Diamond-based quantum sensors for in situ monitoring of spin active chemical species in molecular structures and single particles

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The quantum sensing capabilities of Nitrogen Vacancy (NV) defects in diamonds are widely studied. Advantageously, the defect quantum spin state can be optically addressed and read out and is sensitive to magnetic fields, electric fields, temperature, and chemical oxidation states at room temperature [1]. Major advances in the science and technology underpinning these sensors have been made with significant application in nano- and biotechnology [2]. The work presented here contributes to these developments by demonstrating the use of ensembles of NVs within diamond nanoparticles for in situ monitoring of the magnetic state of photomagnetic materials down to the single particle level, the stability of molecular cages containing atomic Nitrogen, and spin active products of photocatalysis under ambient conditions.

Experimentally optically detected magnetic resonance (ODMR) and modulation of NV photoluminescence by a large off axis magnetic field (magnetic modulation) were performed. An imaging strategy combining transmission electron microscopy and optical microscopy was employed enabling identical-location NV spin sensing of paramagnetic Prussian blue analogue nanoparticles down to the single particle level. The integrity of endohedral fullerenes containing atomic Nitrogen (N@C60) under low power ultraviolet light irradiation in air was reported via time course ODMR and magnetic modulation measurements. The formation of spin-active intermediates generated via photocatalytic processes on low-dimensional and nanostructured materials were also studied using NV based quantum sensing protocols.

The work reported herein, demonstrates the significant potential NV based diamond quantum sensors have in the discovery and development of emerging nano- and biotechnologies. Moreover, the combined electron microscopy and NV sensing strategies presented provide an insight to the unique contrast available through correlation of nanoscale structure and chemical composition with magnetic, oxidation and electronic states of matter, addressing the universal and ongoing need for the discovery of new sensing approaches capable of pushing the boundaries of measurement to sustain frontier science.

[1] M. Radtke et. al. *Nano Futures* **3**, 042004 (2019).

[2] T. Zhang et. al. *ACS Sens.* **6(6)**, 2077-2107 (2021).