Coating carbon nanotubes with photosensitive dye turns these tiny threads into transistor-like photoelectric detectors

While carbon nanotubes are being investigated for nanoelectronics applications, much less work has been directed toward optoelectronic applications, despite the fact that their properties include several direct bandgaps that can be tuned to specific wavelengths. Recent research by scientists at Sandia National Laboratories and the University of Wisconsin-Madison, however, indicates that this situation is about to change. The research team has developed a relatively simple method of turning single-wall carbon nanotubes into useful photoelectric components -- photoabsorbers and emitters – that can serve as nano-switches.

First experimental successes were made by taking chromophores -- pigments that selectively absorb light at certain wavelengths – in the form of a photosensitive dye, Disperse Red 1, and adsorbing them to carbon nanotubes. Illumination with ultraviolet light causes the chromophore molecules to rearrange in a way that changes the ability of the nanotube-hybrid material to conduct electricity. The conductance change is reversible and repeatable over long periods of time, indicating that the structures will prove useful as integrated nanophotodetectors.

These structures -- modified transistors – can be switched repeatedly with a switching time of about 2 seconds. The power required to optically adjust or change the transistor is about 100 microwatts per square centimeter. To switch untreated nanotubes would require the application of about 1 kilowatt per square centimeter.

The team believes that since nanotubes can be invested with different properties as the system is "tuned" to switch at different wavelengths through the use of dyes. "In that light," Dirk Guldi of the Institute for Physical Chemistry at the Friedrich-Alexander University in Erlangen, Germany, wrote in the journal *Nature*, "the work is surely a breakthrough in implementing carbon nanotubes in optoelectronic devices -- technologies from photovoltaic cells to flat-panel displays that have a bright future."

"It's probably too early to speculate on specific devices," says Sandia's François Leonard, who developed the research idea in collaboration with researchers from the University of Wisconsin and performed modeling work to explain the experimental results, "but the main point is that we can detect very low optical intensities, in principle with high spatial resolution."

Single-walled carbon nanotubes come in the form of long, thin strands that might be just a nanometer across, but which are many thousands of nanometers long. They hold promise for application in a number of fields, but "quality control" at that scale is currently insufficient to produce quantities of carbon nanotubes that are predictable in terms of composition and configuration. Such problems have for example hampered the development of nano-scale transistors.

Some scientists, as in the case of the UW-Sandia-team, have elected to go around the problem rather than to attack it directly, since important properties of nanotubes (i.e. structural strength at very small size) can be preserved while the structure serves as a support or host for molecules that are optically active. Typically such molecules change their shape when exposed to light, which alters the conductivity of the nanotube.

Scientists in Sandia's Materials Physics Department in Livermore, California, have been investigating the theory and modeling of electronic transport in nanostructures for some time, in the realization that a better understanding of the operating principles and basic science that govern carbon nanotubes is needed if they are to move from research to the development stage. They developed an approach to calculate photocurrents in nanotube devices which indicated that these devices could have a broad spectral photoresponse, covering the infrared, visible and ultraviolet ranges. Coating the nanotubes with optically active molecules dramatically enhances this response.

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