Engineering and charactering single spin defects in wide bandgap materials

Yu-Chen Chen

Research Center for Applied Sciences, Academia Sinica, 128 Academia Road, Section 2, Taipei 115-29, Taiwan

Optically active spin defects in wide bandgap materials, such as diamond and silicon carbide (SiC), have attracted much attention as candidates of many quantum applications [1,2]. In order to achieve scalable devices, spatially precise generation of high-quality single colour centres on demand are essential. In this regard, ion implantation method has been used to engineer colour centres with high spatial accuracy [3,4], but comes at the expense of creating considerable residual lattice damage, which degrades their spin and optical coherence properties.

We used single, femtosecond pulses laser (λ = 790 nm, t = 250 fs) to generate an array with various pulse energies in a CVD diamond and a 4H-SiC epitaxial film. For the diamond case, single NV^- centres were generated after annealing at high temperature. The positing accuracy of the generated NV^- centres were determined to be about 200 nm in x-y plane. The T_2 spin coherence times were measured up to 700 μs. Some NVs showed narrow, stable zero-phonon-line (ZPL), including a selection which are at the lifetime-limited linewidth of 13MHz at 4K. These indicate the laser writing method can generate the NV^- centres with almost perfect spin and optical coherence properties. Furthermore, we developed a second-generation laser writing method to achieve local annealing. This method successfully increased the yield of single NVs from 37% to almost unity and improved the positioning accuracy to 40 nm.

I have also characterized unknown single spin defects in hexagonal boron nitride 2D materials. we have found a set of isolated optical emitters embedded in hexagonal boron nitride that exhibit optically detected magnetic resonance. We also demonstrated that one of them is single spin defect. The defect spins show an isotropic g_e-factor of ~2 and zero-field splitting below 10MHz. The photokinetics of one type of the defects is compatible with ground-state electron-spin paramagnetism. We extracted spin-lattice relaxation times T_1 of 13-17 μs with estimated spin coherence times T_2^* of around 40-60 ns. We also investigated into the spin dynamics and provided a simple model of the electronic structure. We also used the density functional theory to investigate some potential defect complex candidates. Our results provide some insight into the chemical structure of the defects.

Reference

[1]. M. Atatüre et al. Nat. Rev. Mater. 2018, 3, 38-51.
[2]. D. D. Awschalom et al. Nat. Photon. 2018, 12, 516-527.
[3] S. Pezzagna et al. Small. 2010, 6, 2117-2121.
[4] J. Wang et al. ACS Photonics. 2017, 4, 1054.