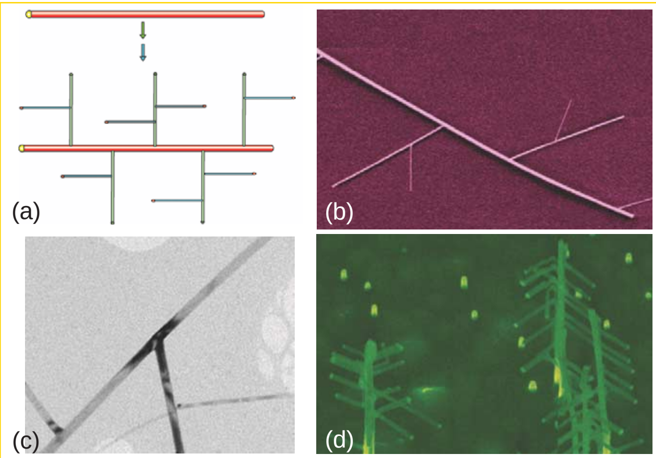
Nanowires branch out

NANOTECHNOLOGY



(a) Schematic of Lieber's multistep synthesis route. Red, green, and blue colors indicate the backbone, first-order branches, and higher-order branches, respectively. (b) Scanning electron micrograph of a hyperbranched Si NW. (c) Transmission electron micrograph of a branched NW. (Courtesy of Charles M. Lieber.) (d) Scanning electron micrograph of Samuelson's GaP nanotrees. (© 2004 Nature.)

Charles M. Lieber at Harvard and Lars Samuelson at Lund University, Sweden have reported the controlled growth of branched and hyperbranched nanowires (NWs) using the vapor-liquid-solid (VLS) technique [Wang *et al.*, *Nano Lett.* (2004), doi: 10.1021/nl049728u; Dick *et al.*, *Nat. Mater.* (2004), published online May 2, doi: 10.1038/nmat1133]. Lieber's multistep, nanocluster-catalyzed VLS synthesis of branched NWs has three key stages. First, a backbone with a specific diameter and composition is prepared. Next, nanocluster catalysts of predefined diameter are deposited onto the backbone and first-order branches are grown. The process can be repeated one or more times to grow higher-order or hyperbranched structures (as shown). The branch density increases directly with the nanocatalyst concentration and the diameter is consistent with the size of the catalysts. The sequential process allows branch diameter and density to be independently varied at each step. High-purity, single-crystal Si and GaN NWs can be grown, which show clean backbone-to-branch junctions consistent with epitaxial growth. Preliminary results indicate that it is possible to grow Si NWs with a *p*-type backbone and *n*-type branches to create *pn*-junctions. "These studies open up a very new class of nanoscale building blocks that are intrinsically three-dimensional in structure and can incorporate a wide-range of distinct electronic and optical functionality," says Lieber. "We envision a number of uses, including three-dimensionally interconnected computing structures analogous to the brain and active, nanophotonic circuits for optical communication." The Lund group uses an aerosol technique to deposit Au nanoparticles to seed the growth of tree-like GaP nanostructures with a trunk, branches, and leaves. Length, diameter, and chemical composition can be controlled at each level of branching. "We have complete control of how the nanowires nucleate and orient via the epitaxially grown trunk-wires," says Samuelson. "This means that not only individual trees, but an entire forest can be described as monolithic structures." The sequential process allows the growth of heterostructures, with InP branches on GaP trunks and GaP nanotrees with GaAsP segments in the branches. Samuelson suggests that such nanotrees could be used for photovoltaic conversion, analogous to photosynthesis in real trees. "It will be possible to design and create nano light-emitting diodes in the branched structure, resembling Christmas trees with lights on their branches," Samuelson told *Materials Today*.

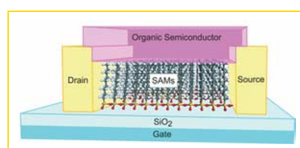
Cordelia Sealy

Controlling doping at the interface

ELECTRONIC MATERIALS

Organic thin-film transistors are of interest because of the high field-effect mobility exhibited by some organic materials. However, organic field-effect transistors (OFETs) differ from traditional Si metal-oxide-semiconductor (MOS) FETs in one vital respect, doping. In Si MOSFETs, doping is used to optimize the transistor characteristics, but no reliable low-density doping method exists for organic semiconductors.

Yoshihiro Iwasa at Tohoku University and colleagues from CREST, SEIKO EPSON Corp., Japan Advanced Institute of Science and Technology, and Iwate University have developed an alternative technique that enables the control of charge density in the device channel [Kobayashi *et al.*, *Nat. Mater.* (2004) published online April 4, doi: 10.1038/nmat1105]. "Since the conduction channel exists at the interface between the organic semiconductor and the gate insulator, we tried to modify the carrier density by inserting self-assembled monolayers (SAMs)," explains Iwasa. As shown, SAMs, which are known to improve field-effect mobility in organic semiconductors such as pentacene, are deposited onto the SiO_2 gate insulator underneath the active organic layer. However, the researchers changed the molecules used for the SAMs and found a surprising result. "We found that holes are accumulated when we use fluoroalkylsilane molecules, while electrons are accumulated by aminoalkylsilane molecules," says Iwasa. "The results indicate that the transistor properties can be controlled by changing the molecules used for SAMs, which can be formed by a low temperature process." The simple



Schematic of the OFET structure showing the SAMs between the gate insulator and the active organic layer. (Courtesy of Yoshihiro Iwasa, Tohoku University.)

technique should be useful for fabricating OFETs with improved functionality, say the researchers, but one hurdle remains. The results were obtained on Si substrates, but the researchers are now working on applying the technique to flexible, plastic substrates.

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