Coherent Spin-Magnon Coupling for Quantum-to-Quantum Transduction

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Primary CNF Tools Used: GCA 5x stepper, AJA sputtering deposition system, P10 profilometer, Westbond 7400A ultrasonic wire bonder, Veeco Icon atomic force microscope, JEOL JBX-6300FS 100 kV electron-beam lithography system, PT770 etcher

Abstract:

Nitrogen-vacancy (NV) centers possess long spin coherence lifetimes and coherent optical transitions at low temperatures. The combination of long-lived ground state spins and a narrow optical transition is useful for quantum-to-quantum transduction between spins and photons and quantum entanglement between NV spins and photons have been demonstrated. Here, we are developing an interface between magnons and NV spins, which is a key link in a quantum network.

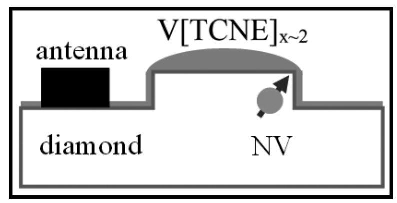

Figure 1: Schematic of coherent coupling between spins and magnons through an NV spin coupling to a magnon mode in $V[TCNE]_{x\sim2}$.

Summary of Research:

A key requirement in building a quantum network is the ability to transduce quantum information from one quantum system to another quantum system [1]. Diamond NV centers have long spin coherence time and a narrow linewidth optical transition, enabling both spin-photon entanglement [2,3] and spin-spin entanglement via photons [3]. NV centers are also suitable for quantum-to-quantum transduction between photons and magnons.

We are developing a platform that coherently couples microwave magnons to NV spins through magnetic dipole interaction. For this platform to perform quantum transduction, the magnons and spins decoherence rates need to be smaller than the coupling rate between magnons and spins. To enhance the coupling, the NV spin needs to be close (~ 30 nm) to the magnetic material (see Figure 1 for a schematic). To reduce magnon decoherence, we work with a low loss organic based magnetic material vanadium tetracyanoethylene ($V[TCNE]_{x\sim2}$) [4] in collaboration with Prof. Johnston-Halperin's group at Ohio State University (OSU).

Diamond polishing results in a highly strained surface, which increases near surface NV centers decoherence. This can be mitigated by etching away the first several microns of diamond using reactive ion etch (RIE) [5,6]. We compare the diamond surface before and after the stress relief etch using the PT770 etcher and observe a significant decrease in polishing streaks and surface roughness (Figure 2).

The spin-magnon coupling strength is maximized when the NV is aligned with the magnon mode. One approach to improve alignment is to etch the diamond with disks like structures and the grown magnetic material will be automatically aligned with the diamond structure. In order to optimize disks dimension and material growth condition, we fabricate SiO_2 arrays as test targets with diameters ranging from 200 nm to 8000 nm using electron beam lithography. The SiO_2 disks will also be used as shadow masks for diamond etching. Our collaborators at OSU have grown $V[TCNE]_{x\sim2}$ films on these disks showing nucleation free growth (Figure 3).

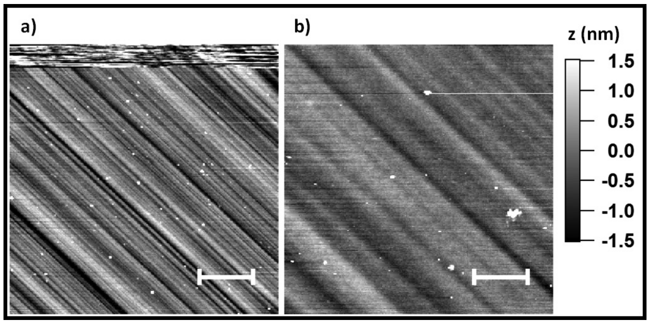

Figure 2: AFM image of the diamond before (a) and after (b) Ar/Cl_2 reactive ion etch. Scale bar is 1 µm.

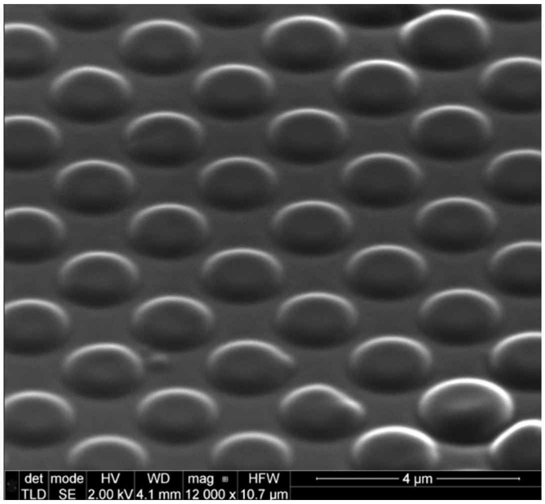

Figure 3: SEM of V[TCNE]$_{x\sim2}$ grown on 1 µm SiO_2 disks.

References:

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