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