TECHNOLOGY UPDATE

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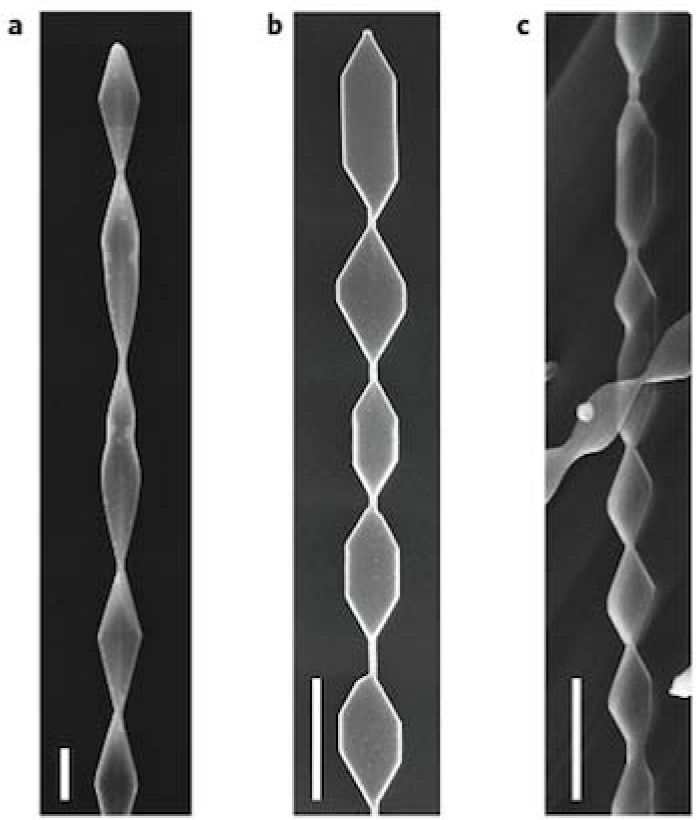
'Plateau-Rayleigh' technique grows nanoshells

A new “Plateau-Rayleigh” crystal growth technique can be used to precisely build up periodic shells of nanomaterials on 1D semiconducting nanowires. The new technique, developed by researchers at Harvard University in the US, Korea University in Seoul and Kyung Hee University in Gyeonggi-do, both in the Republic of Korea, could be important for controlling the morphology and composition of crystals at the nanoscale in future electronics and optoelectronics devices.



(http://images.iop.org/objects/ntw/news/14/5/12/pic1.jpg)

Building periodic shells on a nanowire core (http://images.iop.org/objects/ntw/news/14/5/12/pic1.jpg)

“Let us take a large, flat crystal of silicon as an example,” explains team leader Charles Lieber (http://cml.harvard.edu/) of Harvard. “When we deposit more silicon onto this substrate, we get a flat coating on top – much as you might expect. Until, now, when we deposited silicon onto filament-like 1D silicon nanomaterials (in other words, silicon nanowires), we always observed a conformal, smooth coating or ‘shell’ around the nanowire – again as one would expect.

Now, we have discovered for the first time that if we can grow the silicon shell slowly enough around the 1D silicon nanowire, then we can obtain a completely different and unexpected

morphology, where the silicon material spontaneously arranges itself into periodic shells along the nanowire axis."

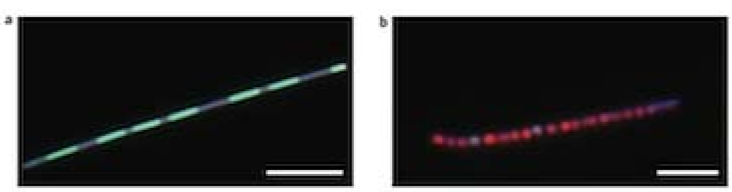
Making use of two well-known phenomena

The researchers say they developed their growth process by making use of two well-known phenomena – namely crystal growth and the so-called Plateau-Rayleigh instability. This instability, which is unique to 1D materials, was first put forward in the 1880s by the scientists Lord Rayleigh and Plateau to describe why a falling stream of water breaks up into droplets to lower its surface tension. "We thus called our technique Plateau-Rayleigh crystal growth and it is a way to grow 3D materials from 1D nanowires," says Lieber.

"We learnt that growing a crystal around a 1D substrate – such as a nanowire – is not necessarily the same as growing a crystal around a 0D sphere or on a flat 2D surface," he adds. "Because of geometric considerations that are unique to 1D materials, it turns out that nanowires whose diameters have been modulated can actually have a smaller total surface area and thus less total energy than a nanowire that has the same volume but a uniform diameter," he tells *nanotechweb.org*. "This effect makes growing modulated structures more energetically favourable when compared to growing uniform-diameter nanowires."

Controlling the dimensions of materials on the nanoscale

To grow nanostructures with varying diameters, the US-Korea team says it employed lower pressures and higher temperatures than those in previous experiments to grow such nanowires. "We found that by making slight adjustments to the growth conditions, we were able to control the morphology of these structures," says Lieber. "For example, we can tune the spacing between the periodic shells grown on the nanowires from around 450 nm to over 12 microns, and the cross-sectional aspect ratio from 1:1 to 4:1 simply by changing the pressure and temperature during growth. Such a range of control during growth is unprecedented."



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Optical properties of Si periodic shell nanowires (http://images.iop.org/objects/ntw/news/14/5/12/pic2.jpg)

Controlling the dimensions of materials on the nanoscale in this way can have a profound effect on their properties, explains team member Hong-Gyu Park (http://physics.korea.ac.kr/people/faculty/park_hg.php) of the Department of Physics at Korea University. For example, a silicon nanowire with a small diameter tends to absorb blue light in the main, whereas one with a large diameter will absorb both blue and green light. Neither absorbs red light very well. However, if you make a nanowire whose diameter alternates along its axis between these larger and smaller diameters, you actually now have a material that absorbs blue, green and red light, even though

the larger nor the smaller diameter nanowires could absorb red light by themselves.

“This is a situation in which the whole is greater than the sum of its parts,” he says. “And in this case, it is much much greater.”

Applications include electronics and thermoelectrics

Although the nanowire has a diameter that varies between around 200 to 300 nm, it can absorb red light just as well as a slab of silicon that is 200 times thicker (at 50 microns). “Reducing material size in this way could hep bring down the cost and footprint of highly sensitive photodetectors,” adds Park, “and although we have only studied these structures for optical applications until now, they should be quite useful for other applications in which the diameter of nanomaterials influences performance. Such applications include electronics and thermoelectrics.”

The researchers say that they are now looking into whether they can extend their growth technique to other materials. “We have shown that the technique works for silicon on silicon, germanium on germanium and germanium on silicon nanowires,” says Lieber. “Some of our theory models suggest that growing diameter-modulated materials should be energetically favourable compared to growing uniform-diameter ones, regardless of the material – be it a metal, dielectric or semiconductor. The challenge here will be to find the specific reaction conditions that can promote this kind of growth.”

The research is detailed in *Nature Nanotechnology* doi:10.1038/nnano.2015.23 (http://www.nature.com/nnano/journal/v10/n4/full/nnano.2015.23.html).

About the author

Belle Dumé is contributing editor at *nanotechweb.org*

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