CARBON NANOTUBES

Grown from seed

Nature **512,** 61–64 (2014)

The properties of single-walled carbon nanotubes depend on their precise structure and, as a result, many of the intended applications of these materials require samples of only one specific type. Methods for growing carbon nanotubes, however, typically lead to a mixture of species. Konstantin Amsharov, Roman Fasel and colleagues at the Swiss Federal Laboratories for Materials Science and Technology, the Max Planck Institute for Solid State Research and the University of Bern have now shown that specific nanotubes can be grown from the bottom up using 'seed' molecules on a platinum surface.

The structure of a carbon nanotube is denoted by two integers (n,m), which are known as chirality indices and refer to the direction in which a hexagonal sheet of carbon atoms would be rolled up to create a given nanotube. Fasel and colleagues created (6,6) carbon nanotubes starting from a polycyclic aromatic hydrocarbon molecule $C_{96}H_{54}$ that was prepared using a multistep organic synthesis. The precursor molecules were adsorbed on the platinum surface and converted into ultrashort singly capped nanotube seeds through a surface-catalysed cyclodehydrogenation reaction. From these seeds, the nanotubes were then grown by incorporating carbon atoms into the bottom of the structures via the surface-catalysed decomposition of a carbon feedstock gas. The resulting nanotubes were defect free and had lengths of up to a few hundred nanometres. *OV*

NITROGEN FIXATION

Nanoparticles do the trick

Angew. Chem. Int. Ed. http://doi.org/f2s5zm (2014)

Nitrogen fixation — the catalytic transformation of nitrogen from the air into ammonia — is one of the most important reactions in the chemical industry. The process, which was developed by Fritz Haber and Carl Bosch, requires high temperature and high pressure. This makes the process expensive and means that it consumes large amounts of energy. Researchers are therefore working to develop nitrogen fixation reactions that can work under ambient conditions. Hiroaki Misawa and co-workers at Hokkaido University have now shown that it is possible to carry out nitrogen fixation at room temperature using visible light irradiation in an artificial ammonia photosynthesis system.

The researchers use a two-chamber reactor: one chamber for the oxidation reaction and one chamber for the reduction reaction. In the oxidation reaction chamber, visible light hits gold nanoparticles supported on a semiconductor material that also acts as a separator for the two chambers. Visible light excites plasmons in gold that decay to produce hot electrons and hot holes. The holes go on to oxidize ethanol (used here as a sacrificial reducing agent). In turn, hot electrons, which can migrate through the membrane into the reduction reaction chamber, and hydrogen ions derived from a hydrochloric acid solution combine with dissolved nitrogen gas to produce ammonia.

The approach will require further work before it would be viable for large-scale applications. But the fact that the quantum efficiency of ammonia formation follows the plasmon resonance of gold, illustrates that plasmon-mediated photochemistry is potentially a useful alternative to the Haber–Bosch process. *AM*

SEMICONDUCTOR DEVICES

A quantum dot thermometer

Phys. Rev. Appl. **2,** 024001 (2014);
Phys. Rev. Appl. **2,** 024002 (2014)

When an object is placed in contact with a thermal bath, its temperature will eventually stabilize to that of the bath itself. There are, however, exceptions to this rule. For example, it is known that if a semiconductor sample is immersed in a thermal bath with a temperature lower than 1 K, an electron population within the semiconductor can be hotter than the thermal bath. But how do you measure this temperature? Martin Kroner and colleagues at ETH Zürich, and Sarah Beavan, Alexander Högele and colleagues at Ludwig-Maximilians-Universität München have now shown in two independent studies that a single quantum dot can be used to measure the temperature of an electron reservoir that is in a helium bath that is a few hundred millikelvin.

The energy of an electron or a hole inside a quantum dot can only assume discrete values, and using a laser beam it is possible to create electron–hole complexes that absorb and emit light at very precise wavelengths. The two research groups used the optical lines that correspond to the spin states of a negatively charged exciton — two electrons and one hole — in a quantum dot. In a magnetic field, the two spin states split due to the Zeeman effect, and their relative population depends on the temperature. By measuring the ratio of the optical emissions it is therefore possible to establish the temperature of the charged exciton. The researchers were able to place the quantum dots close enough to the electron reservoir that the relative population of the charged excitons' states reflected that of the reservoir. In both cases, the teams confirmed that the temperature of the electron reservoir was higher than that of the bath. *FP*

DIAGNOSTICS

Better paper-based assays

Anal. Chem. **86,** 8090–8097 (2014)

Paper-based assays are advantageous because they are inexpensive and can be easily fabricated and disposed of. They are also compatible with biological samples. There are many ways to concentrate and transport the analyte in these assays during paper wetting, but most of these methods depend on passive capillary action. This means that it is generally not possible to further manipulate the analyte after wetting. David Sinton and colleagues at the University of Toronto and University of Ontario Institute of Technology now show that by incorporating a nanoporous membrane and applying ion concentration polarization (ICP), it is possible to concentrate and transport analytes in fully wet paper-based assays.

The researchers developed two classes of device. The first one is an external stamp-like device consisting of an assembly between a silicone rubber layer with an embedded nanoporous membrane and a poly(methyl methacrylate) layer containing buffer reservoirs. To function, the external device is placed on the paper-based assay, the reservoirs are filled with buffer and voltage is applied. ICP occurs at the interface of the nanoporous membrane and the paper. In the second device, the nanoporous material is patterned directly on the paper and acts as a hydrophobic barrier that defines the reservoirs and channels, and forms the micro/nano interface required for ICP. The researchers found that the external device efficiently concentrated and transported dyes directionally over centimetre distances. When used to concentrate proteins and dyes, the second device improved the limit of detection of the paper-based assay. *ALC*

Written by Ai Lin Chun, Alberto Moscatelli, Fabio Pulizzi and Owain Vaughan.

Correction

In the Research Highlight 'Quantum devices: Anomalies explained' (*Nature Nanotech.* **9,** 567; 2014) the wording regarding the researchers' affiliations should have ended "...and other institutions in France and Belgium...". This has now been corrected in the online versions, after print: 13 August 2014.