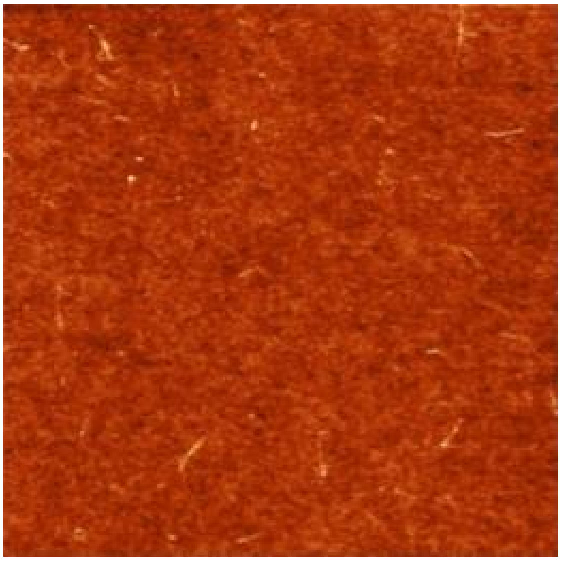
All-carbon solar cell harnesses infrared light

June 21 2012, by David Chandler



An atomic-force microscope image of a layer of single-walled carbon nanotubes deposited on a silicon surface, as the first step in manufacturing the new type of solar cell developed by an MIT team. Individual nanotubes can be seen in the image. Photo: Rishabh Jain et al

About 40 percent of the solar energy reaching Earth's surface lies in the near-infrared region of the spectrum — energy that conventional silicon-based solar cells are unable to harness. But a new kind of all-carbon solar cell developed by MIT researchers could tap into that unused energy, opening up the possibility of combination solar cells — incorporating both traditional silicon-based cells and the new all-carbon cells — that could make use of almost the entire range of sunlight's energy.

"It's a fundamentally new kind of photovoltaic cell," says Michael Strano, the Charles and Hilda Roddey Professor of Chemical Engineering at MIT and senior author of a paper describing the new device that was published this week in the journal *Advanced Materials*.

The new cell is made of two exotic forms of carbon: carbon nanotubes and C60, otherwise known as buckyballs. "This is the first all-carbon photovoltaic cell," Strano says — a feat made possible by new developments in the large-scale production of purified carbon nanotubes. "It has only been within the last few years or so that it has been possible to hand someone a vial of just one type of carbon nanotube," he says. In order for the new solar cells to work, the nanotubes have to be very pure, and of a uniform type: single-walled, and all of just one of nanotubes' two possible symmetrical configurations.

Other groups have made photovoltaic (PV) cells using carbon nanotubes, but only by using a layer of polymer to hold the nanotubes in position and collect the electrons knocked loose when they absorb sunlight. But that combination adds extra steps to the production process, and requires extra coatings to prevent degradation with exposure to air. The new all-carbon PV cell appears to be stable in air, Strano says.

The carbon-based cell is most effective at capturing sunlight in the near-infrared region. Because the material is transparent to visible light, such cells could be overlaid on conventional solar cells, creating a tandem device that could harness most of the energy of sunlight. The carbon cells will need refining, Strano and his colleagues say: So far, the early proof-of-concept devices have an energy-conversion efficiency of only about 0.1 percent.

But while the system requires further research and fine-tuning, "we are very much on the path to making very high efficiency near-infrared solar cells," says Rishabh Jain, a graduate student who was lead author of the paper.

Because the new system uses layers of nanoscale materials, producing the cells would require relatively small amounts of highly purified carbon, and the resulting cells would be very lightweight, the team says. “One of the really nice things about carbon nanotubes is that their light absorption is very high, so you don’t need a lot of material to absorb a lot of light,” Jain says.

Typically, when a new solar-cell material is studied, there are large inefficiencies, which researchers gradually find ways to reduce. In this case, postdoc and co-author Kevin Tvrdy says, some of these sources of inefficiency have already been identified and addressed: For instance, scientists already know that heterogeneous mixtures of carbon nanotubes are much less efficient than homogeneous formulations, and material that contains a mix of single-walled and multiwalled nanotubes are so much less efficient that sometimes they don’t work at all, he says.

“It’s pretty clear to us the kinds of things that need to happen to increase the efficiency,” Jain says. One area the MIT researchers are now exploring is more precise control over the exact shape and thickness of the layers of material they produce, he says.

The team hopes that other researchers will join the search for ways to improve their system, Jain says. “It’s very much a model system,” he says, “and other groups will help to increase the efficiency.”

But Strano points out that since the near-infrared part of the solar spectrum is currently entirely unused by typical solar cells, even a low-efficiency cell that works in that region could be worthwhile as long as its cost is low. “If you could harness even a portion of the near-infrared spectrum, it adds value,” he says.

Strano adds that one of the paper's anonymous peer reviewers commented that the achievement of an infrared-absorbing carbon-based photovoltaic cell without polymer layers is the realization of "a dream for the field."

Michael Arnold, an assistant professor of materials science and engineering at the University of Wisconsin at Madison who was not involved in this research, says, "Carbon nanotubes offer tantalizing possibilities for increasing the efficiency of solar cells and are kind of like photovoltaic polymers on steroids." This work, he says, "is exciting because it demonstrates photovoltaic power conversion using an active layer that is entirely made from carbon." He adds, "This seems like a very promising direction that will eventually allow for nanotubes' promise to be more fully harnessed."

The work also involved MIT graduate students Rachel Howden, Steven Shimizu and Andrew Hilmer; postdoc Thomas McNicholas; and professor of chemical engineering Karen Gleason. It was supported by the Italian company Eni through the MIT Energy Initiative, as well as the National Science Foundation and the Department of Defense through graduate fellowships to Jain and Howden, respectively.

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