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TR10: Nanocharging Solar

Arthur Nozik believes quantum-dot solar power could boost output in cheap photovoltaics.

By David Talbot

Arthur Nozik hopes quantum dots will enable the production of more efficient and less expensive solar cells, finally making solar power competitive with other sources of electricty.
Credit: Lance W. Clayton

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This article is one in a series of 10 stories we're running this week covering today's most significant emerging technologies. It's part of our annual "10 Emerging Technologies" report, which appears in the March/April print issue of Technology Review.

No renewable power source has as much theoretical potential as solar energy. But the promise of cheap and abundant solar power remains unmet, largely because today's solar cells are so costly to make.

Photovoltaic cells use semiconductors to convert light energy into electrical current. The workhorse photovoltaic material, silicon, performs this conversion fairly efficiently, but silicon cells are relatively expensive to manufacture. Some other semiconductors, which can be deposited as thin films, have reached market, but although they're cheaper, their efficiency doesn't compare to that of silicon. A new solution may be in the offing: some chemists think that quantum dots--tiny crystals of semiconductors just a few nanometers wide--could at last make solar power cost-competitive with electricity from fossil fuels.

By dint of their size, quantum dots have unique abilities to interact with light. In silicon, one photon of light frees one electron from its atomic orbit. In the late 1990s, Arthur Nozik, a senior research fellow at the National Renewable Energy Laboratory in Golden, CO, postulated that quantum dots of certain semiconductor materials could release two or more electrons when struck by high-energy photons, such as those found toward the blue and ultraviolet end of the spectrum.

In 2004, Victor Klimov of Los Alamos National Laboratory in New Mexico provided the first experimental proof that Nozik was right; last year he showed that quantum dots of lead selenide could produce up to seven electrons per photon when exposed to high-energy ultraviolet light. Nozik's team soon demonstrated the effect in dots made of other semiconductors, such as lead sulfide and lead telluride.

These experiments have not yet produced a material suitable for commercialization, but they do suggest that quantum dots could someday increase the efficiency of converting sunlight into electricity. And since quantum dots can be made using simple chemical reactions, they could also make solar cells far less expensive. Researchers in Nozik's lab, whose results have not been published, recently demonstrated the extra-electron effect in quantum dots made of silicon; these dots would be far less costly to incorporate into solar cells than the large crystalline sheets of silicon used today.

To date, the extra-electron effect has been seen only in isolated quantum dots; it was not evident in the first prototype photovoltaic devices to use the dots. The trouble is that in a working solar cell, electrons must travel out of the semiconductor and into an external electrical circuit. Some of the electrons freed in any photovoltaic cell are inevitably "lost," recaptured by positive "holes" in the semiconductor. In quantum dots, this recapture happens far faster than it does in larger pieces of a semiconductor; many of the freed electrons are immediately swallowed up.

The Nozik team's best quantum-dot solar cells have managed only about 2 percent efficiency, far less than is needed for a practical device. However, the group hopes to boost the efficiency by modifying the surfaces of the quantum dots or improving electron transport between dots.

The project is a gamble, and Nozik readily admits that it might not pay off. Still, the enormous potential of the nanocrystals keeps him going. Nozik calculates that a photovoltaic device based on quantum dots could have a maximum efficiency of 42 percent, far better than silicon's maximum efficiency of 31 percent. The quantum dots themselves would be cheap to manufacture, and they could do their work in combination with materials like conducting polymers that could also be produced inexpensively. A working quantum dot-polymer cell could eventually place solar electricity on a nearly even economic footing with electricity from coal. "If you could [do this], you would be in Stockholm--it would be revolutionary," says Nozik.

A commercial quantum-dot solar cell is many years away, assuming it's even possible. But if it is, it could help put our fossil-fuel days behind us.