Transparent and Conductive Nanotube Films for Consumer and Military Applications

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A team of University of Florida researchers has made transparent and electrically conductive carbon nanotube films using a process highly suitable for industrial production, an advance that suggests new, large-scale applications for the extremely tiny cylinders, and possibly new products such as bendable video screens. The ultra-thin films, made thus far with areas as large as 12 square inches, appear to be competitive with the electrically conducting layers pervasively used in video displays, solar cells, optical communication equipment and other common electronics. An article about the films, authored by four UF faculty members, a visiting scientist from Hungary and several UF students, is scheduled to appear today in the journal Science.

The pure films also show superior transparency in the infrared part of the spectrum compared with other materials, an attribute scientists say could make the films important for military applications, such as disguising objects from an enemy's night-vision equipment.

"Nanotubes have been considered for all kinds of nanoscale applications – everybody has been thinking about shrinking microelectronics," said Andrew Rinzler, a UF associate professor of physics who heads the lab where the films were developed. "But we shouldn't lose sight of the fact that the nanotubes are also a new material, having unique aggregate properties that can also make them useful as bulk materials."

To demonstrate the potential of the films, the scientists built a device they call an "optical field effect transistor," a kind of small screen that, in response to variations in electrical fields, darkens or lightens in the near-infrared part of the spectrum, and becomes more or less reflective of far infrared light. The prototype suggests it may be useful for dynamic heat shields on space vehicles – shields that would reflect infrared light or heat as the ship rotates toward the sun, then lighten to transmit the heat when the ship rotates away. Another possibility: coating military equipment to make it reflective of infrared light at night, frustrating the infrared-light seeking technology that makes night-vision goggles functional.

Flexible screens made with indium tin oxide, typically used in television and computer screens, quickly fail because the material is brittle. But the nanotube films are much hardier, giving them the potential to be used in electronic versions of today’s paper newspapers, among other possibilities. “You can deposit these films on plastic, and you can flex them with no degradation in electrical conductivity,” Rinzler said.

As reported in the Science article, the team developed what Rinzler characterized as a simple method to make the film. It involves diluting small amounts of nanotubes in a soap-and-water solution and depositing them onto a commercially available filter material. The next step uses solvents to dissolve the filter material, either before or after the nanotube film has been attached to glass or other substrate. The films have been made as thin as 40 nanometers – 40 billionths of a meter or 2500 times thinner than human hair – but could probably be made thinner, Rinzler said.

To the naked eye, the result looks like slightly darkened glass. Under an atomic force microscope, the films resemble a jumbled morass of tangled fibers, somewhat like spaghetti in a colander.
Tests of the films’ conductivity and transparency show they appear to be comparable to commercially available films made of indium tin oxide. “This is not to say that the film properties in the visible region of the

spectrum are as good as those of the best laboratory made indium tin oxide," Rinzler said, "but we're at the very beginning here with nanotubes, whereas indium tin oxide has had about 20 years of history for refinement. That leads me to suspect this (nanotube technology) has tremendous potential."

Moreover, Rinzler said, the manufacturing process for indium tin oxide involves vacuum deposition, a complicated process that requires expensive equipment. By contrast, the nanotube film creation process, called vacuum filtration, is inexpensive and relatively easy. At $14,000 per ounce – about 45 times the prices of gold – the price of nanotubes may seem an impediment, but the films use relatively small quantities: a 12-square-inch film requires about $10 worth of nanotubes, for example. Tobias Hertzel, a professor of physics and astronomy at Vanderbilt University in Nashville, said the relatively simple manufacturing process is key.

"Interest in this specific research article will most likely be directed towards the technology involved in the fabrication of thin, transparent and conductive films made of nanotubes…" he said. "Some of the features that make the work interesting for technological applications are its scalability and presumably low cost."

Richard Martel, the Canada Research Chair on electroactive nanostructures and interfaces at the Université de Montréal in Canada, echoed Hertzel's sentiments.
"The most exciting part for me is that the technique developed by Rinzler's group is amazingly simple, and it can be scaled up to very large area substrates," he said. "I trust that this advance will find its way in applications fairly soon because it is simple, cheap and clever."

The research was funded by the National Science Foundation and the Center for Materials in Sensors and Actuators, a Defense Advanced

Research Projects Agency-funded center of excellence at UF. The other UF faculty co-authors of the paper are David Tanner and Art Hebard, both professors of physics, and John Reynolds, a professor of chemistry.

Source: University of Florida