Fe_3O_4 Nanomachine Manipulated Magnetically

Ever since 1959, when physicist Richard Feynman famously declared "there's plenty of room at the bottom," researchers have worked feverishly to make functional materials smaller and smaller. Of interest to many in this field are micro- and nanomachines that have the ability to manipulate other small materials. Instruments such as these are helping researchers to develop an understanding of mechanical motion on the nanoscale. A team of researchers from Jilin University in China led by H.-B. Sun recently developed a new magnetically controlled micro-spring using two-photon polymerization that may help improve the understanding of nanomechanics.

As described in the March 1 issue of *Optics Letters* (DOI:10.1364/OL.34.000581; p. 581), the researchers prepared iron-oxide–loaded springs using two-photon polymerization. The springs, formed from a photoresist consisting initially of methyl methacrylate as monomer, pentaerythritol triacrylate as the cross-linker, and a small amount of photoinitiator and photosensitizer, were loaded with 10 nm superparamagnetic Fe_3O_4 nanocrystals. The researchers determined loading of iron oxide nanocrystals by thermogravimetric analysis to be 2.4%. Using a computer-controlled Ti-sapphire laser (790 nm), the resin was cured with tightly focused femtosecond laser pulses. Scattering from the nanoparticles limited the overall resolution of the polymerization technique. In the end, the magnetic springs were 15 μm wide and as tall as 200 μm.

Spring motion was induced when the device was subjected to a magnetic field gradient. The spring was shown to stretch and to bend in a variety of organic and aqueous solvents. Regardless of the solvent, no change in elasticity was detected. The researchers said that the new magnetic springs may be more useful than springs driven by typical optical driving mechanisms in certain nanomaterial and biological applications, (e. g., operatng a micromachine inside a blood vessel).

In addition, the researchers look forward to improving the device functionality and to moving on to more complex systems with the hope of placing functional nanomachines inside human blood vessels to perform disease diagnosis and treatment.

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Rewritable Conductive Channels Observed in Multiferroic $BiFeO_3$

An international team of researchers led by R. Ramesh (University of California at Berkeley) has observed conductivity at ferroelectric domain walls in $BiFeO_3$, presenting a new degree of functionality in the popular multiferroic and the possibility of rewritable nanoscale devices. The research team, including J. Seidel and L.W. Martin (UC-Berkeley; Lawrence Berkeley National Laboratory), Y.-H. Chu (UC-Berkeley; LBNL; National Chiao Tung University in Taiwan), A. Rother (Technische Universität Dresden, Germany), P. Maksymovych (Oak Ridge National Laboratory), S. Gemming (Forschungszentrum Dresden-Rossendorf), G. Catalan (University of Cambridge, UK), N.A. Spaldin (University of California at Santa Barbara), and their colleagues, report their findings in the March 2009 issue of *Nature Materials* (DOI: 10.1038/nmat2373; p. 229).

The research team grew $BiFeO_3$ (BFO) films by laser-molecular-beam epitaxy on $SrTiO_3$ substrates with bottom electrodes of $SrRuO_3$. By writing ferroelectric domain patterns with piezoresponse force microscopy (PFM), the researchers created three types of domain walls: 71°, 109°, and 180°, where the angle refers to the change in orientation of the polar moment across the domain wall. They measured conductivity across the films using conductive atomic force microscopy (c-AFM) and found, to their surprise, that the 109° and 180° walls conduct electricity, displaying Schottky-like response when probed with the scanning probe tip, in stark contrast to the resistive behavior measured in the rest of the film.

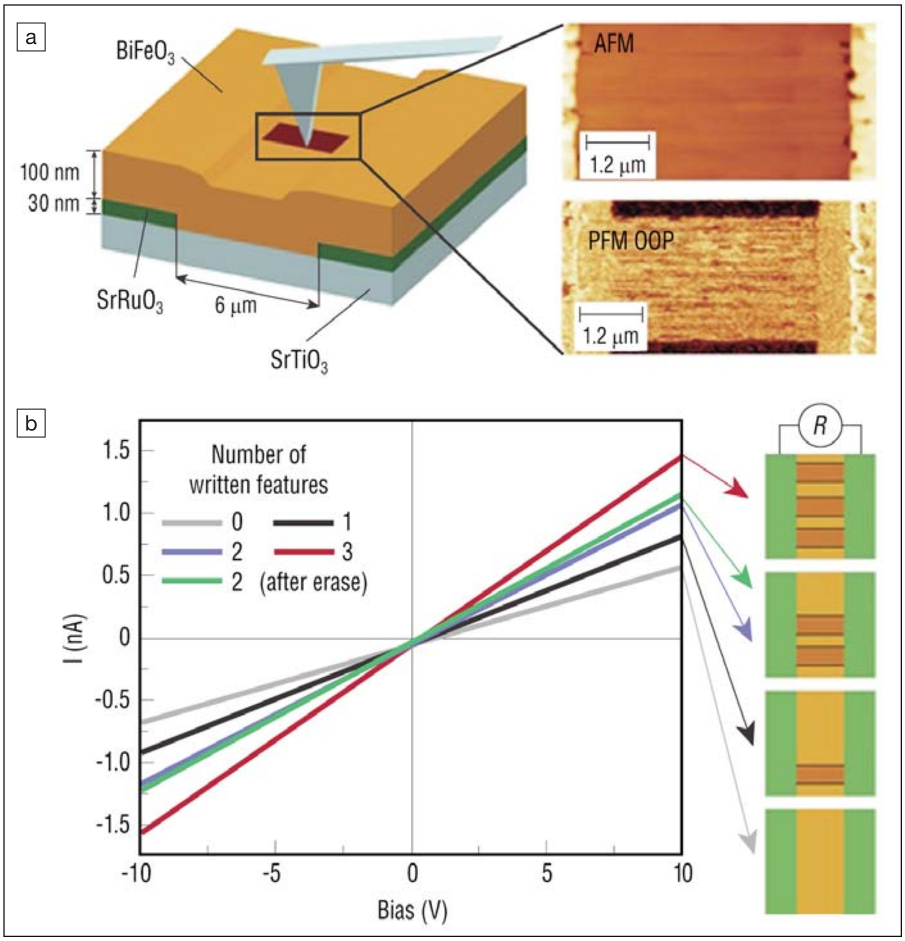

Figure 1. (a) Drawing conductive channels in a $BiFeO_3$ device: (left) a schematic of the in-plane electrode set up; (right) images of the domain area written by atomic force microscopy (AFM, top) and piezoresponse force microscopy (PFM, bottom).
(b) Current–voltage measurements of the device for varying number of channels, showing incremental increase in current and complete reversal on erasing a channel. Reprinted by permission from Macmillan Publishers Ltd: *Nature Materials* **8** (3) (2009), ©2009.

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