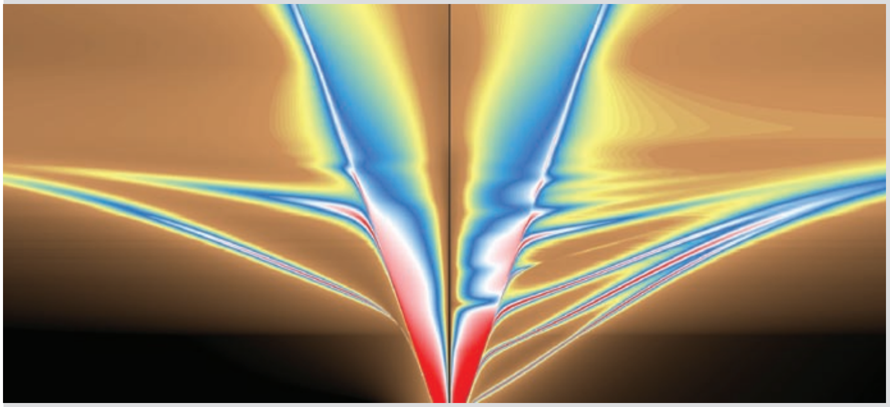
NANOPHOTONICS

Silicon in a new light



Phys. Rev. Lett. **100,** 217402 (2008)

Silicon nanoparticles and related composites could play an important role in future silicon-based photonic devices. However, there is still only a limited understanding of their physical properties at the nanoscale. Now, analysis of the energy lost by electrons travelling at very high speeds through these materials shows potential for studying their optical properties with Angstrom spatial resolution.

Aycan Yurtsever and co-workers from Cornell University sent a beam of 200-keV electrons through silicon nanoparticles embedded in silicon dioxide. Because these electrons travel through the nanoparticles faster than the speed of light in silicon, they produce Cherenkov radiation — the radiation that is responsible for the blue glow observed in nuclear reactors.

The Cornell team found weak but definite Cherenkov radiation and 'wave-guided modes' when silicon nanoparticles with diameters of 4.2 nm were separated by about 8 nm on average. These results imply that the particle size and spacing of these structures were much shorter than the Cherenkov wavelengths.

CATALYSIS

Why size matters

Angew. Chem. Int. Ed. **47,** 4835–4839 (2008)

Until the late 1980s it was generally thought that gold was catalytically inert. Since then, however, gold nanoparticles with diameters of less than 5 nm have been shown to be remarkably good at a range of significant oxidation reactions, even at low temperatures, although the reasons for this have been the subject of much debate. Now, Jens Nørskov and colleagues at the Technical University of Denmark have compared theoretically the catalytic activity of gold with other metals to try to understand the origins of its catalytic properties.

Using density functional theory, Nørskov and colleagues modelled the reaction pathway for the oxidation of carbon monoxide on nanoparticles and extended metal surfaces. They found that the high catalytic activity of gold nanoparticles could be related to the increased number of low-coordinate 'corner atoms' that are created as the size of the metal particle is reduced.

Because the effects of the material supporting the gold — which are usually considered to play an important role in its catalytic properties — were not taken into account in the calculations, the results suggest that gold itself has intrinsic catalytic properties.

GRAPHENE

Let's not stick together

Nano Lett. **8,** 1679–1682 (2008)

The physical properties and potential applications of graphene have intrigued scientists ever since it was shown that single layers of carbon atoms could be peeled off from pyrolytic graphite. However, it is still difficult to produce large quantities of this novel material, partly because graphene sheets have a strong tendency to stick together. Chemical approaches — such as oxidation in strong acids — can prevent such aggregation in aqueous solution, but they also adversely affect the electronic properties of the graphene.

Now, Yongchao Si and Edward Samulski of the University of North Carolina at Chapel Hill have demonstrated a simple and scalable procedure for producing aqueous solutions of isolated sheets of graphene. They start by using sodium borohydride to reduce graphene oxide, and then introduce a small number of *p*-phenyl-SO_3H groups to sulphonate the sample before completing the reduction with hydrazine. Repulsion between the negatively charged $-SO_3$ units prevents aggregation in solution and results in highly dispersed graphene in solution.

Thin evaporated films of the sparingly sulphonated graphene exhibit electrical conductivities of 1,250 S m^{-1}, compared with 6,120 S m^{-1} for similarly prepared graphite, which implies that the bonding structure responsible for the electronic properties of graphene is present in the water-soluble samples.

NANOMATERIALS

Hexagonal help

Science **320,** 1198–1201 (2008)

The formation of bubbles is important in applications as diverse as ultrasound imaging, food preparation, personal care products and construction. However systems of bubbles on the micrometre scale are highly unstable and tend to evolve to lower-energy configurations of larger bubbles. Now, Howard Stone and co-workers at Harvard University and Unilever have made bubbles with diameters of less than 1 μm that remain stable for at least a year.

Stone and co-workers mixed thick glucose syrup and water with sucrose stearate, and then added air by mechanical entrainment. The sucrose stearate molecules act as a surfactant, with hydrophilic parts that stay in the liquid shell and hydrophobic parts that project into the bubble. The researchers found that their bubbles were covered in hexagonal patterns around 50 nm in size. The patterns — which can be predicted from molecular thermodynamic models — appear to be an elastic surface response that prevents further shrinkage of the bubble.

The bubbles remained stable for a year, although the average bubble size increased slightly. The size of the bubbles can be tailored by changing the experimental conditions, but the hexagonal pattern size remains the same.

HEALTH AND SAFETY

Inside and outside

Environ. Sci. Technol. **42,** 4600–4606 (2008)

As the production of nanomaterials increases it becomes ever more important to know the exposure levels experienced by workers during the manufacturing process. Researchers from Virginia Tech measured airborne particles in a small commercial facility producing fullerenes and other carbonaceous nanomaterials, and found them to be well contained.

Linsey Marr and colleagues measured the concentrations of airborne particles at three different locations inside a production facility over a period of time. The fine-particle mass concentrations, submicrometre size distribution and the carbonaceous content of the particles were measured inside the fume hood where the materials were produced, just outside the fume hood where the technicians worked, and in the background. Physical handling of the materials and production activities, such as opening the reactor, increased the number of aerosolized particles, but the fume hood was effective at containing them.

The average mass concentration and particle numbers inside the facility were not significantly different from outside, but daily and hourly variations of ambient particles may affect the measurements, and this is one of several areas in which Marr and co-workers call for further research.

GRAPHENE NANORIBBONS

Quantum conductors

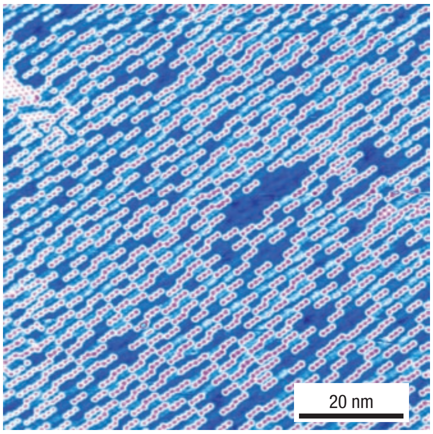
Preprint at http://arxiv.org/abs/0805.0035 (2008)

Graphene has great potential for carbon-based electronics owing to its unusual electronic transport properties. It has been shown that graphene ‘nanoribbons’ can effectively confine charge carriers to move in one dimension, which is similar to what happens in a carbon nanotube. Ribbons with the correct width and crystal structure are expected to have useful semiconducting properties and may also display quantum behaviour on a relatively large scale. Yu-Ming Lin and co-workers at the IBM TJ Watson Research Center have now provided experimental evidence that electrical conductance can be quantized inside graphene nanoribbons.

The IBM team cut sheets of graphene into ribbons just 30 nm wide and measured the conductance as the voltage difference between the two ends of the nanoribbon was increased. At room temperature, the conductance increased smoothly with voltage. However, at 80 K the conductance reached plateaus at certain voltages before increasing again — a sign that the conductance is quantized. The plateaus and steps are caused by the electrons and holes in the ribbon having to overcome energy gaps that they cannot travel around because of the narrowness of the ribbon.

MOLECULAR ELECTRONICS

Up the junction



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Appl. Phys. Lett. **92,** 193301 (2008)

The dimensions of organic molecules offer a direct ‘bottom-up’ means of producing functional components for nanoelectronic circuits. However, despite extensive research, it is still difficult to make self-assembled molecular structures with useful functions such as rectifying junctions. Now, Andrew Wee of the National University of Singapore and co-workers have made self-assembled nanojunction arrays by evaporating carbon-60 molecules onto p-sexiphenyl (6P) nanostripes on silver substrates. The carbon-60 is the electron acceptor, and the 6P is the donor.

The 6P nanostripes had widths of 2.95 nm and a periodicity of ~0.7 nm. When half a monolayer of carbon-60 was deposited and then annealed for 30 minutes at 350 K, the result was a two-dimensional array of carbon-60 ‘triplets’ located on top of the 6P chains. Annealing for a further 30 minutes at 380 K led to the insertion of linear chains of carbon-60 molecules between the 6P nanostripes. The ability to produce both vertical and lateral donor/acceptor nanojunctions with organic molecules could lead to improved solar cells.

TOP DOWN BOTTOM UP

Mass appeal

Nanoparticles can improve the spatial resolution of mass spectrometry imaging of mammalian tissues.

Back in his assistant professor days in the 1990s, Mitsutoshi Setou was looking for a company to fund and commercialize his ideas. Setou, who is now a full professor at the Mitsubishi Kagaku Institute of Life Sciences in Tokyo, wanted to exploit nanoparticles to improve the resolution of mass spectrometry imaging (MSI) — an analytical technique that is used to visualize the spatial distribution of compounds. Only one person took the proposal seriously, but luckily for Setou that person was Shigehiko Hattori, the president of the Japanese equipment company Shimadzu. Part of the problem might have been Setou’s relative youth — he was 33 at the time, whereas most team leaders in Japan tend to be 55 or older.

Ionizing samples is a central part of MSI, and Setou — working with Yuko Ichiyanagi, a physicist at Yokohama National University, and others — has recently developed silicon dioxide-based nanoparticles with hydrophilic groups on their surface to assist with this process when studying mammalian tissue specimens. Traditional reagents based on organic solutions form large crystals when sprayed on the specimens and this decreases the imaging resolution. Setou’s nanoparticles — which have a diameter of just 3.7 nm across — do not suffer from this problem (*Anal. Chem.* **80,** 4761–4766; 2008).

“Letting biologists, physicists and chemists understand nanotechnology-based MSI is a possible, meaningful and fruitful mission,” says Setou. “Everyone was sceptical at the beginning and changing everyone’s way of thinking was most difficult but also most rewarding.” What advice does he have for others facing similar challenges? “We need to study a lot,” he says, “and we should not hesitate to ask naïve questions to understand the different sciences because we do not have to possess all the skills in every technology.”

The definitive versions of these Research Highlights first appeared on the *Nature Nanotechnology* website, along with other articles that will not appear in print. If citing these articles, please refer to the web version.