duced a composite material from a series of thin copper rings and ordinary copper wire strung parallel to the rings. The composite is among a new class of materials called "metamaterials," so called for the way in which the mixing or arrangement of two or more materials at a very fine level can affect the electromagnetic properties of the resulting composite.

This class of materials has the ability to reverse properties such as the Doppler effect, which is the change in the observed frequency of a wave as the source moves relative to the observer. In ordinary materials, the Doppler effect is manifested as an increase in the frequency of emitted radiation as a source approaches. Maxwell's equations, which describe the relationship between magnetic and electric fields, suggest that microwave radiation or light would show the opposite effect in this new class of materials, shifting to lower frequencies as the source approaches.

Similarly, Maxwell's equations suggest that a lens made of such materials, instead of dispersing electromagnetic radiation, would focus it as it passes through.

Schultz said, "If these effects turn out to be possible at optical frequencies, this material would have the crazy property that a flashlight shining on a slab can focus the light at a point on the other side."

The scientists demonstrated the ability to reverse these properties by beaming microwave radiation through the composite material. Their results verified that the composite had negative electric permittivity and negative magnetic permeability. In most known materials in nature, these qualities are positive.

Steel-Recycling Innovation Includes Aluminum to Control Impurities

When steel producers recycle steel scrap, tin from tin-plate scrap and copper from domestic incinerator scrap accumulate in the steel, posing a major problem for the steel industry unless controlled properly. Such impurities have harmful effects on ductility, causing defects in the worked material. Scientists at Leeds University have discovered that the controlled addition of aluminum to molten steel during recycling forms alloys with the tin and/or copper, rendering both harmless.

The method is simple, cheap, and environmentally friendly. The source of aluminum can be pure metal, an alloy, or a compound capable of dissociation at the operating temperature. However, one source is aluminum cans, currently recycled separately from steel cans. "Why go to the trouble of separating them when they contain the very ingredient we want to add?" said team leader Bob Cochrane. "An obvious extension of our process would be to charge mixed loads of scrap, saving on sorting costs."

The addition of a metal as an alloying agent is a radical departure from conventional treatments, which extract the unwanted metals by chemical or electrochemical methods in de-tinning plants. These methods are expensive and use environmentally unfriendly chemicals. De-tinning plants also have limited capacity, and environmental considerations are increasingly putting constraints on their expansion.

Furthermore, Cochrane said that a com-

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bination of tin-plate scrap, aluminum scrap, and domestic incinerator scrap may serve to produce a "master alloy" or stepping stone to produce a higher quality material compared with remelted steel scrap. This would be particularly advantageous to countries that currently have no indigenous steel industry, he said.

Initial studies show that the presence of aluminum causes an increase in the hardness of the steel, implying an increase in mechanical strength. These encouraging findings are being evaluated, and once this has been completed, the team intends to replicate the process at pilot-plant scale.

Si Nanowires Produced with Aid of Gold Quantum Dots

Brian Korgel and Keith Johnston, professors in the Department of Chemical Engineering at the University of Texas—Austin, have produced silicon nanowires by using particles of gold suspended under pressure in a compressed fluid at a high temperature. As reported in *Science*, they heated silicon atoms connected to organic molecules until the Si atoms loosened and formed free Si atoms. Done in the presence of gold quantum dots (QD) or nanocrystals, the free Si atoms then dissolve in the QDs. When the silicon concentration inside the gold becomes great enough, the gold ejects the silicon in the form of a wire. Molecular capping ligands can be attached chemically to the gold QDs during their formation to keep them uniform in size.

The researchers' method involves the use of supercritical fluids, in this case, 5000 lbs/in^2 at 500°C. Johnston said, "We have used supercritical fluids to control chemical reactions…but never for the nanoscale materials."

Korgel said, "At that temperature, we would expect the molecules to form a gas, but the pressure squeezes the molecules back into a fluid. Although this fluid is not a liquid in the sense that we think of liquids, it is, in fact, a supercritical fluid. These supercritical fluids have a variety of very interesting properties in their own right, and we are starting to exploit this unique medium to make new materials that cannot be made any other way."

Korgel said that at the nanoscale, silicon behaves differently than usual. For example, only at the nanoscale does silicon emit light. The researchers want to control the size of the quantum wire to engineer materials with specific properties. Changing the supercritical fluid's pressure affects how the layers of Si in the nanowires are arranged, dramatically changing their optical properties. The researchers want to explore this behavior in order to channel electrons in one direction.

Nanoclusters of Metallic Gold Display Optical Chiral Properties

Robert L. Whetten's research group at the Georgia Institute of Technology has presented experimental evidence that nanoclusters of metallic gold—assemblies containing between 20 and 40 gold atoms encapsulated by a common biomolecule—can display distinctly chiral properties. The chiral nature of the clusters, which means they exist in distinct right-handed and left-handed variations, affects the way in which they absorb polarized light in the visible and near-infrared spectra. This optical effect had been predicted theoretically to occur in metal nanostructures, but Whetten's team measured it experimentally.

T. Gregory Schaaff, a former graduate student in Whetten's laboratory and now a staff scientist at Oak Ridge National Laboratory, attached glutathione—a common sulfur-containing tripeptide—to individual gold atoms to form a gold-glutathione polymer in which the gold atoms make no direct contact with one another. The decomposition of this polymer yielded the gold clusters, which have glutathione molecules adsorbed to their sur-

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