Ultrasensitive, Magnet-Tipped Cantilevers for Magnetic Resonance Force Microscopy

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Abstract
Magnetic resonance force microscopy (MRFM) is a developing technology in the family of force microscopy techniques. MRFM detects magnetic resonance as a force on a magnet-tipped microcantilever facilitating three-dimensional, chemically specific subsurface imaging at the nanoscale [1]. If sufficiently high sensitivities can be reached, this technique could achieve atomic scale magnetic resonance imaging, and could be used, for example, to read out the structure of large biomolecules or to study buried semiconductor interfaces. An essential step in achieving the required sensitivity is the development of high sensitivity cantilevers with nanoscale magnetic tips. Our work at the CNF has focused on creating 50-200 nm wide cobalt magnets which extend from the tips of 5 µm wide silicon cantilevers.

Summary
The purpose for creating overhanging nanoscale magnets is to maximize the force exerted on the cantilever by each magnetic spin, while minimizing noise in the force signal that arises from non-contact frictional forces between the cantilever and the sample. To achieve single-spin sensitivity, the front of the magnet must be within a few nanometers of the sample. Work by our group [2] has found that, within tens of nanometers of sample surfaces, metal has less friction than silicon, and that narrow cantilever tips have less friction than wider ones. Thus our cantilever design has the magnet extending past the end of the silicon cantilever, and the very tip of the silicon cantilever is narrowed from 5 µm to 1. Figure 1 is of a 50 x 50 x 1000 nm overhanging Co magnet on a test structure. The dotted line outlines the location of the cantilever edges in the final product. Figure 2 shows the entire cantilever and base. The octagonal area on the cantilever is the laser pad for our interferometer based motion detection system.

The fabrication process starts with <111> oriented silicon-on-insulator wafers. Electron-beam lithography with the JEOL-9300 is used to define the magnets, which are created through thermal deposition of cobalt and subsequent liftoff. A thin layer of oxide is deposited using the GSI PECVD to protect the magnets in subsequent processing. Next, the electron-beam lithography is used to define rectangular etch pits adjacent to the magnets. Plasma etching is used to etch these pits through the device layer of the wafer. The wafer is then etched in heated KOH. The design of the etch pits, the <111> orientation of the silicon, and the anisotropy of the KOH etch combine to undercut the silicon below a portion of the magnets, leaving the magnets extending...
The work in the past year has focused on process integration. After exhaustive testing, we suspect that cobalt silicide formation is causing the degradation of the magnets during the Unaxis backside etch step. Our current work is in modifying the backside etch process to minimize heating of the magnets, and seeking ways of reducing or eliminating the PECVD oxide layers.

References