Selective coatings create biological sensors from carbon nanotubes

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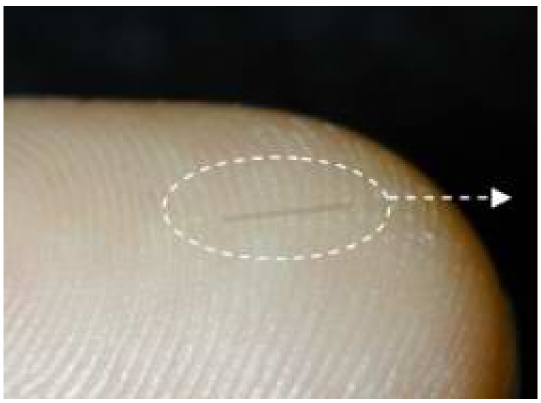

Protein-encapsulated single-walled carbon nanotubes that alter their fluorescence in the presence of specific biomolecules could generate many new types of implantable biological sensors, say researchers from the University of Illinois at Urbana-Champaign who developed the encapsulation technique.

In a paper accepted for publication in the journal Nature Materials, and posted on its Web site, the researchers showed the viability of their technique by creating a near-infrared nanoscale sensor that detects glucose. The sensor could be inserted into tissue, excited with a laser pointer, and provide real-time, continuous monitoring of blood glucose level.

Image: This glass capillary tube, shown here on a fingertip, has been loaded with glucose-sensitive nanotubes. The capillary tube keeps the nanotubes confined, but has porous walls so that glucose molecules can get to them. Credit: Michael S. Strano

"Carbon nanotubes naturally fluoresce in the near-infrared region of the spectrum where human tissue and biological fluids are particularly transparent," said Michael Strano, a professor of chemical and biomolecular engineering at Illinois. "We have developed molecular sheaths around the nanotube that respond to a particular chemical and modulate the nanotube's optical properties."

To make their biological sensors, Strano, postdoctoral research associate Seunghyun Baik, and graduate students Paul Barone and Daniel Heller begin by assembling a monolayer of the enzyme glucose oxidase on the surface of nanotubes suspended in water. The enzyme not only prevents the nanotubes from sticking together into useless clumps, it also acts as a selective site where glucose will bind and generate hydrogen peroxide.

Next, the researchers functionalize the surface with ferricyanide, an ion that is sensitive to hydrogen peroxide. The ion attaches to the surface through the porous monolayer. When present, hydrogen peroxide will form a complex with the ion, which changes the electron density of the nanotube and consequently its optical properties.

"When glucose encounters the enzyme, hydrogen peroxide is produced, which quickly reacts with the ferricyanide to modulate the electronic structure and optical characteristics of the nanotube," Strano said. "The more glucose that is present, the brighter the nanotube will fluoresce."

To prove the practicality of their technique, Strano's team loaded some of the sensors into a porous capillary that confined the nanotubes but allowed glucose to enter. When inserted into human tissue, the fluorescent emission of the sensor corresponded to the local glucose concentration.

"The advantage of the near-infrared signaling to and from such a capillary device is its potential for implantation into thick tissue or whole blood media, where the signal may penetrate up to several centimeters," Strano said. "And, because nanotubes won't degrade like organic molecules that fluoresce, these nanoparticle optical sensors would be suitable for long-term monitoring applications."

One important aspect of the new surface chemistry, Strano said, is that no bonds are broken on the nanotube. "This allows us to shuttle electrons in and out without damaging the nanotube itself."

Another important aspect is that the technique can be extended to many other chemical systems. "We've shown that it is possible to tailor the surface to make it selective to a particular analyte," Strano said. "There are whole classes of analytes that can be detected in this manner."

Source: University of Illinois at Urbana-Champaign