Selected NIST/EEEL Accomplishments in Nanoscale Science, Engineering, and Technology in 2003

NIST Ultra-Sensitive Microcantilevers Measure Magnetic Films with Sub-Atomic-Layer Resolution

Work at NIST/EEEL to develop ultra-sensitive torque magnetometers has lead to quantitative measurements of micrometer-scale magnetic dots. Measurements are based on the detection of mechanical torques on thin films deposited onto microcantilevers. A main challenge of these techniques is getting well-defined micromagnetic samples onto the cantilevers. To this end, NIST scientists developed a wafer-level microfabrication process in which the film deposition and patterning are combined with the cantilever micromachining process. This allows magnetic measurements of samples with a total magnetic moment smaller than that detectable with conventional magnetometers.

Cantilevers with low spring constants and high mechanical quality factors are essential for these measurements. The NIST cantilevers are double torsional oscillators made from single-crystal silicon with resonant frequencies of 120 kilohertz and mechanical quality factors of 12,000 or more. In the dynamic deflection method, the cantilever and magnetic film are placed in an external magnetic field. A small orthogonal ac torque field is applied at the cantilever resonant frequency, and the resulting torque is measured as a function of external field. A Ni-Fe square, 5 micrometers x 5 micrometers x 30 nanometers thick, had a measured magnetic moment of 0.51 picojoule per tesla. The cantilevers have a torque resolution of 0.84 attonewton-meter, corresponding to a magnetic moment noise level of 6.7 femtojoules per tesla. Thus, magnetic moments can be measured with a resolution below that of a complete atomic layer of Ni-Fe. With improvements in microfabrication, the target sensitivity is 100,000 Bohr magnetons (1 attojoule per tesla) at room temperature.

Micrometer and sub-micrometer scale magnetic measurements have proven to be a challenge for conventional magnetometers. Conventional measurements are made on arrays of micromagnetic dots. However, due to fabrication limitations, the results are clouded by statistical variations in dot shape, size, and spacing. Thus, more sensitive detectors are needed that can measure magnetic properties on individual dots. One way to understand spin damping in ferromagnetic systems is to investigate size effects as magnetic devices are reduced to sub-micrometer dimensions. Studies of magnetic nanodots will give a better understanding of spin damping and aid in the development of faster disk drives.

Moreland, J.M., "Micromechanical instruments for ferromagnetic measurements," J. Phys. D, 36, 39 (January 2003); Chabot, M.D., Moreland, J.M., "Micrometer-scale magnetometry of thin Ni80Fe20 films using ultra-sensitive microcantilevers," J. Appl. Phys. 93, 7897 (May 2003).

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