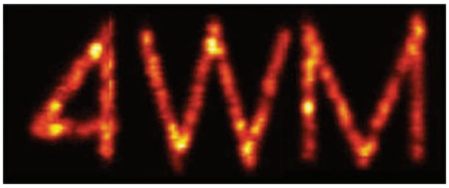
MICROSCOPY

A better shot in the dark

Nano Lett. doi:10.1021/nl1033304 (2010)



Dark-field microscopy relies on keeping radiation that has not been scattered by the sample of interest away from the optics that are used to form the final image. This approach offers improved sensitivity and signal-to-noise ratio, but it also reduces resolution. Now Lukas Novotny and colleagues at the University of Rochester and two research centres in Spain — the ICFO and the ICREA, both in Barcelona — have shown how this problem can be overcome through the use of nonlinear optics.

The new approach relies on a process called four-wave mixing in which two lasers of different frequencies, ω_1 and ω_2, interact with each other to produce an electromagnetic field with a frequency $2\omega_1 - \omega_2$. When the angles of incidence for the two laser beams have certain values, the four-wave mixing field is evanescent — that is, it decays with distance rather than propagating through space. However, when it is scattered by the sample, it is converted into a propagating field that can be collected by an objective lens and used to form a dark-field image of the sample.

Novotny and colleagues used their approach to image patterns made by depositing titanium dioxide on a gold substrate to spell '4WM', and by scratching a silicon surface with an atomic force microscope. They also found that the contrast of the images depended on the relative alignment of the features in the sample and the plane defined by the two laser beams.

OXYGEN DOPING

Easier detection

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Modifying the sidewalls of single-walled carbon nanotubes can affect the optical and electronic properties of the tubes. Covalent reactions have been used to join different chemical groups to the sidewalls of nanotubes but these reactions randomly erode the ordered π-electron structure and suppress the near-infrared fluorescence signature peaks of the tubes. Bruce Weisman and colleagues at Rice University have now shown that introducing a low concentration of oxygen atoms to single-walled carbon nanotubes can systematically change their optical properties for better detection.

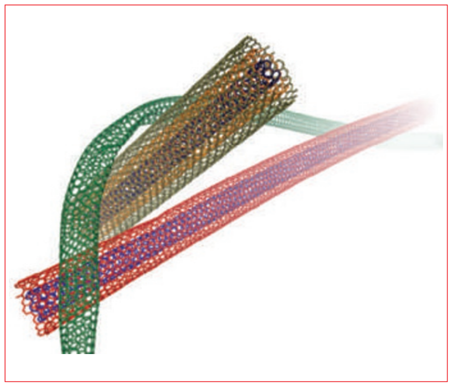
To prepare the oxygen-doped nanotubes, Weisman and colleagues exposed an aqueous suspension of pristine, semiconducting single-walled carbon nanotubes to low doses of ozone followed by light. Fluorescence spectroscopy showed that treated samples had distinct near-infrared fluorescence at longer wavelengths than pristine tubes, and Resonance Raman spectroscopy confirmed the presence of covalently bonded oxygen in the treated samples. The red-shifted emission, which is absent in pristine nanotubes, meant that the doped nanotubes were more readily detected in cultured cells than pristine tubes.

The method offers a simple way to systematically shift the optical properties of pristine nanotubes to achieve better fluorophores for imaging.

CARBON NANOTUBES

A new bounce in their step

Science **330,** 1364–1368 (2010)



Viscoelastic materials such as rubber can both recover their shape when a stress is removed (elasticity) and dissipate energy (viscosity), making them useful dampers of vibration and sound. However, these properties are usually temperature dependent. For example, silicone rubber hardens at −55 °C and degrades at 300 °C. Now Kenji Hata and co-workers at AIST and JST in Japan have demonstrated a viscoelastic material made from carbon nanotubes with a much wider functional temperature range.

The material consists of long nanotubes with a high density of physical interconnections, analogous to a clump of hair. Electron microscope images show the randomly aligned and tangled nanotubes reversibly straightening in the direction of applied strain, for strains up to 5%. The viscoelastic properties are similar to those of silicone rubber, but constant from −196 °C to 1,000 °C, with these temperatures limited by the measuring instrumentation. The material also allows for the rapid dissipation of heat, which is a common cause of degradation, and its properties can be tuned by varying the nanotube density.

FUEL CELLS

A star catalyst

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Proton-exchange membrane fuel cells convert chemical energy into electricity using an electrochemical cell and could be used as portable power sources with high energy densities. At the anode of these devices, the fuel (usually hydrogen) is broken down into protons and electrons using a catalyst. The protons then travel through the membrane to the cathode, whereas the electrons are forced to travel round an external circuit to reach the cathode. At the cathode, the protons and electrons react with oxygen to produce water with the help of another catalyst, which is typically composed of platinum nanoparticles dispersed across a carbon support. These nanoparticles can, however, degrade over time, compromising the performance of the fuel cell.

Xueliang Sun and colleagues at the University of Western Ontario and General Motors Research and Design Center have now developed a fuel cell catalyst that is both active and durable. The catalyst is comprised of single-crystal platinum nanostructures that have a star-like shape, each with several nanowire arms. Compared with a commercial platinum nanoparticle catalyst, the new catalyst is three times more active for the oxygen reduction reaction (as occurs at the cathode of the fuel cell). Furthermore, in accelerated durability tests the nanoparticles of the commercial catalyst significantly increased in size, reducing the active surface area of the catalyst, whereas the star-shaped nanostructures were relatively unaffected.