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Ultrasensitive magnetometry and magnetic resonance imaging using cantilever detection[1]

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Micromachined cantilevers make remarkable magnetometers for nanoscale measurements of magnetic materials and for magnetic resonance imaging (MRI). We present various applications of cantilever magnetometry at low temperature using cantilevers capable of attonewton force sensitivity. Small, unexpected magnetic effects can be seen, such as anomalous damping in magnetic field. A key application is magnetic resonance force microscopy (MRFM) of both electron and nuclear spins. In recent experiments with MRFM-based NMR imaging, 3D spatial resolution better than 10 nm was achieved for protons in individual virus particles. The achieved volumetric resolution represents an improvement of 100 million compared to the best conventional MRI. The microscope is sensitive enough to detect NMR signals from adsorbed layers of hydrocarbon contamination, hydrogen in multiwall carbon nanotubes and the phosphorus in DNA. Operating with a force noise on the order of 6 aN per root hertz with a magnetic tip that produces a field gradient in excess of 30 gauss per nanometer, the magnetic moment sensitivity is $\sim$0.2 Bohr magnetons. The corresponding field sensitivity is $\sim$3 nT per root hertz. To our knowledge, this combination of high field sensitivity and nanometer spatial resolution is unsurpassed by any other form of nanometer-scale magnetometry.

[1]Work performed in collaboration with H. J. Mamin, M. Poggio, C. L. Degen, T. Oosterkamp and C. T. Rettner