Fabrication of Ultra-Sensitive Silicon Cantilevers with Integrated, Overhanging Nickel Magnet Tips for Magnetic Resonance Force Microscopy

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Magnetic resonance force microscopy (MRFM) is a technique that may one day allow us to acquire magnetic resonance images of single molecules – an extremely exciting prospect. To date we have demonstrated that MRFM can achieve a sensitivity of ~10^5 proton spins, using a custom-fabricated silicon cantilever with a hand glued, 9 micron diameter magnet tip. By making improved magnetic tips and mitigating surface dissipation, it may be possible to achieve single-proton sensitivity, leading to such exciting prospects as structural determination of large biomolecules.

Achieving the attonewton force sensitivity necessary to image single proton spins requires custom-fabricating cantilevers with extreme aspect ratios. In MRFM the force exerted on the cantilever, per spin, is proportional to the field gradient from the cantilever's magnetic tip. Achieving single proton sensitivity therefore also requires dramatically reducing magnet size. Unfortunately, all MRFM tips produced to date have been made by manually affixing magnets one-at-a-time to a cantilever. Even if the tips are ion-beam milled, it is difficult to see how they can be made small enough to detect a single proton. Likewise, ion-beam deposited tips have not yet reached the purity to produce the high magnetic field gradients desired for MRFM. We have developed an electron-beam-lithography (EBL) process for batch fabricating nanoscale tip magnets on ultrasensitive silicon cantilevers.

Research by our group has shown that surface induced dissipation is a major source of noise. This surface dissipation results from charge in the cantilever interacting with electric field fluctuations in the sample. This surface dissipation can be minimized by fabricating the magnets overhanging the end of the silicon cantilever.

We will present 50-600 nm wide nickel overhanging magnets fabricated by EBL and isotropic plasma etching. Cantilever magnetometry measurements show that the overhanging magnets have magnetic properties comparable to bulk nickel. The force sensitivity of the cantilevers is a few attoNewtons at 4.2 K. We will also present work on producing overhanging magnets by fabrication of magnets over sacrificial oxide pillars, and talk about the challenges of moving to higher field magnetic materials, such as cobalt and iron. With our designed cantilever, we expect a sensitivity of better than 10^3 protons.

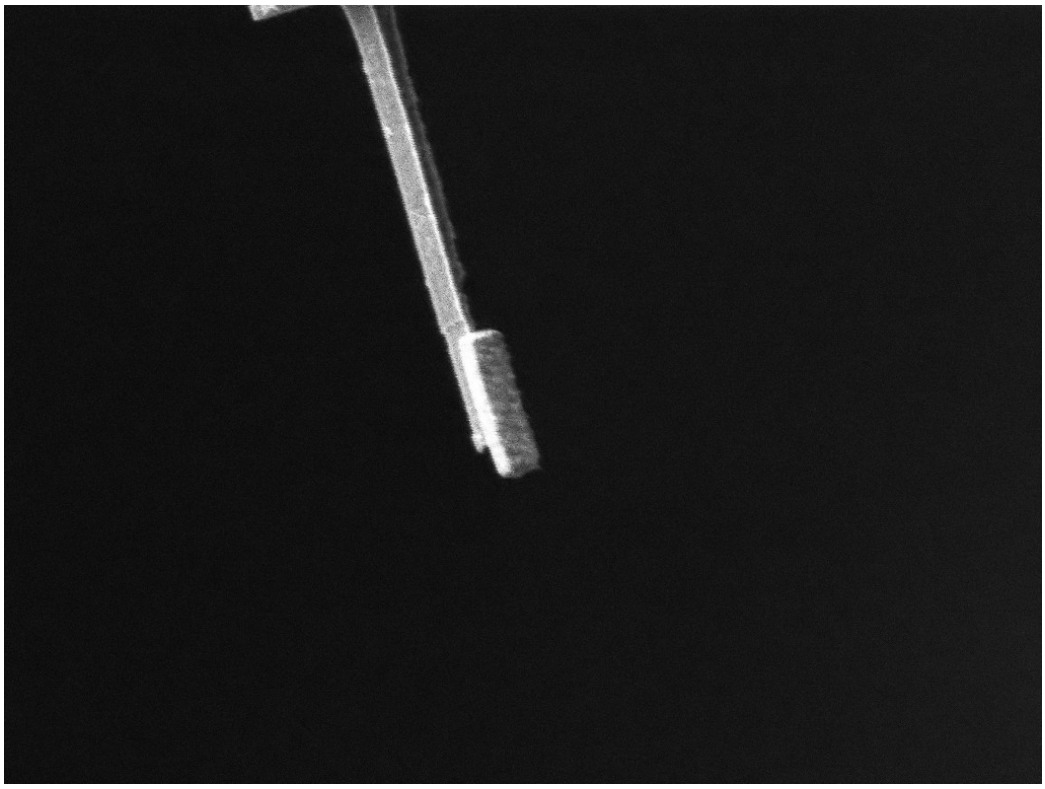

Figure 1: Nickel magnet (600 nm wide, 200 nm thick, 1500nm long) overhanging the end of a 340nm by 5 μm by 400 μm single crystal silicon cantilever