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Tiny Solar Cells

Photovoltaics made of nanowires could lead to cheaper solar panels.

By Kevin Bullis

Researchers at Harvard University have made solar cells that are a small fraction of the width of a human hair. The cells, each made from a single nanowire just 300 nanometers wide, could be useful for powering tiny sensors or robots for environmental monitoring or military applications. What's more, the basic design of the solar cells could be useful in large-scale power production, potentially lowering the cost of generating electricity from the sun.

Each of the new solar cells is a nanowire with a core of crystalline silicon and several concentric layers of silicon with different electronic properties. These layers perform the same functions that the semiconductor layers in conventional solar cells do, absorbing light and capturing electrons to create electricity. To make the cells, Charles Lieber, a professor of chemistry at Harvard University, modified methods he'd previously used to make nanowires that could serve as sensors or transistors. He then demonstrated that his solar cells can power two of his earlier nanowire devices, a pH sensor and a set of transistors.

"This paper provides the very first example of using a single silicon nanowire for harvesting solar energy," says Zhong Lin Wang, professor of materials science and engineering at Georgia Tech. He calls Lieber's work "breakthrough research in the field of nanotechnology."

At first, the nanowire solar cells will most likely be useful in niche applications where their small size is key, such as extremely small sensors, or robots whose sensors and electronics might benefit from an integrated power source. "There has been a lot of talk recently about making independent nanomachines and nanosystems," says Phaedon Avouris, a fellow at IBM Research. "The issue has always been, how are you going to power them? If you want to have an independent nanosystem that's self-contained, that's not plugged into a central power supply, then you need something like this."

The ultimate goal would be to build electronic components that can self-assemble into devices that might not be possible to make otherwise. (Lieber has shown that it's possible to make such components from nanowires, which can then be assembled into regular arrays in solution.) "We'd like to incorporate memory, a nanoprocessor, maybe a sensor, and a power source to drive that," Lieber says. "If you try to put together all of these pieces with conventional technology, it gets pretty cumbersome."

In addition to powering tiny machines, solar cells made from microscopic wires might eventually be bundled together into large arrays to replace conventional rooftop solar panels. Lieber's research is still at an early stage, but his new nanowires suggest that a theoretical solar cell proposed by researchers at the California Institute of Technology could be viable. Harry Atwater, a professor of applied physics and materials science at Caltech, and Nathan Lewis, a professor of chemistry there, have suggested that solar cells made of microscopic wires would be much cheaper than conventional solar cells, since they could be made from less expensive materials--including, Lewis says, rust.

Until now, solar cells made from such cheap materials have been impractical because of a fundamental contradiction in their design requirements. To be efficient, solar cells must do at least two things well. First, they must absorb light, so they need active materials thick enough that light can't pass through them. But they also need to collect the electrons knocked loose by absorbed photons. For this, extremely thin materials are usually better; otherwise, electrons can get trapped inside the material. One way to reconcile these competing design constraints is to make relatively thick layers of material but to use extremely pure, crystalline materials that lack the defects and impurities that can trap electrons. Such materials work well, but they're expensive, keeping the price of solar panels high.

Nanowires such as those Lieber used for his solar cells offer an alternative. The nanowires can absorb significant amounts of light along their length. At the same time, electrons have only to move a short distance in the nanowire, from one concentric layer of material to another, to be collected. (The layers serve to separate electrons from their positive counterparts, holes, which allows the electrons to be collected.) Since the materials are thin, the chances of an electron being trapped by a defect before escaping from one layer to the next are low, so it's possible to use cheaper materials with more defects.

Lieber demonstrated that nanowires can indeed produce electricity, but a number of challenges remain before they will find their way into commercial solar cells. Lieber has tested only small numbers of nanowire solar cells. For large-scale applications, the nanowires would need to be chemically grown in dense arrays. Atwater and Lewis recently took steps in this direction, publishing in the past month two papers in which they describe growing dense arrays of microscopic wires, but wires without the multiple layers that Lieber's have. Paired with a liquid electrolyte, the wires generated electricity from light. Since it may prove easier to manufacture solid-state solar cells such as Lieber's, however, Lewis and Atwater are working to produce arrays of wires with multiple layers.

The most significant limitation of the work of both groups is the poor efficiency of their solar cells. For example, Lieber's cells converted 3.4 percent of incoming light into electricity. While that's an encouraging number for proof-of-concept solar cells in the lab, it's a far cry from the 20-plus percent efficiency of conventional silicon solar panels. Even with the potential advantage of cheaper materials, wire-based solar cells would probably need to be about 10 percent efficient if they were to compete with existing technology. The researchers' next steps include finding ways to make more dense arrays of wires to absorb more light and, in Lieber's case, to find ways to generate increased voltage from nanowire solar cells.
