Triangular Diode Acts as Asymmetric Energy Barrier to Magnetic Domain Wall Movement

Control of domain wall propagation in magnetic nanostructures is vital to both the understanding of domain wall properties such as wall resistance along with the science required for applications such as novel domain wall logic devices. In the October 4 issue of *Applied Physics Letters* (p. 2848), D.A. Allwood and co-workers from the University of Durham, UK, have reported the synthesis and characterization of a lithographically-patterned magnetic structure that allows control of wall propagation along a single direction. A domain wall diode is constructed by joining planar nanowires (fabricated by focused ion-beam milling of a 3 nm thick thermally evaporated $Ni_{80}Fe_{20}$ permalloy thin film on silicon) with a structure in the form of an isosceles right-angle triangle having a 500-nm base length. Each nanowire is 9 µm in length; one 200-nm width wire is joined at the apex of the triangle along with a 100-nm width wire at the base.

Three different magnetic structures were created containing this diode. Structure I has no additional components, Structure II has a 3 µm × 600 nm "domain wall injection pad" connected to the 200-nm width wire, and Structure III has a 3 µm × 600 nm pad connected to the 100-nm width wire. Analysis on these structures was performed using a high-sensitivity magneto-optical Kerr effect (MOKE) magnetometer with a 27 Hz alternating magnetic field applied along the wire long axis and a 5 µm diameter laser interrogation spot. Hysteresis loops were measured for each structure (Figure 1). For Structure I, nucleation and propagation of a wall is manifested as a sharp transition. However, single 200 nm wires exhibited transitions at the same value of coercivity, indicating that these domain walls may originate in the wire ends of the structure. For Structure II, a wall is injected from the pad into the 200-nm width wire. The geometry of the diode requires the width of the propagating wall to increase, causing minimal pinning before propagation to the 100-nm width wire occurs. For Structure III, a wall is injected into the 100-nm width wire, but is unable to de-pin from this section through to the diode (reversal in the 200-nm width wire is due to nucleation). Calculations of the pinning field suggest the triangular diode can be seen as an asymmetric energy barrier to wall propagation. Overall, said the researchers, these measurements demonstrate that wall propagation occurs in one direction. Hence this is truly a domain wall diode that can be utilized in memory applications requiring intrinsically defined directions of wall propagation, they said.

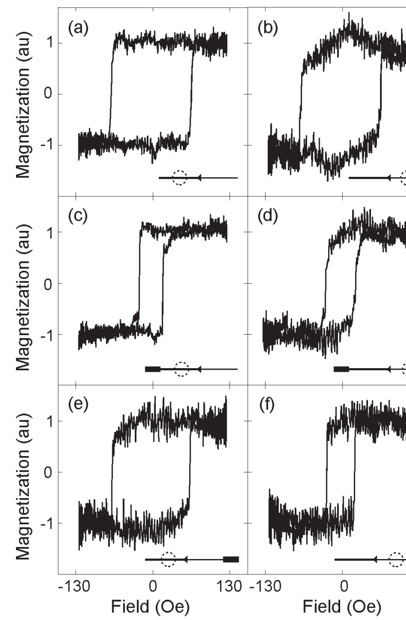

Figure 1. Hysteresis loops measured by magneto-optical Kerr effect for Structure I (a) with the laser beam on the 200 nm wire and (b) with the laser beam on the 100 nm wire; Structure II (c) 200 nm wire and (d) 100 nm wire; and Structure III (e) 200 nm wire and (f) 100 nm wire. Also inset to each plot is a schematic of the relevant structure and MOKE measurement position, indicated by the broken circle. Reprinted with permission from Applied Physics Letters ***85*** *(October 4, 2004). © 2004 AIP.*

ADITI S. RISBUD

New Photochromic Bands Observed in Functionalized Semiconducting SWNTs

Nanosensors are one of the many potential applications for single-walled carbon nanotubes (SWNTs). Previously, it was shown that SWNTs can function as sensors by using chemical doping, high-pressure reforming, or adsorption of atoms or functional groups to modify their electronic properties. Recently, R.F. Khairutdinov of the University of Alaska in Fairbanks and M.E. Itkis and R.C. Haddon of the University of California in Riverside have demonstrated that light can be used as a simple and convenient tool to control the electronic characteristics and, thereby, the conductivity of SWNTs.

As reported in the August issue of *Nano Letters* (p. 1529), the research team

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reversibly modified the interband transition (S_{11}) intensities in semiconducting SWNTs—by light-induced refilling and depletion of the valence band—and in spiropyran-functionalized SWNTs (SP-SWNTs) by photoinduced changes in the dye's polarity. It is well-known that spiropyran molecules exhibit photochromic effects under UV-excitation, undergoing a transition to the merocyanine form. In this work, the researchers showed that the S_{11} modulation of SP-SWNTs corresponds to the UV-induced, reversible conversion of spiropyran by a ring-opening reaction to its merocyanine form. However, they also observed an absorption band at 440 nm that they indicate is due to the merocyanine aggregation by the functionalized SWNTs. Absorption-band shifts observed for merocyanine-SWNTs indicated to the researchers that the dye's π-electron system strongly interacts with the SWNT. In addition, the researchers interpreted other spectral features as evidence that spiropyrans/merocyanines are either bonded to the sidewalls or to the ends of the SWNTs. They used atomic force microscopy to show that SP-SWNTs exist in solution both as individual nanotubes and bundles of 2–5 nanotubes with lengths in the range of 0.4–2 μm.

The researchers said that discovering the nature of SWNT-substrate interactions will lead to further advances in SWNT-based chemical sensors. Furthermore, they believe that their work "presents an impetus for an exploration of a new type of chemical sensors based on the interaction of an analyte with a host molecule."

STEVEN TROHALAKI

WS_2 Nanotubes Synthesized for Lithium Storage

The discovery of fullerenes and carbon nanotubes has led to extensive research aimed toward the synthesis of similar one-dimensional nanostructures to carbon nanotubes, but based on different materials. These novel nanomaterials could find applications in diverse fields such as quantum computing, sensing and biomedical devices, and energy needs such as hydrogen storage. An example for such one-dimensional nanomaterials is WS_2 nanotubes discovered by R. Tenne and co-workers in the early 1990s.

In the October issue of *Electrochemical and Solid-State Letters* (p. A321), G.X. Wang, S. Bewlay, J. Yao, H.K. Liu, and S.X. Dou from the University of Wollongong, Australia report a major breakthrough in utilizing such WS_2 nanotubes for storing lithium in Li-ion batteries. Li-ion batteries are the most commonly used type of rechargeable batteries in portable electronic devices. Wang's research team has focused on how lithium is stored in WS_2 nanotubes, which represents an important process in using these materials as electrodes or anodes in rechargeable batteries.

The researchers synthesized WS_2 nanotubes from amorphous WS_3 at high temperature in a hydrogen atmosphere. They report a very high yield of ~80%. Characterization of the material by transmission electron microscopy with field emission indicated that the nanotubes have a length of a few hundred nanometers, have open tips, a diameter between 30 nm and 40 nm, with wall thicknesses of ~15 nm. The hollow core measured roughly 4.6 nm. Electrochemical properties were assessed based on coin cell testing.

Wang and co-workers identified electrochemical properties of the WS_2 nanotubes that differ significantly from WS_2 as a powder material. The WS_2 nanotube electrode

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