source, giving off a yellow or blue light depending on whether the group used nitric acid (yellow) or aqueous hydrogen peroxide and acetic acid (blue) as an oxidizing agent. No luminescence was observed in the absence of an oxidant. The acid oxidation step is therefore key to enriching the soot with luminescent, hydrophilic and individually dispersed CNPs.

The authors separated the carbon materials by size and charge with gel electrophoresis and found that these parameters correlate with the optical properties of the CNPs. The CNPs are, on average, about 1 nm in size and the percentage of absorbed photons that result in an emitted photon — the quantum yield — is approximately 1%. They also dissolve well in several solvents including water, methanol, dimethyl formamide and dimethyl sulphoxide, and they contain a higher content of oxygen than soot.

A great advantage of these purified CNPs is that they can be synthesized rapidly, effortlessly and without the need for sophisticated and expensive equipment. In terms of applications, the CNPs are potentially good light emitters for bioimaging. The presence of carbonyl groups on their surfaces — which the Purdue group confirmed with spectroscopy — allow the CNPs to be covalently coupled to macromolecules through *N*-hydroxysuccinimide activation chemistry. They also exhibit a pH-dependent photoluminescence that could be exploited to sense specific molecules[3] or to follow intracellular processes[4].

The quantum yields of these CNPs are quite low, at least in comparison with semiconductor nanocrystals, organic luminophores and CNPs produced through laser ablation of graphite and cement powders[5]. In the latter case, studies have shown that quantum yield can be improved by coating the surfaces with hydrophilic molecules, such as poly(ethylene glycol) and a similar strategy may well work for the CNPs produced from candle soot.

Owing to the interest in developing nanoparticles for imaging and therapeutic applications, the short- and long-term toxic effects of many nanomaterials are under intense study. Such tests will certainly be necessary before the soot-derived CNPs can be used for bioimaging. Carbon nanotubes, semiconducting nanocrystals and gold nanoparticles show signs of dose-dependent toxicity, which is highly dependent on particle dimensions, chemical functionalization and contaminants. For example, CNP by-products from the production of single-walled carbon nanotubes in arc furnaces also have low quantum yield, carboxyl groups on their surfaces and a luminescence in the blue to yellow–green range[6,7].

We have investigated these particles in our laboratory, and preliminary (unpublished) data suggest that they are well tolerated by T lymphocytes in cell culture at concentrations of up to 1 mg l^{-1}. This result is encouraging for the potential use of CNPs for imaging and perhaps even medical applications, but, naturally, further in-depth toxicological evaluation will be necessary for the latter.

More than ten years ago, scientists discovered that candle soot also contains fullerenes[8]. Thus, we now realize that humans have been synthesizing fullerenes and luminescent carbon nanoparticles for thousands of years. The question is: what else are we making that we do not yet see?

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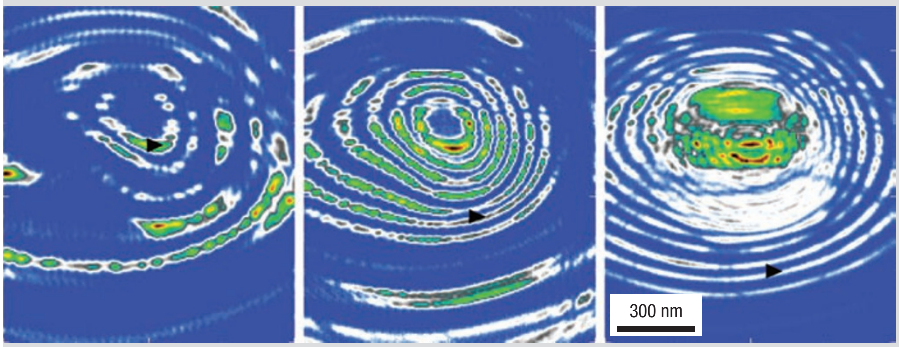
PROBE MICROSCOPY

Finding quantum dots inside nanowires



Semiconductor nanowires could have applications in a wide range of technologies including optics, biosensing, data storage and quantum computing (see pages 622 and 626). However, disorder can lead to the formation of quantum dots and other defects that compromise the performance of the nanowires. These defects have now been imaged with a scanning probe microscope by Robert Westervelt and co-workers at Harvard University, Delft University of Technology and Philips Research Laboratories (*Nano Lett.* **7**, 2559–2562; 2007).

Measurements of the conductance of indium arsenide nanowires at liquid-helium temperatures reveal the signature of a Coulomb blockade — a phenomenon that is often observed in quantum dots. Now Westervelt and co-workers have used a scanning probe microscope to image electron flow through the nanowires and investigate the effects of the quantum dots in more detail. The three figures show the conductance as a function of the position of the probe tip. Quantum dots are located at the centre of the rings of high conductance (shown in green and white), which move outwards as the tip voltage is increased from left to right. The ability to image the electronic properties of nanowires in this way should lead to improvements in device performance.

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