Disentangling aggregation kinetics in CVD diamond for quantum sensing

Exceptional technological progress in diamond means that it is now at the forefront of many quantum technologies. For instance, diamond-based sensors can detect the magnetic field of a single atom and determine precisely what and where it is; or probe the fundamental nature of our universe by employing quantum entanglement between two diamonds. On the micro- and macroscopic scale, diamond-based quantum technologies are capable of sensing magnetic effects in bacteria, probing defects in computer chips, and providing high-precision magnetic navigation in challenging environments [1–9].

These amazing capabilities are enabled by “point-defects” – atomic-scale “faults” in the diamond crystal formed by displacing, replacing, and/or removing carbon atoms – within the diamond structure. Most quantum technology applications of diamond exploit the electro-optical and spin properties of the negatively-charged nitrogen-vacancy centre (NV^-) – a defect consisting of a nitrogen atom next to a missing atom (the vacancy).

It is an ongoing challenge to produce the ideal diamond material for NV-based quantum technologies – namely low-strain, low-parasitic-spin density, highly charge-stable material with tightly-controlled NV^- concentrations. Recent advances in plasma-assisted chemical vapour deposition (CVD) diamond synthesis have opened up a new regime of material which is nominally ideal for quantum technology applications, but which is as-yet poorly understood. Creating optimal material for quantum technologies will require an intimate understanding of the defects present, their interactions, and how to modify, create, and destroy them in this new diamond material.

This ambitious project will combine Warwick’s world-leading understanding of diamond point defects and their interactions under annealing, with extensive state-of-the-art experimental facilities and novel CVD diamond. It is anticipated that this work will result in the identification and characterisation of several new point defects and will drive understanding on optimal strategies for producing high-nitrogen material for quantum technology applications.

The research will be carried out in the physics department at Warwick, and will involve but is not limited to:

- characterization and treatment of novel high-nitrogen CVD diamond to develop routes toward optimized material for ensemble quantum sensing
- identification and characterization of novel defects using cryogenic optical and magnetic resonance techniques
- understanding of defects' electronic properties to deduce their chemical constituents and atomic configuration
- production of defects by irradiation and high temperature treatment to optimize their properties and understand their interactions with other defects
- interaction with the large multidisciplinary cohort of leading diamond researchers based at Warwick as part of the Centre for Doctoral Training in Diamond Science and Technology
- regular meetings with leading diamond industry figures to help maximally exploit our new understanding

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