Magnetic Resonance Force Microscopy
Cantilever Detection by Quantum Tunneling

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Abstract
Magnetic resonance force microscopy is a novel characterization technique, with promising applications to nondestructive three-dimensional sample imaging. Magnetic resonance is detected as force on a magnet-tipped cantilever, with potential for atomic scale magnetic resonance imaging of biomolecules or semiconductors [1]. To achieve such a lofty characterization goal, high-Q nanomechanical magnet-tipped cantilevers are required. Here, we present a fabrication project in progress at the CNF that aims to appease this need; the integration of tunnel-based displacement detectors into the MRFM cantilevers.

Summary of Work
Magnetic resonance force microscopy (MRFM) aims to interrogate nuclear spins locally by setting the Larmour spin resonant condition with high spatial selectivity [1]. This is accomplished by a nanomagnet on the tip of an RF nanoscale singly-clamped cantilever. In an attempt to eliminate coupling between the cantilever and detection interferometer, we are considering a tunnel-based displacement detector. The tunnel sensors themselves consist of a break junction [2] between the beam and a fixed electrode; as the beam oscillates, the junction separation changes, and the tunneling current through the junction varies measurably. Calculations have shown that the measurement sensitivity is approximately $10^{-13} \text{m}/\sqrt{\text{Hz}}$, well within that required for MRFM. More importantly, this technique is viable around ambient temperatures of 300 K, while alternative methods (RF-SET’s, etc.) require cooling. The tunnel sensors are patterned with the JEOL JBX-9300 dedicated electron-beam lithography system, with a feature size of 30 nm. Optical lithography is used to define the interconnects to the probe station. RIE is then used to define the cantilevers and junction underetch.

To date, we have generated a fabrication protocol for tunnel sensors in doubly clamped cantilevers. We are currently characterizing the doubly-clamped beams with the magnetomotive actuation technique. Upon completion of the characterization, we will integrate the tunnel-based displacement detection mechanism with the nanoscale tip magnets (in a singly-clamped beam) to create a new generation of MRFM cantilevers.

References
Figure 1: Here, we see an array of fabricated tunnel sensors.

Figure 2: Up close, one can see the separation between the tunnel sensor and fixed electrode.