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(YIP 11) Nanoscale probe of magnetism based on artificial atoms in diamond

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Final Report

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14. ABSTRACT

This final report details our lab's accomplishments on nanoscale magnetic sensing using a nitrogen-vacancy (NV) center in diamond. Significant accomplishments funded by this award include 1) characterization of the surface induced decoherence with shallow, depth calibrated NV spins exhibiting long coherence times (accepted to PRL). 2) Construction of a combined atomic force microscope (AFM) and confocal microscope with 1 nm position stability. 3) The formation of high-quality factor single-crystal diamond mechanical resonators with integrated nanowire tips. 4) The formation of high-quality NV centers via chemical vapor deposition diamond growth with nitrogen delta-doping and the development of techniques such as patterned transmission electron microscope irradiation and patterned 12C implantation to form localized NV centers with long coherence times. 5)Scanned probe detection of a nanoscale volume of Gd3+ ions attached to a scanning tip using relaxation imaging. 6) Detection of a nanoscale volume of nuclear spins using a single spin in bulk diamond.

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magnetometry, quantum sensing, nitrogen-vacancy center

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Nanoscale probe of magnetism based on artificial atoms in diamond
Award #FA9550-11-1-0013
Program manager: Harold Weinstock

This final report details our lab's accomplishments on nanoscale magnetic sensing using a nitrogen-vacancy (NV) center in diamond, an atomic-scale, optically addressable magnetometer. Significant accomplishments funded by this award include: 1) Characterization of the surface induced decoherence with shallow, depth calibrated NV spins exhibiting long coherence times. This result has been accepted to Physical Review Letters[1] and will be appear in the next week. 2) Construction of a combined atomic force microscope (AFM) /confocal microscope with 1 nm position stability, 1.49 numerical aperture optical access, and high power RF electronics. This system was used in reference 1 and for the unpublished results in Fig 1. 3) The formation of high-quality factor single crystal diamond cantilevers[2] with integrated nanowire tips. The nanowire tips are 200 nm in diameter and act as waveguides for the NV fluorescence. Continuing efforts in the lab are focused on performing magnetometry with these probes at low temperatures. We are currently building a low temperature AFM with sub-nm position stability in a closed cycle cryostat that should be completed Sep. 1. 4) The formation of high quality NV centers via chemical vapor deposition diamond growth with nitrogen delta-doping[3] and the development of techniques, such as patterned transmission electron microscopy irradiation[4] and patterned ^{12}C implantation to form localized NV centers with long coherence times. 5) Scanned probe magnetic detection of a nanoscale volume of Gd^{3+} ions attached to a scanning tip using relaxation imaging[5] (Fig 1), and 6) Detection of a nanoscale volume of nuclear spins using a single spin in bulk diamond[1] (Fig 2).

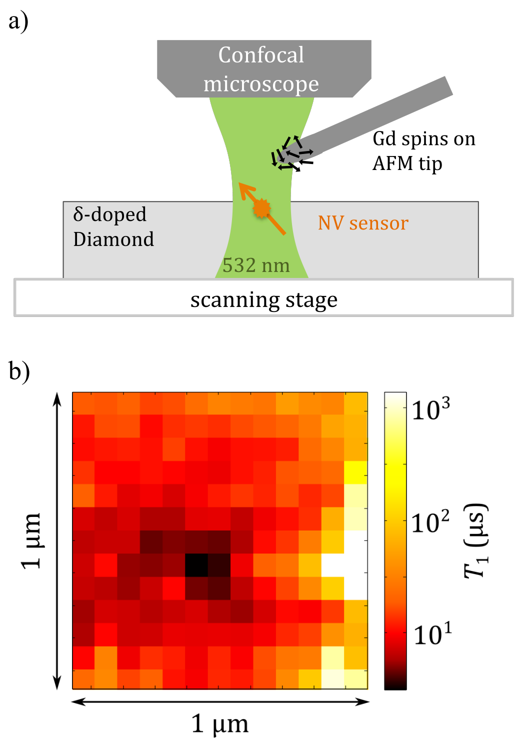

Figure 1: NV-based scanning magnetometry a) AFM tip functionalized with Gd^{3+} spins is scanned over NV sensor b) Image shows NV relaxation time (T_1) as a function of tip position. T_1 is dramatically affected by proximal Gd ions. Gd ions are commonly used spin labels for biological imaging.

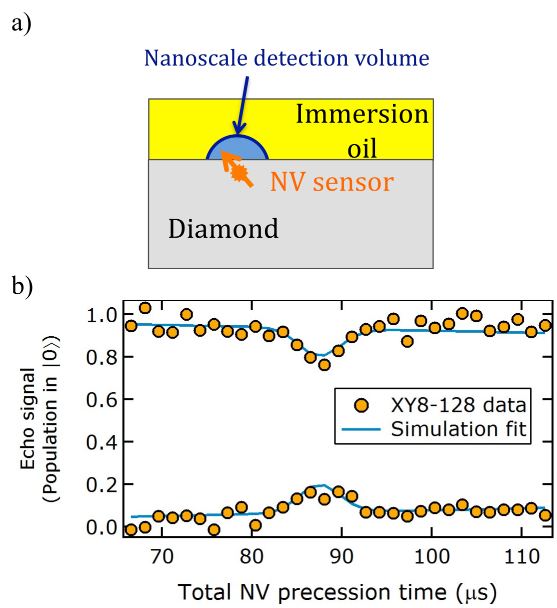

Figure 1: Nuclear magnetic resonance detection of a 10 nm^3 volume of nuclear spins in oil using a single NV centers in diamond. a) Plotted is the NV's Hahn echo signal, which dips at the frequency corresponding to the proton Larmor precession rate

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