Looking **through** **a** *nanocrystal*

A team of US scientists has announced a method of making defect-free patterns of semiconductor nanocrystal films. The development could allow scientists to study a film's fundamental properties.

There are two common approaches to patterning films – micro-contact printing and inkjet printing – but neither enables them to be formed with nanoscale precision that is crack-free and electrically conductive. The technique, developed at MIT, uses electron-beam lithography and a lift-off process to solve those problems.

The method reported by the researchers relates to the preparation of lead sulphide (PbS) nanocrystal films, although the same approach holds for films of other types of nanocrystal. To pattern the films, silicon dioxide was used as a substrate, owing to its prevalence in semiconductor devices.

In the first instance, a 100nm positive resist layer of polymethyl methacrylate (PMMA) is coated onto the substrate and then nanoscale trenches are patterned into it. The nanocrystals are prepared by high-temperature pyrolysis of Pb and S precursors in an oleic acid/octadecene mixture.

The growth solution is then processed to remove remaining salts and byproducts, and to replace the native oleic acid capping molecule with a smaller molecule, n-butylamine – it is this exchange of capping ligand while the nanocrystals are still in solution that is critical for making films with a measurable current that are free of cracks, the researchers say. The PbS nanocrystals are then drop-cast into the trenches.

To lift off the film, the substrate is immersed in acetone to dissolve any remaining PMMA and leave a 50nm film of PMMA-defined nanocrystals on the substrate. It is then briefly sonicated in the acetone to ensure the film tears cleanly at the pattern boundaries.

The scientists say the resulting films have patterns down to 30nm in size, are robust and show an electrical conductivity about 180 times that of unpatterned microscopic films – 17µS/cm against 0.09µS/cm. In addition, the thickness of the nanocrystal pattern can be tuned to emit and absorb a wide spectrum of light, and the substrate can be recycled if necessary.

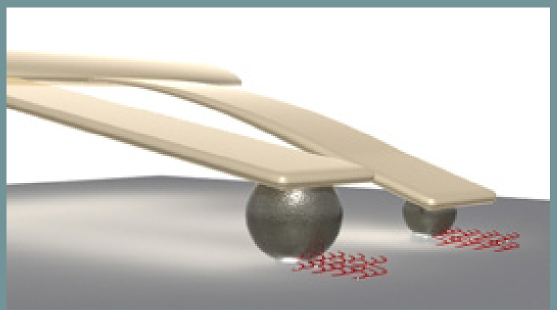
Lead author of the research paper, Dr Tamar Mentzel, says, 'The ability to pattern the films with nanoscale resolution enables precise placement of the nanocrystals in devices for applications such as solar cells and nanoelectronic or nanophotonic circuits.

'For solar cells, a higher electrical conductivity may yield a more efficient device, and because the nanocrystals can be tuned they could enable a new kind of broad-spectrum solar cell.'

Dr Mentzel does not know when these applications might become reality as his prime interest is in studying the films' properties. 'In these films, we are studying a new regime of charge transport, because we can study transport between nanocrystals unimpeded by cracking and may be able to learn more about the transport mechanism on a microscopic scale,' he says. 'This system has the potential to reveal new physics.'

Aidan Quinn, Head of the Nanotechnology Group at the Tyndall National Institute in Cork, Ireland, comments, 'The MIT team has developed a versatile technique to combine bottom-up approaches for synthesis and self-assembly of semiconductor nanocrystals, with top-down methods for patterning these nanocrystal films at length scales down to the 30nm. This work certainly opens up new routes for precise integration of nanostructures with top-down fabricated devices and offers a host of possibilities for hybrid nanodevices – from on-chip photodetectors to nanocrystal-based LEDs.'

Guy Richards



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Lithography **on the cheap**

Cantilevers of 150µm long silicon strips may be the secret to achieving a more cost-effective nanolithography technique for biomedical applications. The cantilevers can be tipped with spheres made of polymer, or with naturally occurring spores. The spheres and spores, which are also water absorbent, are then coated with ink and dried, but when exposed to humidity the tips drag down into contact with a substrate. The technique, according to researchers at North Carolina State University, USA, is less expensive because the cantilevers do not rely on electronic components.

Ship shape nanowires

A 'nano machine shop' that can shape nanowires and ultra-thin films could provide a novel manufacturing method for tiny graphene structures. Researchers at Purdue University, Indianapolis, USA, used the technique to stamp nano- and microgears to form tiny circular shapes from graphene. The method, called laser shock-induced shaping, is able to tune nanowires by altering electrical and optoelectrical properties. The researchers also used the method to change the material's properties, to create ultra-high magnetism and plasmonic resonance for improved optics, computers and electronics.

'Til the Concrete Angel Falls

Craig Durham puts forward a candidate for the greatest material on Earth that is literally the foundation of modern society, and yet evidence of its use has been found dating back 9,000 years.

Originally comprising nothing more than clay and limestone fired together and ground to a powder, lime cement was extensively used by the Ancient Egyptians, Greeks and Romans to provide the mortar that held together, among other things, the Great Pyramid at Giza and the Colosseum in Rome.

The birth of modern cement can be traced to Joseph Aspdin's 1824 patent for Portland cement, so called because he thought the colour resembled Portland stone. Today, Ordinary Portland Cement is the construction industry's standard, ranging from Type I, general purpose and the most common, through to Type V, which has very high sulphate resistance and is used where the concrete will come into contact with highly alkaline soil or moisture.

Many people use the words cement and concrete interchangeably, but strictly speaking concrete is an aggregate mixture of cement, water, sand and gravel, whereas cement mortar is cement, water and sand only. In fact, even the word concrete comes from the Latin concretus, meaning grown together or compounded.

Concrete also has a very high compressive strength compared to cement alone, typically around 40MPa and comparable with many naturally occurring rocks such as sandstones and dolomites (20–170 MPa), which consequently made it an obvious foundation material as engineers sought to build ever higher, and heavier, structures. An early proponent was Robert McAlpine of the company that still bears his name. Known as Concrete Bob because of his enthusiasm for the material, in 1897 McAlpine built one of the longest bridges at the time entirely out of mass concrete. The Glenfinnan Viaduct sweeps majestically across its namesake in Scotland, carrying the West Highland line extension from Fort William to Mallaig, regularly voted as one of the most beautiful railway journeys in the world. And having made this journey by both steam and diesel train this summer, I can attest to that claim. The viaduct is now world famous thanks to the exploits of Harry Potter, although few cinema goers will have appreciated that, as with many engineering feats, necessity was the mother of invention – the local Lewisian Gneiss being unsuitable for cutting and shaping to the blocks required for a stone viaduct.

Of course, concrete's compressive strength is offset by a relatively weak tensile strength, and it was as early as 1830 that the first idea of reinforced concrete was mentioned in the *Encyclopedia of Cottage, Farm and Village Architecture*, which suggested that a lattice of iron tie-rods could be embedded in concrete to form a roof. Once again, the Romans had tried something similar with bronze strips but this was not very successful because the bronze had a higher rate of thermal expansion than the concrete, which caused it to spall and crack.

But it is was the second half of the 20th Century that saw the boom in concrete construction as a fast and relatively cheap method of rebuilding from the devastation of the Second World War. This also saw some of the least loved buildings constructed, with terms such as concrete jungle and concrete carbuncle being used to describe many of the new town centres and municipal offices. Despite this common perception, some of the most iconic structures in the world are concrete, including Sydney Opera House, the Hoover Dam and countless bridges and skyscrapers. In recognition of this, every year, the Concrete Society hosts Awards for Excellence in Concrete. Last year's winner in the Mature Structures category was the refurbished Department of Metallurgy and Materials Building, University of Birmingham, of which many alumni are IOM3 members and no doubt readers of this magazine.

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Craig Durham CEng MIMMM