SOLAR'S NEW DAWN, WITH APPLICATOR BRUSH

Michael Haederle[1]

The lone photovoltaic panel, perched like a pterodactyl on a suburban rooftop, is an ungainly reminder of the stillborn response to the 1973 oil crisis, when energy self-sufficiency was an all-too-brief national priority. Back then it all seemed simple: sunlight was free and abundant and solar panels looked like an obvious energy solution. But solar energy never quite caught on with Americans. The oil crisis passed, while panels were costly, bulky and not very efficient at converting sunlight to electricity. Most people decided hooking up to the electrical grid was both easier and cheaper.

Nearly 40 years on, that picture is being redrawn. New chemical and materials science research is paving the way for cheaper and more efficient solar cells as global climate change adds urgency to the search for fossil fuels alternatives. Improved photovoltaics made from silicon wafers now achieve energy conversion efficiencies nearing 25 percent, compared to 16 percent levels in the 1980s.

Meanwhile, multi-junction concentrator solar cells made with thin films of gallium arsenide have achieved efficiencies of around 40 percent (although they're pricey — they were developed to power satellites). But silicon and other inorganic minerals need high-temperature processing that makes the resulting cells more expensive, notes Calvin K. Chan, a postdoctoral fellow in the semiconductor electronics division of the National Institute of Standards and Technology.[2]

A cheaper approach involves using organic semiconductors — basically, plastics that conduct electricity — to make solar cells, Chan says. Organics are processed at much lower temperatures than inorganics, and while their efficiencies are substantially lower (about 3 percent), they can be spread over wide areas, yielding an equivalent amount of energy. "One of the promising things about organics is you can just put it on a roll," Chan says. "You can unroll it on your roof with a couple of nails, maybe. You can imagine instead of having shingles, you can have shingles that are active solar cells. When you have to change your shingles, you just change your solar cells."

A photovoltaic surface could be made even more simply – as easy as applying paint, he says. In a recent experiment, Chan and his colleagues at NIST showed that a polymer called poly(3-hexylthiophene) — P3HT for short — could be sprayed onto a surface and made to function like a transistor. Laboratory conditions were not exacting, to say the least. "We had a little paint brush," Chan says. "We had a hot plate, put down a sample, sprayed on a couple layers and measured it. We were surprised to see that it worked so well."[3] "Instead of having to have centralized manufacturing and fabrication, you could just have a technician come spray your

[1] Miller-McCune report, July 8, 2010 (www.miller-mccune.com/)
[2] National Institute of Standards and Technology, Gaithersburg, Maryland 20899-8120, USA
[3] Chan, C.K., L.J. Richter, B. Dinardo, C. Jaye, B.R.Conrad, H.W. Roo, D.S.Germack, D.A. Fischer, D.M. Longchamp and D.J. Gundlach. 2010. High performance airbrushed organic thin film transistors. Appl. Phys. Lett. 96, 133304 (2010); doi:10.1063/1.3360230 (*3 pages*)

roof and create a solar cell," Chan says. "This is kind of an area where the electronics industry and the paint industry can interact and get something going."

First described in 1839, the photovoltaic effect occurs when a semiconductive material absorbs photons of light energy that excite some of the electrons in its atoms to join a flow of electrical current. The familiar silicon-based solar cell was developed in the 1940s. Polymers historically have played only limited roles in photovoltaic cells and other electronic applications, says Yueh-Lin (Lynn) Loo, an associate professor of chemical engineering at Princeton University. "The reason plastics are so pervasive in our lives is it's a good thermal and electrical insulator," Loo says. That means electrons normally don't move through plastics to create electrical current. So when Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa discovered and developed the first conductive polymers in the 1970s (for which they shared the 2000 Nobel Prize in chemistry), it was "a big deal," she says.

Loo and her team recently overcame some technical hurdles making these organic conductors into the thin films needed for photovoltaics. These materials have "pretty high conductivities" to begin with, she says, but in order to make them moldable or water dispersible they must be processed in ways that cause the polymer to lose its conductivity. Working with polymers, such as polyaniline and poly(ethylene dioxythiophene) — better known as PDOT — Loo found that exposing the polymer to an acid after it has been applied to a surface improves its conductivity by up to two orders of magnitude.[4]

A thin layer of conducting polymer could become an inexpensive replacement for indium tin oxide, an increasingly rare (and expensive) transparent material widely used as an anode in solar cells, computer LED monitors and touch screen displays, Loo says. Polymers are comparatively inexpensive to make, but that is only part of their attraction. "It's more than the cheapness," Loo says. "With organics and plastics the chemical reaction is very, very versatile." Chemists can readily add or subtract atoms that alter a polymer's physical properties, she points out. "Let's not forget that organics and plastics, if you make them right, dissolve in common solvents – even water – so you can use very inexpensive techniques to apply them."

Organic solar cells are already making their way to market. Konarka, a Lowell, Mass., company, has developed a flexible solar cell it calls Power Plastic. It can be incorporated into windows and curtain walls, so that a building actually produces the power it uses. The material is already being used in backpacks, briefcases and messenger bags to provide portable recharging. As organic solar cell technology matures, efficiencies will likely increase steadily, in much the way personal computers have evolved. Consumers might simply switch out their low-cost organic cells every few years, Chan says. "Right now, when you buy a solar cell, it could be 3 percent (efficiency), but you know in five years it will be relatively cheap to change it out, and when you change it out it will be for something better," he says.

Despite their promise, organic solar cells will be only one part of the quest to bring photovoltaics to the point where their cost-per-kilowatt is competitive with electrical power generated by fossil fuels or nuclear energy, Chan says. "From a commercial standpoint, there are a lot of materials and there's a lot of techniques and a lot of methods," he says. "It's difficult to really synthesize an end system where people agree on which method is best. That's up to the manufacturers to do."

[4] Yoo, J.E., K.S. Lee, A. Garcia, J. Tarver, E.D. Gomez, K. Baldwin, Y. Sun, H. Meng, T.-Q. Nguyen and Y.-L. Loo. 2010. Directly patternable, highly conducting polymers for broad applications in organic electronics. Proc. National Academy of Sciences, Vol. 107, March 2010.