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Quantum point defects in wide band gap semiconductors: Donor properties in ZnO and charge states of diamond

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Abstract

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 defect 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 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, longitudinal spin lifetimes up to 0.5 s and coherence times up to 50 μs which are limited by substrate purity. 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. Further, we have demonstrated isolation of single In donors by probing only a small sample volume. 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. 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 demonstrate that the bleaching of SiV– induced by the DUV is accompanied by a dramatic

increase in the neutral SiV^0 population. 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.