Development of Focused Ion Beam-Fabricated Scanning Diamond Nitrogen-Vacancy Center Probes Beyond the Optical Diffraction Limit Resolution

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Electron spins at the apex of a diamond nitrogen-vacancy (NV) center scanning probe microscopy (NVSPM) is a versatile quantum sensor for studying condensed matter phenomena at the nanoscale[1]. Ga^+-ion focused ion beam (FIB) milling has been used to fabricate diamond NV nanostructures due to its high design flexibility and precise control, and it has recently been adopted for creating NVSPM tips[2]. However, Ga^+-ion FIB milling is known to produce an amorphous carbon layer about 30 nm thick[3], which damages the quantum spin properties of the NVSPM and restricts the tip diameter to the micrometer size. We introduce a method to preserve the spin properties of the NVSPM tip by protecting the surface with polyvinyl alcohol and Pt/Pd capping during FIB fabrication. Using this approach, we successfully fabricated an NVSPM tip with a diameter of 330 nm, below the diffraction limit of a confocal microscope with an air objective lens. The NVSPM tip is mounted on a sharpened tungsten rod, attached to a laterally oscillating tuning fork-based phase-locked loop (PLL)-regulated AFM system. The coherence properties of the probe showed a Rabi contrast of 9 %, a T_2 coherence time of 14 µs, and a T_1 of 1.6 ms, resulting in estimated dc and ac magnetic field sensitivities of 8 $\mu T/\sqrt{Hz}$ and 55 $nT/\sqrt{Hz}$, respectively. Finally, we demonstrated the NVSPM's application as a magnetometer by imaging the magnetic domain structure of a ferrimagnetic BiLuIG, resolving its 300 nm domain walls.

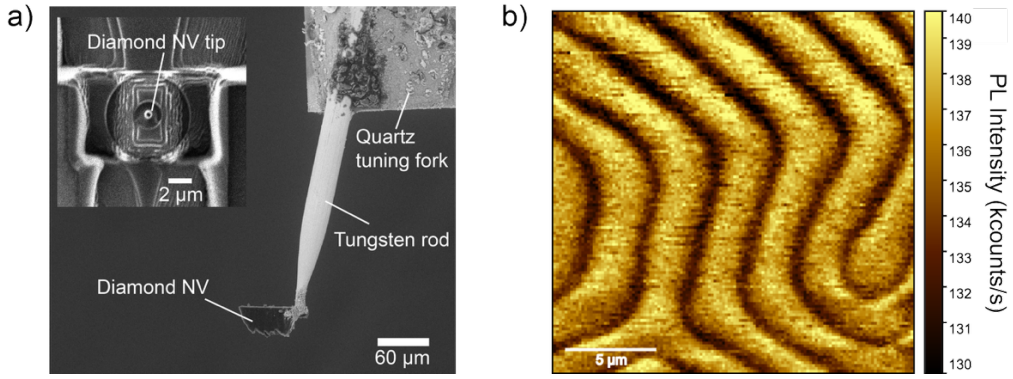

Figure 1. a) Scanning electron micrograph of the NVSPM, consisting of the FIB-fabricated diamond NV mounted on an electrochemically sharpened tungsten rod attached to one prong of a quartz tuning fork. Inset is the image of the NVSPM tip seen from the bottom. b) Photoluminescence quench image of the BiLuIG magnetic domain structure under zero external magnetic field.

Acknowledgement: This work was supported, in part, by the JPSP KAKENHI grants No. 24K01286 and No. 24K17580.

Reference

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