Template-Grown Ni-Cu Nanowires Show High Magnetization and Enhanced Coercivities

Magnetic nanoparticles and their potential applications have received increasing attention in recent years. Nanoscale particles of ferromagnetic elements are the size of single magnetic domains and exhibit high coercivities relative to the bulk metals, making them candidates for use in memory devices. However, current methods of assembling ordered arrays of nanoparticles for inclusion in devices are not cost-effective. As reported in the February 11 issue of *Chemistry of Materials*, a group of researchers at the Chinese Academy of Sciences has prepared an ordered array of Ni-Cu composite nanowires by using a facile template-based method. The nanowires exhibit the same desirable properties as arrays of simple nanoparticles.

Yu-Guo Guo and co-workers used anodic aluminum oxide (AAO) membranes with well-defined arrays of columnar pores as templates for nanowire growth. The templates were immersed in a solution of copper sulfate and nickel sulfate, and the plating potential was pulsed in order to fill the pores with alternating layers of Ni and Cu. The AAO membrane was then dissolved, leaving behind an ordered array of nanowires, as confirmed by transmission electron microscopy.

Magnetic force microscopy revealed that each Ni segment behaved as a single magnetic domain, and that the magnetization direction was the same for all segments in the wire. The coercivity for an array of nanowires was found by superconducting quantum-interference device measurements to be ~490 Oe, compared with 0.7 Oe for bulk Ni. The researchers said that the saturation magnetization was comparable to that of the bulk metal.

Arrays of magnetic nanowires had previously been grown within AAO membranes, but the single-domain structure seen in nanoparticles was lost, and the coercivity was accordingly much lower. The researchers concluded that alternating segments of ferromagnetic Ni with nonferromagnetic Cu within the nanowire preserves the enhanced coercivities found in nanoparticles while allowing for a simple method of preparation. The group said that these features make composite nanowires suitable for use in high-density recording media or in other technological applications.

CATHERINE OERTEL

Review Articles

The January 2003 issue of *Reviews of Modern Physics* **75** (1) (partial issue) contains the following review articles: W.G. van der Wiel, S. De Franceschi, J.M. Elzerman, T. Fujisawa, S. Tarucha, and L.P. Kouwenhoven, "Electron Transport through Double Quantum Dots," p. 1; and J.R. Banavar and A. Maritan, "Colloquium: Geometrical Approach to Protein Folding: A Tube Picture," p. 23.

The *Journal of Applied Physics* **93** (2) (2003) contains D.G. Cahill, W.K. Ford, K.E. Goodson, G.D. Mahan, A. Majumdar, H.J. Maris, R. Merlin, and S.R. Phillpot, "Nanoscale Thermal Transport," p. 793.

The *Annals of Biomedical Engineering* **31** (1) (2003) contains A.C. Shieh and K.A. Athanasiou, "Principles of Cell Mechanics for Cartilage Tissue Engineering," p. 1.

Microelectronics Reliability **43** (1) (2003) contains M. Ruprecht, G. Benstetter, and D. Hunt, "A Review of ULSI Failure Analysis Techniques for DRAMs. Part II: Defect Isolation and Visualization," p. 17.

Advanced Materials **15** (1) (2003) contains S.M. O'Flaherty, S.V. Hold, M.J. Cook, T. Torres, Y. Chen, M. Hanack, and W.J. Blau, "Molecular Engineering of Peripherally and Axially Modified Phthalocyanines for Optical Limiting and Nonlinear Optics," p. 19.

Reviews of Scientific Instruments **73** (12) (2002) contains J.F. Power, "Inverse Problem Theory in the Optical Depth Profilometry of Thin Films," p. 4057.

AIAA Journal **40** (11) (2002) contains I. Chopra, "Review of State of Art of Smart Structures and Integrated Systems," p. 2145.

Advanced Engineering Materials **4** (12) (2002) contains F. Christin, "Design, Fabrication, and Application of Thermostructural Composites (TSC) like C/C, C/SiC, and SiC/SiC Composites," p. 903.

Proteomics **2** (12) (2002) contains B. Seliger and R. Kellner, "Design of Proteome-Based Studies in Combination with Serology for the Identification of Biomarkers and Novel Targets," p. 1641.

The International Journal of Quantum Chemistry **91** (3) (2003) contains the proceedings of the Ninth International Conference on the Application of the Density Functional Theory to Chemistry and Physics—Part II.

The November 2002 issue of the *Journal of Vacuum Science and Technology B* contains papers from the Third Low Energy Electron/Microscopy Photoemission Electron Microscopy Workshop and papers from the 46th International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication.

The October 2002 issue of the *Journal of Biomedical Optics* features a special section on "Tools for Biomolecular and Cellular Analysis."

In Situ Soldering Attaches Nanotubes to Electrodes

In order to exploit the mechanical and electrical properties of carbon nanotubes (CNTs) in nanodevices, several attachment methods have been developed. These methods rely on lithographic techniques, involve electrical connections, or depend on the particular nanocomponents involved. Recently, however, a team of researchers from the Microelectronik Center (MIC) at the Technical University of Denmark and the catalyst company Haldor Topsøe A/S in Lyngby, Denmark, has developed a general, *in situ* soldering method for attachment of CNTs to microelectrodes by using a highly conductive gold–carbon composite. This method allows three-dimensional nanostructure assembly without many of the limitations of those previously developed.

As reported in the January issue of *Nano Letters*, Technical University of Denmark researcher P. Bøggild and co-workers performed the soldering by locally decomposing dimethylacetylacetonate gold(III) (which has a vapor pressure of 1 Pa at 25°C) with an electron beam. The organometallic compound is placed in a container with a narrow bore tube to control the diffusion of vapor onto the sample. At room temperature, a growth rate of 500 nm/min was obtained with a 0.8-mm-diameter, 2-mm-long tube. Soldering bonds with lengths >10 μm were grown without a conspicuous decrease in the growth rate.

Two cantilever microelectrodes on a silicon chip, positioned with a nanomanipulator stage, were connected to a dc voltage source. Freestanding multiwalled CNTs were prepared by chemical vapor deposition and shown by transmission electron microscopy (TEM) to be >20 μm long and 80–120 nm wide. In an environmental scanning electron microscope, a microelectrode pair was manipulated so that a nanotube extending from the sample traversed and contacted the electrodes. Two cross-shaped, gold–carbon soldering bonds were then formed by slowly scanning the beam across the nanotube at the point of contact to one of the electrodes. In addition, a set of protective bonds near the edge of the electrode were deposited so that the nanotube section extending past the electrode could be broken off without affecting the soldering bonds.

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The researchers said that electrical contact was established the instant the nanotube was soldered to the second electrode. Metallic conduction was indicated by a linear current–voltage relationship. The researchers connected four nanotubes to microelectrode pairs and obtained reliable ohmic contacts with resistances in the range of 9–29 kΩ. The resistances show no clear correlation to the lengths of the bridges, were unaffected by the nanotube extensions, and were found to be constant in air for several days.

The researchers verified the intrinsic conductivity of the soldering material by depositing gold–carbon bridges between microelectrode pairs and measuring the current–voltage characteristics. Ohmic resistances between 80 kΩ and 520 kΩ were observed. By using scanning electron microscopic images to estimate the bridge's cross section and assuming a 60-Ω serial resistance, the researchers calculated resistivities of ~10^{-4} Ω cm. TEM analysis revealed that the soldering material is composed of a gold–carbon composite structure with a porous crust of 3–5 nanoparticles surrounding a dense core.

"There are strong indications that this core is almost pure gold," said Bøggild, "and we know now how to control the core diameter with respect to the crust to engineer the composition of the material.

Attaching multiwalled CNTs to microelectrodes with a nonmetallic carbonaceous material resulted in devices with electrical conduction in the megohm range, which the researchers believe indicates that the metallic content of the soldering material is necessary for good electrical contact.

The researchers found the soldering bonds to be mechanically strong compared to the multiwalled CNTs. Further quantitative investigation will involve integration of a piezoresistive force sensor into their setup. The researchers said that they "anticipate automated electron-beam nanosoldering to be useful for quickly connecting complex circuitry consisting of nanoscale components in a way similar to the soldering of electronic components on the macroscale."

Bøggild added, "The solder material is a metal-containing gas, the soldering iron is a beam of electrons, but apart from that, it's basically the same thing."

STEVEN TROHALAKI

Electrochemical Technique Forms High Corrosion-Resistant Silicate Layer on Zn-Plated Steel

Currently, Cr conversion coatings, which are deposited from toxic hexavalent baths, are used to protect steel, zinc, and other metals from corrosion, but silicate coatings are being considered as a substitute. The silica deposit yields better corrosion characteristics as compared to Cr conversion coatings, but the fabrication procedure is laborious, time-consuming, and not suitable for commercial application. As reported in the February issue of *Electrochemical and Solid-State Letters*, a group of researchers from the University of South Carolina and Elisha Technologies Co. have synthesized a stable deposit with uniform layers of SiO_2 on a zinc surface by cathodic electrolysis of zinc-plated panels.

B.N. Popov from the university and coworkers used an N sodium silicate solution with 28.4 wt% SiO_2, 9.1 wt% Na_2O, and 62.5 wt% H_2O for SiO_2 electrodeposition. They found that optimal conditions for cathodic electrodeposition of a dense SiO_2 film on Zn-coated steel consist of a concentration of 5.6 wt% of sodium silicate in water (pH = 10.5), potential 12 V (in a two-electrode cell) for 15 min at 75°C. A SiO_2 film forms because of an increase in pH near the electrode surface and hence, the polymerization of silicates on the surface. At the same time, dipping the same sample into the solution with no current applied did not lead to the formation of SiO_2 film. Air-drying the samples after electrodeposition significantly increased the resistance of the coatings due to a decrease in the average crack size in the coating, as confirmed by scanning electron microscopy. Corrosion resistance measurements showed that the silicate coating provided a much better performance with at least one order of magnitude higher resistance than the Cr conversion coating.

MAXIM NIKIFOROV

Ellipsometry Achieves Determination of Optical Constants and Crystal Orientation for Biaxial Absorbing Materials

Ellipsometry is a well-known technique used to determine optical constants from isotropic bulk and thin-film structures, and generalized ellipsometry extends to layered anisotropic materials. In the December 1, 2002 issue of *Optics Letters*, M. Schubert (Universität Leipzig, Germany and University of Lincoln—Nebraska, USA) and W. Dollase (University of California, Los Angeles, USA and Universität Bayreuth, Germany) have shown that the generalized ellipsometry technique is able to determine not only all optical constants of a biaxial absorbing material, meaning the indices of refraction and extinction coefficients for the three principal axes of refraction, but also the specific crystal orientation from a single bulk sample.

The researchers studied the metal chalcogenide stibnite (Sb_2S_3), an orthorhombic material that has become of interest recently because of its use in television cameras, microwave switching, and optoelectronic devices. Ellipsometric measurements were performed for a wavelength of 589 nm, for incidence angles from 20° to 70°, every 10°, and as a function of the in-plane sample rotation, that is, for a full sample azimuth revolution. The technique revealed the three principal indices of refraction (3.379, 5.075, 4.417) and the three extinction coefficients (0.090, 0.1, 0.27). Furthermore, assuming the existence of an oxide overlayer on the surface of the material, the data analysis showed an index of refraction of 1.15, and a thickness of the order of 11–12 nm. The absolute orientation of the samples was also determined through the identification of the three Euler angles that describe the orientation of the crystal axes relative to the lab axes. The orientation for three different samples reached excellent agreement with that obtained by x-ray diffraction. The researchers suggest that generalized ellipsometry could be a powerful tool for measurement of anisotropic optical function spectra of biaxial materials.

ROSALIA SERNA

High-Efficiency Electro-Optic Modulator with Low-Loss Waveguides Fabricated

Electro-optic (EO) waveguides and modulators are critical components in modern fiber-optic communications systems. Currently produced devices are limited by high loss of light signal in the near-IR region. Recently, the fabrication and testing of a potentially superior EO modulator design was reported by W.H. Steier and co-workers in the Department of Electrical Engineering at the University of Southern California along with researchers at Zen Photonics in Daejon, Korea, and Pacific Wave Industries in Los Angeles, Calif. The researchers describe a Mach-Zehnder (MZ) modulator which incorporates low loss passive polymers in noncritical areas of the device, and features passive polymer waveguides to reduce signal loss due to mode mismatch between the modulator and connecting optical fibers. While the created device exhibited lower efficiency than their best modulators, the researchers believe that this reflects a limitation of the materials used for device construction and not the design itself. According to Steier, "The integration of passive and EO polymers makes this a practical approach for use in large-scale optical integrated circuits."

As described in the December 1, 2002, issue of *Optics Letters*, the researchers used

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