Carbon nanotubes made into conductive, flexible 'stained glass'

April 9 2008

Carbon nanotubes are promising materials for many high-technology applications due to their exceptional mechanical, thermal, chemical, optical and electrical properties.

Now researchers at Northwestern University have used metallic nanotubes to make thin films that are semitransparent, highly conductive, flexible and come in a variety of colors, with an appearance similar to stained glass. These results, published online in the journal *Nano Letters*, could lead to improved high-tech products such as flat-panel displays and solar cells.

The diverse and exemplary properties of carbon nanotubes have inspired a vast range of proposed applications including transistors, logic gates, interconnects, conductive films, field emission sources, infrared emitters, biosensors, scanning probes, nanomechanical devices, mechanical reinforcements, hydrogen storage elements and catalytic supports.

Among these applications, transparent conductive films based on carbon nanotubes have attracted significant attention recently. Transparent conductors are materials that are optically transparent, yet electrically conductive. These materials are commonly utilized as electrodes in flat-panel displays, touch screens, solid-state lighting and solar cells. With pressure for energy-efficient devices and alternative energy sources increasing, the worldwide demand for transparent conductive films also is rapidly increasing.

Indium tin oxide currently is the dominant material for transparent conductive applications. However, the relative scarcity of indium coupled with growing demand has led to substantial cost increases in the past five years. In addition to this economic issue, indium tin oxide suffers from limited optical tunability and poor mechanical flexibility, which compromises its use in applications such as organic light-emitting diodes and organic photovoltaic devices.

The Northwestern team has taken an important step toward identifying an alternative transparent conductor. Utilizing a technique known as density gradient ultracentrifugation, the researchers have produced carbon nanotubes with uniform electrical and optical properties. Thin films formulated from these high purity carbon nanotubes possess 10-fold improvements in conductivity compared to pre-existing carbon nanotube materials.

In addition, density gradient ultracentrifugation allows carbon nanotubes to be sorted by their optical properties, enabling the formation of semitransparent conductive films of a given color. The resulting films thus have the appearance of stained glass. However, unlike stained glass, these carbon nanotube thin films possess high electrical conductivity and mechanical flexibility. The latter property overcomes one of the major limitations of indium tin oxide in flexible electronic and photovoltaic applications.

“Transparent conductors have become ubiquitous in modern society -- from computer monitors to cell phone displays to flat-panel televisions,” said Mark Hersam, professor of materials science and engineering in Northwestern’s McCormick School of Engineering and Applied Science and professor of chemistry in the Weinberg College of Arts and Sciences, who led the research team.

“High purity carbon nanotube thin films not only have the potential to

make inroads into current applications but also accelerate the development of emerging technologies such as organic light-emitting diodes and organic photovoltaic devices. These energy-efficient and alternative energy technologies are expected to be of increasing importance in the foreseeable future."

Source: Northwestern University