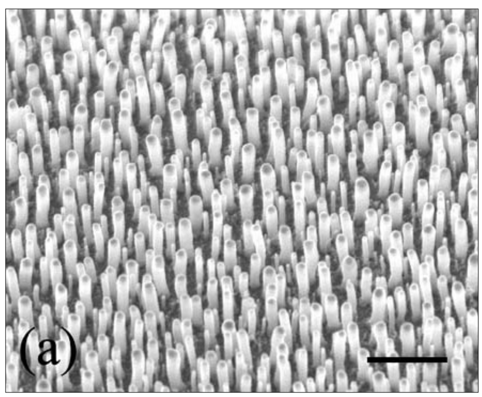
# Nanotube Molecules for Novel Applications

By G. Derrick Hinton

A research team led by Dr. Yang Wang at Boston College reported in the September 27, 2004 issue of *Applied Physics Letters* that arrays of aligned, ultra-tiny carbon nanotube molecules exhibit antenna-like effects when illuminated with visible light. In this antenna effect, the nanotubes were able to convert the visible light directly to an electrical effect that might be interpreted as a signal by an electronic circuit or computer. The research team foresees applications of the nanotube antennas in high frequency, terahertz communications, as well as for visible and infrared light detection. Other potential applications include solar power generation or optical transmission and reception of television signals.

Using the nanotube molecules for these novel applications is possible because of their unusual, conductive, metallic character, as well as their ultra-small size. Each of the tubular molecules of pure carbon used in the experiment is only about 50 nanometers wide and in the range of a few hundred nanometers long. A nanometer is one billionth of a meter, a length about the same as 10 atomic diameters. Thus, each of the conductive nanotube antennas is approximately 20,000 times thinner than a human hair. An array of many trillions of them, such as was used in the recent experiment, still only occupies an area about the size of a postage stamp.




*An array of aligned, but randomly placed, carbon nanotube molecules that can act like a radio antenna for detecting light at visible wavelengths. The scale bar is one micron (one millionth of a meter) in length.*

Antennas work by taking advantage of the oscillating electric field that is a component of all electromagnetic radiation. The oscillations in the field cause the electrons in the conductive material of the antenna to oscillate as well, resulting in a current. This current can then be amplified and filtered electronically to extract a signal.

In order to be effective, though, the size of the antenna must be on the order of the wavelength of the incoming electromagnetic wave. For radio communications, this is easily accomplished because the wavelengths involved are macroscopic, typically on the order of meters, so the antennas can be large and made of metal. For visible light, however, which is also a form of electromagnetic radiation, the wavelength is very short, only a few hundred nanometers. Thus, it has been difficult to receive visible light signals and convert them to electrical signals. Carbon nanotube molecules make this possible because they are so conductive and because they can be synthesized easily in a range of very short lengths comparable to the few hundred nanometer-size scale of the wavelength of visible light.

Similarly, somewhat longer carbon nanotubes may be useful in antennas for radio communications at millimeter or submillimeter wavelengths. Recently, it has been shown that carbon nanotubes can be made in the lengths required for this, up to millimeters, or even centimeters in length, but still only a few nanometers wide.

Carbon nanotubes were first discovered in Japan in 1991 by Sumio Iijima. These tiny tubular molecules are made entirely of carbon and possess remarkable electrical and mechanical properties. One unique trait of carbon nanotubes is that their electrical properties can range from metallic to semiconducting depending on their structure.

In the experiments by Dr. Wang and his team, the investigators deposited arrays of metallic conducting carbon nanotube molecules on a silicon substrate. Each of the trillions of nanotubes that they used was on the order of 50 nanometers wide and ranged in length from 200 to 1,000 nanometers. The team was able to successfully demonstrate two effects. The first was the polarization effect, where reflection of incident light radiation does not occur if the electric field component of the radiation is perpendicular to the axis of the nanotubes, so that the energy of the radiation is mostly absorbed. The second demonstration showed the length matching antenna effect, where the maximum electrical response of a nanotube occurs when the wavelength of the incident light is similar to the length of the nanotube.

The frequency of the electrical oscillations generated in the nanotubes by the incident light is so high that conventional electronics are not easily able to measure this response with accuracy. Instead, the team relied on the secondary radiation emitted from the nanotubes when they were excited by incident light. ❑

*G. Derrick Hinton is a member of the staff of the Director, Operational Test and Evaluation (DOT&E), Office of the Secretary of Defense.*