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 layer-by-layer growth 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

**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 Topsoe 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 nanoscale assembly within 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 dimethylethylacetonate 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.

**Review Articles**


The October 2002 issue of the *Journal of Biomedical Optics* features a special section on “Tools for Biomolecular and Cellular Analysis.”
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 how to control the core diameter with respect to the crust to engineer the composition of the material.

Attaching multiwalled CNTs to microelectrodes without metallic 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**

**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. Döllase (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 (Sb2S3), an orthorhombic material that has become of interest recently because of its use in telecommunication, 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.

**Rosalía Serna**