Copper-nickel nanowires could be perfect fit for printable electronics

May 29 2012

While the Statue of Liberty and old pennies may continue to turn green, printed electronics and media screens made of copper nanowires will always keep their original color.

Duke University chemists created a new set of flexible, electrically conductive nanowires from thin strands of copper atoms mixed with nickel. The copper-nickel nanowires, in the form of a film, conduct electricity even under conditions that break down the transfer of electrons in plain silver and copper nanowires, a new study shows.

Because films made with copper-nickel nanowires are stable and are relatively inexpensive to create, they are an attractive option to use in printed electronics, products like electronic paper, smart packaging and interactive clothing, said Benjamin Wiley, an assistant professor of chemistry at Duke. His team describes the new nanowires in a *NanoLetters* paper published online May 29.

The new copper-nickel nanowires are the latest nanomaterial Wiley's lab has developed as a possible low-cost alternative to indium tin oxide, or ITO. This material is coated on glass to form the transparent conductive layer in the display screens of cell phones, e-readers and iPads.

Indium, at $600 - $800 per kilogram, is an expensive rare-earth element. Most of it is mined and exported from China, which is reducing exports, causing indium's price to increase. Indium tin oxide is deposited as a vapor in a relatively slow, expensive coating process, adding to its cost.

And the film is brittle, which is a major reason the signature pads at grocery store checkout lines eventually fail and why there is not yet a flexible, rollable iPad.

Last year, Wiley's lab created copper nanowire films that can be deposited from a liquid in a fast, inexpensive coating process. These conductive films are much more flexible than the current ITO film. Copper is also one-thousand times more abundant and one-hundred times cheaper than indium. One problem with copper nanowire films, however, is that they have an orange tint that would not be desirable in a display screen. The copper-based films also oxidize gradually when exposed to air, suffering from the same chemical reaction that turns the Statue of Liberty or an old penny green, Wiley said.

Nickels, however, rarely turn green. Inspired by the U.S. five-cent piece, Wiley wondered if he could prevent oxidation of the copper nanowires by adding nickel. He and his graduate student, Aaron Rathmell, developed a method of mixing nickel into the copper nanowires by heating them in a nickel salt solution.

"Within a few minutes, the nanowires become much more grey in color," Wiley said.

Rathmell and Wiley then baked the new nanowires at various temperatures to test how long they conducted electricity and resisted oxidation. The tests show that the copper-nickel nanowire films would have to sit in air at room temperature for 400 years before losing 50 percent of their electrical conductivity. Silver nanowires would lose half of their conductivity in 36 months under the same conditions. Plain copper nanowires would last only 3 months.

While the copper-nickel nanowires stack up against silver and copper alone, they aren't going to replace indium-tin-oxide in flat-panel displays

any time soon, Wiley said, explaining that, for films with similar transparency, copper-nickel nanowire films cannot yet conduct the same amount of electricity as ITO. "Instead, we're currently focusing on applications where ITO can't go, like printed electronics," he said.

The greater stability of copper-nickel nanowires makes them a better alternative to both copper and silver for applications that require a stable level of electrical conductivity for more than a few years, which is important for certain printed electronics applications, Wiley said.

He explained that printed electronics combine conductive or electronically active inks with the printing processes that make magazines, consumer packaging and clothing designs. The low cost and high speed of these printing processes make them attractive for the production of solar cells, LEDs, plastic packaging and clothing.

More information: "Synthesis of Oxidation-Resistant Cupronickel Nanowires for Transparent Conducting Nanowire Networks'" Rathmell, A. R., Nguyen, M., Chi, M. and Wiley, B. J. *NanoLetters*, May 29, 2012. DOI: 10.1021/nl301168r

Provided by Duke University