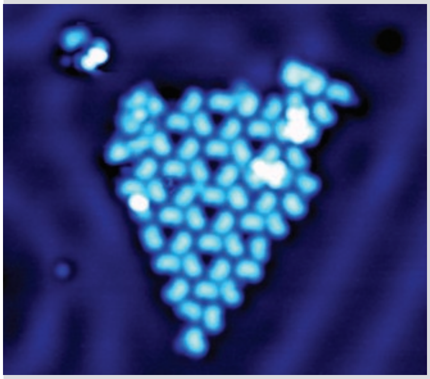
SURFACE CHEMISTRY

A noble cause



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Nano Lett. **8,** 131–135 (2008)

Tetracyanoethylene (TCNE) is a small organic molecule that readily accepts electrons from other compounds to form so-called charge-transfer complexes. Some of the materials formed in this way exhibit potentially useful properties such as superconductivity or magnetism. In particular, certain metal salts of TCNE have ferromagnetic properties that suggest they may be important for molecular magnetism-based applications.

A detailed structural characterization of these materials is often lacking, however, and this limits our understanding of their magnetic and electronic properties. Now, a team from the University of California, Berkeley led by Daniel Wegner and Michael Crommie have studied how TCNE molecules behave on different noble metal surfaces (Au, Ag and Cu) in order to gain some insight into their structural and electronic properties at the organic/inorganic interface. Using a scanning tunnelling microscope, it was found that the TCNE molecules interact very differently with each metal surface. On a Au(111) surface, the molecules tilt to one side and cluster together loosely to form islands, whereas on a Ag(100) surface, they lie flat and remain isolated from one another. In contrast, on a Cu(100) surface the TCNE molecules lie flat, but are tightly bound into ordered islands and chains.

Scanning tunnelling spectroscopy experiments and theoretical calculations suggest that a number of factors influence the behaviour of the TCNE molecules on the metal surfaces. The strength of the charge-transfer interaction between the molecule and the surface, combined with how well the substrate lattice matches with that of the assembled molecules, determines whether TCNE–TCNE or TCNE–metal interactions dominate the growth processes. These results suggest it may be possible to tune the assembly of functional molecular building blocks in thin films to make nanoscale devices.

NANOTUBES

Bugs bounty

Proc. Natl Acad. Sci. USA **104,** 20410–20415 (2007)

It is known that some bacteria found in geothermal fluids of hot springs can precipitate arsenic trisulphide particles. This important infrared-transparent inorganic material has been used for many different optoelectronic applications, such as waveguides and photonic crystals. Now, researchers in Korea and the US have discovered that, under the correct conditions, a special strain of bacteria can produce arsenic sulphide nanotubes, which may prove useful for making nanoscale devices.

The team, lead by Hor-Gil Hur from the Gwangju Institute of Science and Technology, found that in the absence of oxygen, cultures of *Shewanella sp.* — a strain of bacteria that can reduce arsenic through respiration and detoxification reactions — can produce long (~30 μm) filamentous arsenic sulphide nanotubes with diameters ranging from 20–100 nm. X-ray diffraction analysis showed that freshly produced nanotubes were amorphous, but became crystalline over time. These tubes could conduct electricity like metals, were sensitive to UV light, and showed photoluminescence similar to the bulk material, suggesting their potential as building blocks for optoelectronic nanodevices.

Control experiments revealed that a polymeric substance on the outside of the bacteria may serve as a template for the nucleation of the nanotubes. Although the process is not yet fully understood, these bacteria may prove to be an ecologically friendly alternative to making semiconducting nanotubes without needing additional chemical agents.

NANOPHOTONICS

Controlling cavities

Nature **450,** 857–861 (2007)

Quantum dots and photonic crystals are two of the most intensely studied systems in labs around the world, so it is no surprise that researchers are also interested in the interactions between these two types of structures. Jelena Vučkovič and co-workers at Stanford University and the University of California, Santa Barbara, have now shown that a single quantum dot can control the reflectivity of a cavity in a photonic crystal.

Photonic crystals are periodic structures that are transparent to light in certain wavelength ranges. The periodicity of the gallium arsenide photonic crystal studied by Vučkovič and co-workers was disrupted by a defect to create a cavity with a resonant mode at a wavelength of 926 nm. This cavity was coupled to an indium arsenide quantum dot, which had a characteristic emission wavelength that depended on its temperature.

The Stanford–Santa Barbara team showed that the quantum dot could change the reflectivity of the cavity by as much as 40% under certain conditions and that the system behaves as predicted by theory in both the weak and strong coupling regimes. The work could have applications in quantum information processing.

DNA–NANOTUBE HYBRIDS

It's a wrap

Nano Lett. **8,** 69–75 (2008)

Hybrid structures that combine biological molecules with inorganic nanomaterials are finding applications in electronics, medicine and security. One particularly promising structure arises when a strand of DNA, one of the most important biomolecules, becomes wrapped around a carbon nanotube. Now, Charlie Johnson and co-workers at the University of Pennsylvania in Philadelphia have used computer simulations to explain how this unexpected marriage comes about.

The researchers simulated the molecular dynamics of a 14-base random segment of single-stranded DNA being adsorbed onto a single-walled carbon nanotube under typical experimental conditions. Owing to strong van der Waals interactions, the nucleotide bases on the DNA molecule rotate by up to 90° to stack on the nanotube surface. Within a few nanoseconds, the entire DNA strand wraps itself around the nanotube in either a right or left-handed helix, in loops, or in a disordered kinked structure, depending on the initial conformation of the molecules.

These remarkable arrangements seem to be caused by electrostatic interactions that rearrange the angles of bonds in the DNA sugar-phosphate backbone. This new understanding could allow scientists to exploit DNA-nanotube hybrids in novel methods of chemical sensing, nanotube sorting and even ultrafast DNA sequencing.

MOLECULAR ELECTRONICS

The strongest link

J. Am. Chem. Soc. **129,** 15768–15769 (2007)

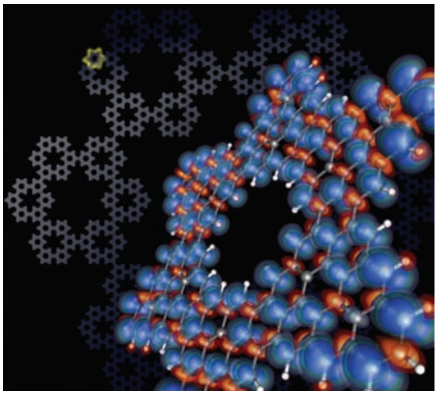
Molecules terminated at each end with a chemical group that is capable of binding to a metal surface can be used to form a junction between two electrodes. The conductance characteristics of such molecules can be greatly influenced by factors such as their chemical structure, length and shape. However, little is known about the effect that different molecular end groups can have on the electronic properties of these systems.

Now, Latha Venkataraman and colleagues at Columbia University have compared the conductance of a series of alkane molecules terminated by three different chemical groups — amines, sulphides and phosphines. Junctions were created by moving the gold tip of a scanning tunnelling microscope in and out of contact with the surface of a Au electrode immersed in solutions of the different molecules. As the tip moved away from the electrode, the conductance decreased until the contact was reduced to a single chain of Au atoms. Pulling the tip further broke the contact, but in the presence of the alkanes, conductance was observed beyond this point, suggesting that the molecules were bound across the gap between the two electrodes.

When the different end groups were tested, it was observed that the alkanes terminated by phosphines gave the highest conductance . It is thought that this result stems from the fact that Au–P bonds are stronger than either Au–S or Au–N bonds, but the size and shape of the electron orbitals that interact with the gold surface also play a role.

GRAPHENE

Cut to size



Nano Lett. **8,** 241–245 (2008)

Graphene has a number of electronic properties that make it an ideal material for spintronics applications. The possibilities are all the more interesting for nanoscale graphene strips in which localized spins form along the edges owing to unpaired bonds.

A theoretical study from Efthimios Kaxiras and colleagues at Harvard University now explores the shape-dependent magnetic properties of graphene 'nanoflakes'. On the basis of a graphical analysis of the unpaired bonds of different graphene geometries — from triangles to complex looking snowflakes — the Harvard group predicts which shapes will have a finite spin. With the aid of first principles calculations, they determine how large this spin will be.

The spin on a triangular-shaped graphene flake scales linearly with the length of its side, or at least up to the point when the flake is a few nanometres in size. These flakes assume the properties of an infinite sheet of graphene. One other shape that is particularly interesting is a fractal 'star of David' in which it is shown that the spin state increases exponentially with the complexity — or fractal level — of the star edges.

BIOSENSING

Keeping it renal

Appl. Phys. Lett. **91,** 222101 (2007)

AlGaN/GaN heterostructures are used to produce high-power field-effect transistors, where a gate voltage modulates the source–drain current flowing through a two-dimensional electron gas (2DEG) at the AlGaN/GaN interface. This 2DEG is formed because of polarization effects, and counter positive charges are induced below the AlGaN surface. These positive charges are extremely sensitive to environmental conditions, leading to fluctuations in the source–drain current.

Now, Fan Ren and colleagues from the University of Florida, Gainesville, and Nitronex Corporation in North Carolina have exploited the environmental dependence of the source–drain current in these structures to detect a substance known as kidney injury molecule-1 (KIM-1), an important factor for early diagnosis of kidney disease. KIM-1 antibodies were immobilized on a 5-nm-thick gold gate electrode on top of the AlGaN layer by thiol-group-mediated self assembly. When the Au region is exposed to KIM-1, the carrier concentration of the 2DEG is altered owing to surface charge accumulation, resulting in a decrease in the conductance of the device.

The detection limit of 1 ng ml^{-1} KIM-1 for a 20×50 μm^2 sensing area and the compact size of the sensor should enable the use of AlGaN/GaN heterostructures as arrays for multi-analyte detection, thus overcoming limitations of conventional enzyme-linked immunsorbent assay protocols.

TOP DOWN BOTTOM UP

Give and take

Engineers, geneticists and microscopists have used carbon nanotubes to measure the electrical conductivity of single DNA molecules.

Understanding the electronic properties of DNA has been a controversial issue for a number of years, partly because it is difficult to be sure that you are measuring the DNA itself and not, for example, effects due to the electrodes or the surface that is supporting the DNA. Achieving good contact between the DNA molecule and the electrodes is a major challenge, which is why Wonbong Choi, an engineer at Florida International University in the US, decided to use carbon nanotubes for the electrodes rather than a traditional metal. Choi wanted to measure the electrical conductance of single- and double-stranded DNA, so he recruited experts in atomic force microscopy from POSTECH in Korea and geneticists from the National Institute of Genetics in Japan to work on the project.

The team suspended a single DNA molecule across a tiny trench and bonded each end to a single-walled carbon nanotube electrode that was deposited on a silicon wafer. Because the diameter of a nanotube (~2 nm) is similar to that of a DNA molecule, it was possible to measure electrical signals passing through the DNA molecule more accurately than in previous experiments with much larger metal electrodes. Choi hopes that such a measuring platform will lead to a better understanding of the properties of DNA and therefore help in developing techniques for reversing DNA damage caused, for example, by mutations (*Nano Lett.* **8,** 26–30; 2008).

Choi and his collaborators already knew each other, which helped them to overcome the cultural barriers between the US, Korea and Japan. "Communicating with a person who is in different research area and sending samples to foreign countries were the most difficult parts," Choi recalls, "but the rewarding part was that we could reach our goal in the shortest time. We also learned a lot from working in a multidisciplinary collaboration. The meaning of collaboration is 'give and take.'"

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.