

Integration of Carbon Nanotubes, Magnetic Nanocrystals, and Silicon Microstructures for Ultra-High-Resolution Magnetic Force Microscopy

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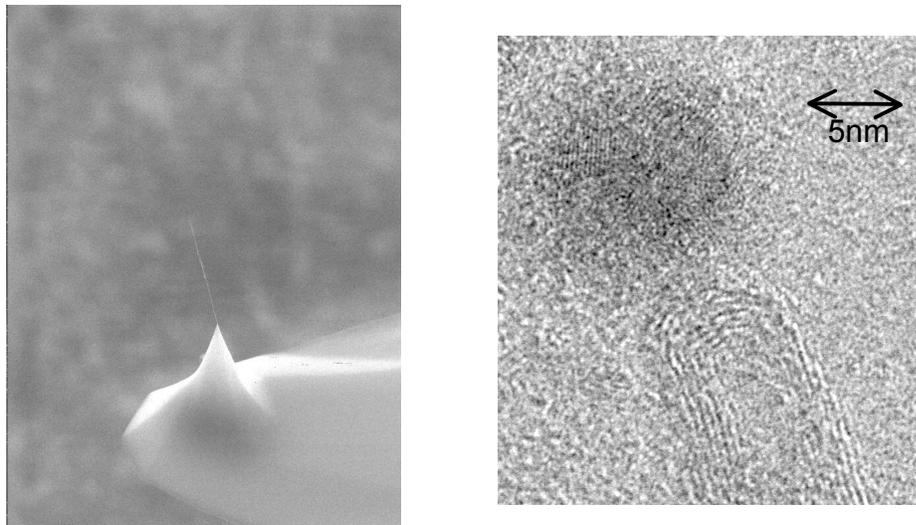
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Magnetic Force Microscopy (MFM) is one of the most promising and best-known techniques for probing magnetic phenomena on length scales approaching 10 nanometers, but the spatial resolution of MFM is presently limited to about 30 nanometers. Factors limiting the spatial resolution include both the force sensitivity of the cantilevers used for MFM and the ability to create controlled magnetic nanostructures on the cantilevers. In this project, we are investigating whether MFM sensors based on the integration of nanomagnets, carbon nanotubes, and optimized silicon microstructures can push these limits to allow sub-10-nm spatial resolution [1]. The PIs individually have experience in atomic force microscopy, novel magnetic microscopies, the growth of single-walled and multi-walled carbon nanotubes, the integration of carbon nanotubes with silicon microstructures, the growth and characterization of cobalt nanomagnets and nanorods, and the fabrication of high-bandwidth ultra-sensitive force cantilevers with integrated displacement sensors.

Research on "nanomaterials" such as bucky-balls, nanotubes, nanomagnets, molecular manufacturing, and many other examples has led to excited speculation regarding the technological promise of nanoscience. However, these nanotechnologies do not easily merge with conventional technologies such as microfabrication. Researchers in the Dai group have demonstrated methods for localizing the growth of carbon nanotubes on specific locations within a conventional microfabrication process [2], including the wafer scale production of carbon nanotube scanning probe tips for atomic force microscopy [3]. Researchers in the Kenny group have demonstrated that optimized cantilevers can allow atomic force microscopy with attonewton and even sub-attonewton force sensitivity [4,5]. Researchers in the Bawendi group have developed organometallic chemistry techniques to grow magnetic cobalt nanocrystals of a well-controlled size sheathed in organic ligands [6]. These three breakthroughs could allow nanotechnology to approach important technological applications. Combining these breakthroughs to integrate nanotubes and nanomagnets into MicroElectroMechanical Systems (MEMS) fabrication will allow us to produce a useful new family of ultrasensitive physical probes and develop realistic processes for the integration of nanomaterials and silicon microstructures.

We are pursuing three specific approaches to integrating nanomagnets with MEMS cantilevers for ultra-high-resolution MFM. The first approach is to attach a nanomagnet to a cantilever using a nanotube (see figure). The second approach is to attach a magnetic nanorod directly to a cantilever. The third approach is to coat a nanotube on a cantilever with a magnetic thin film. Each approach has potential advantages for MFM, and to make each approach work on real MFM cantilevers requires solving specific nanotechnology problems.



Left: SEM image of an AFM cantilever with a nanotube attached to it. The nanotube is barely visible. Right: TEM image of a single 9 nanometer cobalt nanomagnet attached to a nanotube. Both structures were fabricated by Van Ortega Cayetano, an undergraduate REU student working in the Moler group, using nanotubes from the Dai group and nanomagnets from the Bawendi group.

This research is being undertaken by an interdisciplinary research team, populated by a collection of graduate and undergraduate students from several departments in science and engineering. The fabrication of these sensors requires the integration of advanced nanomaterials and modern fabrication processes, benefiting researchers and industrial developers. Undergraduate and graduate students whose research includes the development of these techniques and their application to materials science will be well suited to make ongoing contributions to nanoscience and technology.

References

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