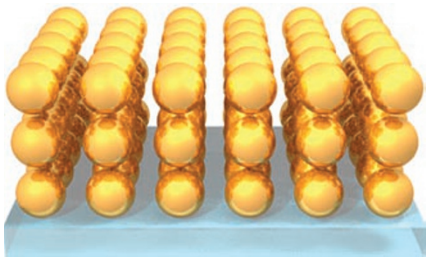
The strands captured by the master each have a chemical group at the end furthest away from the surface, which enables them to bond to a new substrate onto which the master is then 'stamped'. The DNA strands dehybridize when heated, and the two solid substrates can be pulled apart to regenerate the master and create an exact replica of it.

Now, Francesco Stellacci and co-workers from MIT and the University of Michigan in the US have developed two new supramolecular nanostamping processes that overcome some of the limitations of the existing technique. In the first of these, instead of using a solid secondary substrate, the master array is coated with a viscous polymer precursor that can be cured to form a hardened surface. This modification eliminates the need for contact between two solid surfaces and allows for large-area printing as many masters can be used to pattern a single secondary substrate. In the second approach, the need for the secondary surface to be made from a specific material is removed, which opens up nanostamping to a broader range of substrates including silicon, quartz, polystyrene and acrylic. This is achieved by coating the secondary substrate with a reactive polymer coating that can be made with chemical vapour deposition.

These new developments broaden the scope of this nanostamping technique and could prove useful for a number of different applications in which chemical information on a surface needs to be replicated in a precise fashion, such as in DNA microarrays.

NANOPARTICLE FILMS

Stretch to the limit



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Quantum mechanics allows an electron to travel between two metals separated by a barrier of infinite resistance, provided the barrier is only a few tenths of a nanometre thick. This effect is the basis for scanning tunnelling microscopes, which are able to measure atomically sharp features on a surface, but could it also be applied to a more everyday application?

Now, a group of researchers from the Commonwealth Scientific and Industrial Research Organisation in Australia show that changing the tunnelling resistance through films of gold nanoparticles linked together with organic molecules can be the basis for a simple but sensitive strain gauge. Jan Herrmann and colleagues used an airbrush gun to spray gold nanoparticles functionalized with 4-nitrothiophenol onto an inkjet transparency. By stretching the transparency over rollers, the group could change the width of the organic tunnelling barrier between the nanoparticles and hence the resistance of the film.

The change in resistance of the film in response to an applied strain is large — indicating a sensitivity about 50 times greater than standard metal foil strain gauges and comparable to those made from semiconductors. And, as they can be 'sprayed' onto an arbitrarily shaped or sized surface, these nanoparticle-film strain gauges may be considerably more flexible.

SURFACE CHEMISTRY

Deterministic doping

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The controlled doping of semiconductors is a critical step in the fabrication of microelectronic devices. In the case of silicon, the addition of phosphorous atoms produces regions with excess electrons (n-type doping), whereas the inclusion of boron atoms results in an increased number of positive charge carriers or 'holes' (p-type doping). Despite tremendous advances in the synthesis of semiconductor nanostructures, there is a lack of simple, accurate and reproducible means for doping them at such small scales.

Now, Ali Javey and colleagues from the University of California, Berkeley and Lawerence Berkeley National Laboratory, both in the USA, have controllably doped Si surfaces using molecular monolayers. In the first step, a single layer of organic molecules — containing either phosphorus or boron atoms — were assembled on a Si substrate that was then capped with a 50-nm-thick oxide layer. A rapid thermal annealing step, using temperatures in the region of 1,000 °C, caused the P or B dopant atoms to diffuse into the Si lattice, and the oxide layer was subsequently etched away with HF. Doping concentrations were typically the highest near the surface, and sharply decreased by several orders of magnitude at depths of around 20 nm.

This strategy was also used successfully to dope other Si nanostructures, such as wires and belts. The ability to form atomically sharp doping profiles and control areal dopant concentrations so precisely may prove useful in the design and construction of nanoelectronic devices, and could extend to semiconducting materials other than Si.

TOP DOWN BOTTOM UP

Shared vision

University professors and companies in Japan will see the fruits of their joint labours later this year when the first quantum-dot lasers hit the market.

It was not possible to make quantum dot lasers back in the 1980s so Yasuhiko Arakawa, an electrical engineer at the University of Tokyo, focused on the theory of these devices instead. By the mid-1990s, however, experimental techniques had improved to the extent that Arakawa and, independently, researchers at Fujitsu were able to grow the first indium arsenide (InAs) quantum dots by metal–organic chemical vapour deposition.

Since this breakthrough, Arakawa, Fujitsu and a variety of other researchers and companies have been funded by the Japanese government to develop a range of new technologies based on quantum dots. For example, as part of the Center of Excellence for Nano Quantum Information Electronics, the University of Tokyo has opened joint laboratories with four companies — Sharp, Hitachi, NEC and Fujitsu — at its Komaba research campus. Government support was essential to maintain research in these areas after the telecommunications bubble burst earlier this decade.

Arakawa and Fujitsu have now created the world's first high-speed quantum dot laser. As well as being able to reach speeds of 10 gigabits per second, it can operate across a temperature range of 20–70 °C without the need to adjust the electrical input and with minimal fluctuations in the laser output. The laser, which is expected to reach the market in July, has already won awards from the *Wall Street Journal* and the Japanese prime minister.

Arakawa remembers it was not easy to convince companies and funding managers that quantum-dot lasers had a commercial future. "The most important thing was to share visions and enthusiasm," he says, "and to establish strong channels between researchers and also with the decision-makers in top management. Without the support of top management, one would need much more energy and time and still be unsuccessful sometimes."

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.