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Silicon branches out

Branches grown onto semiconductor nanowires could provide a thicket of interconnected nanoscale electronic devices.

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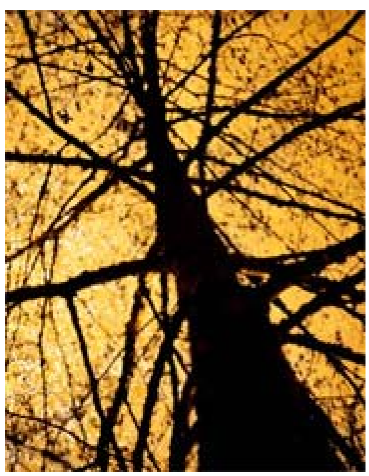

Silicon can be grown into nano-trees.

US researchers have grown tree-like networks of branched nanowires, which they speculate might lead to "three-dimensionally interconnected computing structures analogous to the brain".

Charles Lieber and colleagues at Harvard University in Cambridge, Massachusetts, have found a way to make nanoscale wires made from semiconductors sprout branches. By repeating the branching procedure, they have grown secondary branches from the first ones, creating semiconducting nano-trees[1].

By growing each generation of branches from a different type of semiconductor — for example, from p-type and n-type materials, in which an electrical current is carried respectively by positively and negatively charged particles (holes and electrons) — the researchers can turn the branching points into electronic devices. Junctions between p-type and n-type semiconductors can act as diodes, for example.

In this way, the branched nanowire structure becomes a collection of devices wired together, which might function as a circuit. But to build this in a fully rational way, the researchers will have to gain more control over the sprouting of new branches.

Lieber's group has previously developed methods for making nanowires from various semiconducting materials: silicon, so-called III-V semiconductors such as indium phosphide, and II-VI semiconductors like

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cadmium selenide and zinc sulphide. The technique involves chemical deposition of a vapour of the semiconducting material onto catalytic metal nanocrystals. The diameter of the wires is controlled by the diameter of the catalyst particles.

To make branched nanowires, this process is simply repeated with new catalyst particles attached to an existing wire. Lieber and colleagues have demonstrated the principle using silicon nanowires catalysed by gold, and gallium nitride wires catalysed by nickel. They deposit the catalytic nanoparticles from solution onto an existing 'backbone' wire, using particles that are somewhat smaller in diameter than the wire itself.

For example, gold nanoparticles 20 nm wide, distributed sparsely along the length of a 30-nm silicon nanowire, generated branches about 22 nm wide. The density of these branches is determined by the concentration of catalyst particles in the original solution. As yet, however, the researchers don't have any detailed control over where the branches sprout.

On silicon, new branches grow at fairly well-defined angles of 60°–70° relative to the backbone. By inspecting the junctions closely in a transmission electron microscope, Lieber and colleagues saw that the growth is epitaxial: the atomic lattice of the new branches is aligned with that of the backbone. This means that the branching angle is determined by the crystallographic axes of the material.

That's important, because it means that if the backbone and branches are, say, p-type and n-type silicon respectively, there is a smooth, high-quality junction between the two that can display device-like electronic characteristics. The Harvard group's preliminary studies show that indeed such junctions can act not only as p–n diodes but also as field-effect transistors. In other words, the branching nanostructure can contain electronic switches linked by semiconductor wires.

So far, the researchers have got as far as making second-generation branches, growing 10-nm wires on the 20-nm branches from a 40-nm silicon backbone by using catalyst particles of the respective diameters. The hierarchy of branches is not yet perfect, however: some 10-nm gold nanoparticles stick to the backbone as well as to the 20-nm branches, causing 10-nm wires to sprout directly from the backbone. The deposition of the catalyst particles must somehow be made more selective if this is to be avoided. And to link the branches up into a complex network like the vascular or neural networks of biology, it will be necessary to find a way of getting the branches on separate backbones to fuse together.

References

1. Wang D., Qian F., Yang C., Zhong Z. & Lieber C. M. Rational growth of branched and hyperbranched nanowire structures. *Nano Letters* advance online publication (2004)