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Chemical & Engineering News

Latest News

October 22, 2007
Volume 85, Number 43
p. 11

Nanoelectronics

Nanowire Powers pH Meter

Design of coaxial nanostructures yields stable, powerful solar cells

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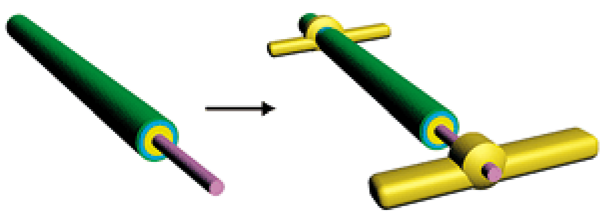
NANOSTRUCTURES and nanostructured materials are of key interest to some solar cell designers, both to provide next-generation materials for commercial solar panels and to power nanoelectronic devices. In a leap forward for nanoenabled power technology, researchers at Harvard University have constructed a layered, coaxia silicon nanowire that can directly absorb light and turn it into electricity, as well as power a nanoelectronic device.

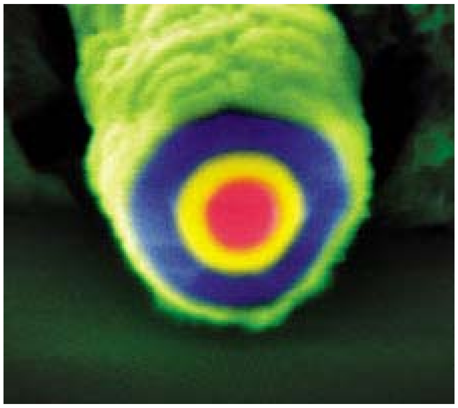


Assembly To use coaxial nanowires in a photovoltaic device, the outer layers are etched to expose the p-core, then metal contacts are laid down by lithographic patterning.

A standard approach to manufacturing amorphous silicon solar cells involves the assembly of "p-i-n" diodes, in which intrinsic, or undoped, silicon is layered between p- and n-type materials, which accommodate positive and negative charge carriers, respectively. The layering sets up an electric field between the p- and n-layers, with the intrinsic component serving as a resistor. Light generates electrons and holes in the intrinsic region; the holes anc electrons then separate to the p- and n-layers.

The Harvard researchers, led by chemistry professor Charles M. Lieber, took p-i-n diodes and shrank them to the nanoscale by creating a coaxial layered nanowire (*Nature* **2007**, *449*, 885). First, they grew a core of silicon doped with B_2H_6 as the p-type material. Then they added pure silicon as the intrinsic layer, followed by a third layer of silicon with an n-dopant, PH_3. Finally, they covered the wire with SiO_2 as a protective mask.

Although the p-type core is a single crystal, the other layers are all nanocrystalline. The nanocrystalline structures appear to be key to enable absorption of five to 10 times more light than a wire composed entirely of single-crysta materials, Lieber says.


Bozhi Tian/Harvard University

Layered Look A coaxial nanowire has a single-crystal p-type core (pink) surrounded by nanocrystalline intrinsic (yellow) and n-type (blue) layers and is topped with SiO_2 (green), as shown in this artificial-color scanning electron micrograph.

Other nanotechnology approaches to solar cells have been hampered by the need for additives, which often are unstable. For example, ZnO nanowires must be coated with light-harvesting dye molecules, or CdSe nanocrystals must be blended with conducting polymers. Additionally, the efficiency at which solar photons are converted into electricity by nanostructured solar cells has hovered around 2%, whereas current commercial silicon solar cells have 12 to 18% efficiencies. Although the coaxial nanowires didn't show a huge improvement in efficiency compared with earlier nanoenabled devices, ranging from 2.3 to 3.4%, they showed better stability, especially under intense light at up to 8,000 W/m^2, or 8 sun-equivalents. Varying the thickness of the intrinsic layer may allow tuning of the efficiency, Lieber says. The coaxial nanowire devices also produced current densities comparable with those from commercial silicon solar cells.

Most important, the group was able to connect the nanowire to a nanoelectronic device, a pH sensor made by modifying a silicon oxide nanowire with 3-aminopropyltriethoxysilane (C&EN, Aug. 20, 2001, page 34). Under 8 sun-equivalents, the photovoltaic nanowire successfully powered the pH sensor, which showed reversible changes in voltage as solution pH varied.

The work "merges a mature idea in solar-to-electric energy conversion with new nanowire synthesis and manipulation methods and opens up new technological possibilities in realizing solar cells and power sources for integrated nanoelectronic devices," says Eray Aydil, a professor of chemical engineering and materials science at the University of Minnesota. "There is no doubt that this is a significant advance."

Phaedon Avouris, manager of nanometer scale science and technology at IBM, agrees. He notes in particular that other nanoscale approaches to powering nanoelectronics produce electricity only in the femtowatt range, whereas the Lieber group's nanowires reached into the nanowatts. "It's a more realistic source of power" for nanoelectronic devices, he says.

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ISSN 0009-2347