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Prospects for Imaging Magnetic Nanoparticles Using a Scanning Squid Microscope[1]

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Magnetic nanoparticles have a number of present and proposed uses: in the fields of nanobiotechnology for magnetic separation, magnetic manipulation, magnetic sensing, and in situ heating; for high density storage in both conventional and patterned media; and for spintronic devices. Although there are well established techniques for measuring the magnetic properties of large numbers of particles, it is desirable to magnetically image individual nanoparticles and clusters with small numbers of nanoparticles to determine such properties as their coercive fields, magnetic moments, and anisotropy energies. Wernsdorfer and co-workers [1] have shown that the magnetic reversal fields of small magnetic particles can be determined using a nanoSQUID. However, in these experiments nanoparticles were deposited directly on the SQUID. Such a technique would be difficult to use for the determination of, for example, the distribution in particle properties of a collection of particles. Woods and coworkers [2] determined the anisotropy energy of a film of magnetic particles from SQUID microscope measurements of the magnetic noise. In these experiments a large number of particles were included in the region sensed by the SQUID pickup loop, so that only average properties were determined. Measurement of the magnetic properties of individual nanoparticles is a challenge using any scanning probe microscopy, but is possible with the scanning SQUID microscope. In this talk I will describe different modes for imaging magnetic nanoparticles, present simple calculations of the size of signal expected for these modes as a function of such parameters as the size and saturation magnetization of the particles, the size of the pickup loop, and the spacing between the SQUID pickup loop and the nanoparticle, and compare these signals with the noise currently and ultimately available in scanning SQUID sensors [3]. I conclude that such measurements should be possible with the very small pickup loop (0.6 μm diameter) nanoSQUIDs that have now been demonstrated [4]. We have built and operated a high spatial resolution, variable sample temperature scanning SQUID microscope for imaging magnetic nanoparticles. I will describe this microscope and present results on imaging magnetic nanoparticles. * Work done in collaboration with Beena Kalisky, Lisa Qian, and Kathryn Moler.

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