Shortfalls in Electron Production
Dim Hopes for MEG Solar Cells

Four years ago, researchers were delighted to discover that light-absorbing nanoparticles could readily generate more than one electron for every photon of light they absorb. Those extra charges, they hoped, would sharply increase the electrical output of future solar cells. But at the meeting, several teams reported setbacks in reaching that goal.

In typical solar cells, when a semiconductor such as silicon absorbs a photon of light with the right amount of energy, it generates an exciton: an electron paired to a positively charged electron vacancy called a hole. The solar cell then separates those opposite charges and collects them at the electrodes. In 2004, researchers led by Victor Klimov of the Los Alamos National Laboratory in New Mexico reported that when lead sulfide (PbS) nanocrystals were hit with high-energy photons from a laser, they could generate up to seven excitons. Other groups jumped in and found a similar multiple exciton generation (MEG) effect in a variety of other nanocrystals, including cadmium selenide (CdSe) and silicon.

Then doubts began to creep in. Last year, Moungi Bawendi, a chemist at the Massachusetts Institute of Technology in Cambridge, and his Ph.D. student Gautham Nair reported that when they used a different technique, they spotted only a negligible MEG effect in CdSe nanocrystals, a result they later extended to PbS and lead selenide (PbSe). This year, a Dutch group that had previously reported a sharp increase in MEG in indium arsenide nanocrystals reported it couldn’t reproduce the result. “The more results that came in, the more controversy there was,” Klimov says.

At the meeting, John McGuire, a post-doctoral assistant from Klimov’s group, reported new evidence that MEG in nanocrystals is far weaker than originally thought. In contrast to the 700% initially reported, the new Los Alamos results suggest the increase is likely about 40%, only slightly higher than the 25% increase seen by Bawendi’s group. The upshot, both Bawendi and Klimov agree, is bad news. “These numbers at this point are not of practical use for solar energy,” Bawendi says.

So what changed? Klimov says that for their current experiment, the results of which were also published online 12 November in Accounts of Chemical Research, the Los Alamos team stirred the samples to keep the nanoparticles from absorbing more than one photon at a time—potentially a source of false-positive results.

Hope for a strong MEG effect isn’t entirely lost, Klimov says. In some samples, the MEG effect was more than three times as high as in other samples. Synthetic differences between samples may have left some with surfaces that enhance the effect, he says—and if so, researchers may learn to engineer particles to optimize it.

Even if a large MEG turns out to be real, however, two separate teams found that getting those charges out of the nanocrystals won’t be easy. Randy Ellingson of the National Renewable Energy Laboratory (NREL) in Golden, Colorado, reported that his group had made simple solar cells containing a layer of PbSe nanocrystals, with electrodes above and below. Creating the nanocrystals leaves them decorated with organic groups around the outside. When they are put straight into the films, the crystallites are too far apart to pass charges to the electrodes, where they can be sent through a circuit to do work. So in their current study, Ellingson and his team treated their nanocrystals with hydrazine, which shortened the organic groups and allowed the nanocrystals to sit closer to one another. The solar cells worked. But spectroscopic studies suggested that the hydrazine treatment killed the MEG effect.

Meanwhile, Byung-Ryool Hyun, a graduate student in Frank Wise’s group at Cornell University, reported another challenge in getting charges out of PbS. In this case, the nanocrystals were linked to titanium dioxide (TiO$_2$) nanoparticles. When electrons are generated in the nanoparticles, they should move readily to the TiO$_2$. But Hyun reported that electrons moved so slowly that the charges typically recombined with holes and gave up their energy before the TiO$_2$ could snag them.

So is this the end of the road for MEG? Arthur Nozik, who has helped lead the MEG effort at NREL, says he hopes not. “It’s kind of a messy situation,” he says. He’s hopeful that further research will reveal ways to produce a large MEG effect. For now, however, hopes are dimming for MEG solar cells.

Protein Chip Promises Cheaper Diagnostics

Ever since recent advances made it possible to study thousands of genes and proteins at once, researchers have dreamed of nipping diseases in the bud by spotting telltale proteins with simple blood tests. So far, that vision remains a long way off. Few individual proteins in blood and tissues have proven to be conclusive indicators of disease. Even if they were, clinical lab tests that measure proteins don’t come cheap. Standard diagnostic panels can cost $50 each or more. At that price, scanning millions of patients for dozens or more proteins would cost a fortune. But new glass and plastic microfluidic chips could begin to change that equation.

At the meeting, James Heath, a chemist at the California Institute of Technology
Graphene Recipe Yields Carbon Cornucopia

The hottest material in physics these days is graphene, sheets of carbon just a single atom thick. Graphene is flexible yet harder than diamond. It conducts electricity faster at room temperature than anything else. And it’s nearly transparent, a handy property for devices such as solar cells and displays that need to let light through. The only trouble is that people have been able to make only small flakes of the stuff—until now.

At the meeting, Alfonso Reina Cecco, a graduate student in chemist Jing Kong’s lab at the Massachusetts Institute of Technology (MIT) in Cambridge, reported that he and several colleagues have come up with a cheap, easy way to grow high-quality graphene films and then transfer them wherever they want. “That’s a big deal,” says Andre Geim, a physicist at the University of Manchester, U.K., who first reported making graphene (Science, 22 October 2004, p. 666). “It promises wafers of graphene. That changes everything.” It opens the door both to better ways of exploring the new physics of atomically thin materials and to potential applications.

To create the first graphene sheets in 2004, Geim peeled single layers of graphene off chunks of graphite with clear tape. But that low-tech approach would be hard to scale up for industrial use. Researchers at the Georgia Institute of Technology in Atlanta came closer in 2004 by growing graphene films atop a substrate made of silicon carbide. But silicon carbide is expensive and must be processed in an ultra-high vacuum, which also raises the cost.

At the meeting, Cecco reported that the MIT team had done away with the silicon carbide. Instead, they deposited a film of nickel atop a standard silicon wafer. They then used a conventional film-growing technique known as chemical vapor deposition to add graphene in either a single sheet or a stack of a few sheets.

To transfer their graphene sheets to another surface, the MIT team coated it with a polymer known as PMMA, then etched away the silicon and the nickel after that, leaving only the graphene on the polymer film. Finally, they covered the newly reexposed graphene surface with glass and then dissolved away the PMMA. By initially patterning the nickel layer, Cecco and his MIT colleagues also showed that they could make graphene films in arbitrary patterns, such as those typically used to make electronic devices. The same day Cecco gave his talk, a paper on the topic was published online in Nano Letters. This ability to pattern and place graphene wherever it’s needed, Geim says, will only increase the amount of research done with the material, ensuring that it will stay among the hottest materials in physics.

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