessed via the donor-bound exciton ( $D^0X$ ) with high radiative efficiency. We have recently measured the optical and coherence properties of In defects in ZnO, *in situ* doped and formed by implantation and annealing. We observe an inhomogeneous linewidth of several GHz [1], longitudinal spin lifetimes up to 0.5 s [2] and coherence times up to 50  $\mu$ s which are limited by substrate purity [3]. Two-laser spectroscopy also reveals the large, 100 MHz hyperfine coupling of the In electron spin-1/2 to the In nuclear spin- 9/2 [4]. Thus, there is a path toward deterministic formation of In donors with access to a nuclear spin memory. Further, we have demonstrated isolation of single In donors by probing only a small sample volume [5]. We further investigate the role of substrate purity by studying In donors fabricated in high-purity ZnO grown by molecular beam epitaxy. Finally, we discuss the outlook for new defect centers in an ultra-pure ZnO host.

A fundamental property that must be controlled in any defect-based technology is the charge state. We demonstrate the use of deep-ultraviolet (DUV) radiation to dynamically neutralize nitrogen- (NV) and silicon-vacancy ( $SiV^-$ ) centers in diamond [6]. We first examine the conversion between the neutral and negatively charged NV states by correlating the variation of their respective spectra, indicating that more than 99% of the population of NV centers can be initialized into the neutral charge state. We then examine the time dynamics of bleaching and recharging of negatively charged  $SiV^-$  centers and observe an 80% reduction in  $SiV^-$  photoluminescence within a single 100- $\mu$ s DUV pulse. Finally, we demonstrate that the bleaching of  $SiV^-$  induced by the DUV is accompanied by a dramatic increase in the neutral  $SiV^0$  population;  $SiV^0$  remains robust to extended periods of near-infrared excitation despite being a non-equilibrium state. Our results on two separate color centers at technologically relevant temperatures indicate a potential for above-band-gap excitation as a universal means of generating the neutral charge states of quantum point defects on demand.

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