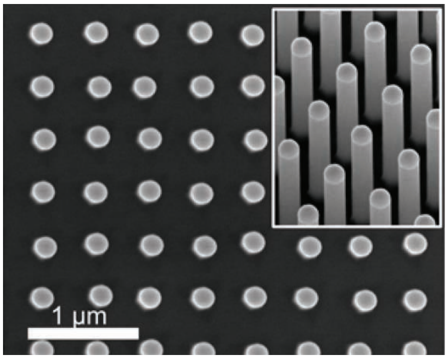
SOLAR ENERGY

Performance of Nanowire Solar Cells on the Rise

There's no shortage of ways to convert sunlight into electricity. Solar cells made from silicon, thin semiconductor alloy films, and even plastics are all commercial technologies. About 10 years ago, researchers began to consider a new alternative: using arrays of tiny, semiconducting nanowires to harvest light and produce power. Because they use so little semiconductor material and can potentially be produced very cheaply, nanowire solar cells had the look of a solar upstart with plenty of upside. But for years their performance lagged far behind other technologies: Even when the nanowires converted the sun's photons to electrical charges, they had trouble getting those charges out of the cell and putting them to work.



Big gains. Vertically aligned nanowires are the heart of increasingly efficient array-based solar cells.

Now, nanowire photovoltaics are on the ascent. In a paper published online this week in *Science*, researchers from Sweden, Germany, and China report creating nanowire solar cells that convert 13.8% of the energy in sunlight into electricity. And several other groups are also hot on the trail. At the fall meeting of the Materials Research Society in November in Boston, researchers led by Jung-Ho Lee, a chemical engineer at Hanyang University, Ansan, in South Korea, reported wire array solar cells made with high-grade crystalline silicon wires that are 12.8% efficient. And in the 12 December 2012 issue of *Nano Letters*, researchers led by Xiang Zhang of the University of California, Berkeley, reported similar cells made from cheap "metallurgical" silicon. All of these devices still trail the 15% to 22% efficiency of commercial silicon solar cells. But according to several solar cell experts, the nanowire solar cells are improving fast and have plenty of room for further growth.

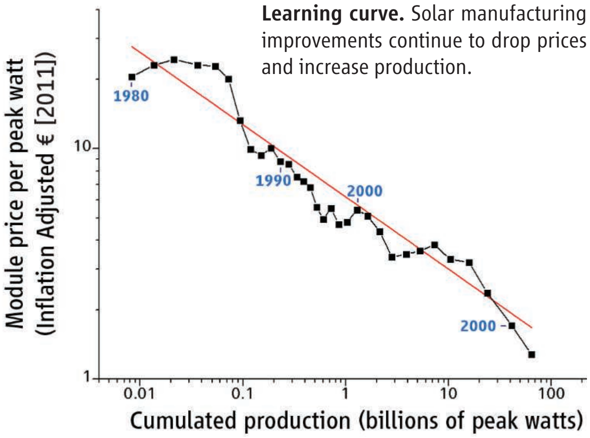
"From a science and technological point of view, the new results are exciting," says Paul Alivisatos, a chemist and director of the Lawrence Berkeley National Laboratory in California who isn't affiliated with any of the teams behind the recent results. The improvements in controlling the nanostructure of the materials needed to produce the higher efficiency are "a big development," Alivisatos says. However, he adds, "they still have a ways to go beyond this" to have a shot at making a commercial impact.

Compared with other solar technologies, they've already come a long way very quickly. It has taken nearly 40 years for some of the early thin-film technologies to improve from about 5% to 17% efficiency. And over just the past few years, nanowire cells have leapfrogged other decades-old technologies, such as amorphous silicon cells, plastic cells, and dye-sensitized solar cells.

In each case, the improved results of current wire array solar cells came about in part by overcoming the major efficiency killer: electrical charges giving up their energy before they're collected. Light absorbed in a solar cell excites electrons and gives them enough energy to hop from atom to atom through the wire to an electrode. The big advantage of nanowire cells is that electrons have a direct path to the point where they are collected, which reduces the amount of semiconductor needed by as much as 90%. But as electrons make these jumps they leave behind electron vacancies, called holes. If an electron happens to fall into one of these holes, it gives up its extra energy as light or heat, and the efficiency of the cell drops.

The downside of wire array cells is that the wires have a high ratio of surface area to volume, and electrons and holes tend to pair more readily at the crystalline imperfections found at surfaces. Each of the recent advances used tight control of growth techniques to minimize the number of such recombinations. The Swedish-led group, for example, used indium phosphide for its 13.8%-efficient cells because it tends to have slower electron-hole recombination, says Magnus Borgström, a physicist at Lund University in Sweden who directed the research effort. The team also used a newly developed refinement of a growth method known as MOCVD to grow arrays of pristine nanowires. The Korean- and American-led teams grew silicon-based wires using different array designs and growth techniques, but they also managed to minimize recombination losses. And all three teams say they expect this improving nanoscale control to bring even better results soon.

But despite such advances, Alivisatos notes, all new solar technologies face fierce competition from crystalline silicon cells, the dominant technology on the market. The efficiency of silicon cells has barely improved in decades. But since 1980, the cost of silicon modules, the finished packages of cells that are put in service, has fallen by 90% (see figure). That drop in price has accelerated in recent years as China has become the dominant manufacturer of the technology. Over the past 3 years, the price drop has been so sharp that in some countries the cost of installing new solar capacity is now on par with that of building conventional power plants. That's still not the case in the United States, which already has an electric power infrastructure in place and where the installation costs of solar power remain high. But the upshot, Alivisatos notes, is that the market for conventional silicon solar cells is exploding, growing 65% a year. "In a few years we could be looking at a terawatt-[1 trillion watts]-a-year market instead of the tens of gigawatts [billions of watts] now," Alivisatos says. So even though wire array cells are improving fast, the bar is rising. And that's a good thing for the growth of clean energy.



Learning curve. Solar manufacturing improvements continue to drop prices and increase production.

–ROBERT F. SERVICE

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