Imaging of dark spins using nitrogen-vacancy centers in diamond

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The negatively-charged nitrogen-vacancy center (NV) belongs to the most-studied paramagnetic defects in diamond as it shows coherence times up to milliseconds at room temperature[1] and enables optical polarization and coherent control of the electron spin[2]. To optimize the sensitivity of NV-based quantum sensors, the spin environment in diamond has to be well controlled and understood.[3] However, even in engineered diamond grown by chemical vapor deposition (CVD) dark spins like substitutional nitrogen (P1) and negatively charged nitrogen-vacancy-hydrogen (NVH) defects out-number the nitrogen vacancy defect by usually at least one order of magnitude.[4] Therefore, for minimizing magnetic noise originating from dark spins, the nitrogen-to-NV conversion during CVD growth has to be maximized while keeping the density of P1 and NVH at a minimum.[5] To develop such optimized CVD processes usually electron paramagnetic resonance (EPR) spectroscopy is the method of choice for quantifying dark spin densities with sub-ppm precision.[4] In nm-thick epitaxial layers, however, the total number of paramagnetic spins becomes eventually too low for state-of-the-art EPR spectrometers.[4] As a consequence, we exploit double-electron-electron-resonance spectroscopy with NV centers as local sensors[6] (NV-DEER) to quantify P1 and NVH concentrations in epitaxially grown (100)-diamond layers with thicknesses of about 500 nm. Furthermore, by moving from a confocal to a wide-field microscope with a CCD camera, we even image the spatial distribution of P1 and NVH spins on the sub-µm scale. Comparing then the NV-fluorescence with the density maps for P1 and NVH, we get access to the correlation of nitrogen-related spins on the micron scale in diamond which yields valuable information on the defect formation in diamond.

References

1. Balasubramanian, G. et al., Nature Mater. 8 (2009), 383–387.
2. Degen, C. L., Reinhard, F. & Cappellaro, P., Rev. Mod. Phys. 89 (2017), 35002.
3. Edmonds, A. M. et al., Mater. Quantum. Technol.. 1 (2021), 25001.
4. Edmonds, A. M. et al., Phys. Rev. B. 86 (2012), 35201.
5. Rondin, L. et al., Reports on progress in physics. Physical Society (Great Britain). 77 (2014), 56503.
6. Osterkamp, C. et al., Adv Quantum Tech. 3 (2020), 2000074.