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News

Nanoparticle solar cells make light work

Cheap, printable photovoltaics might finally live up to their early promise.

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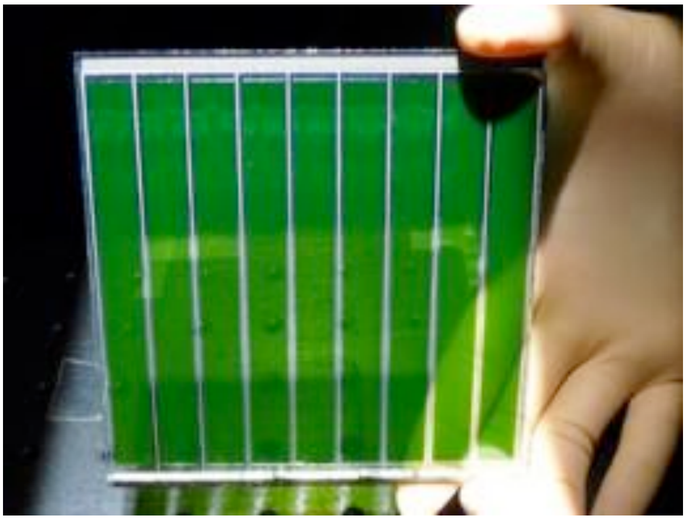

Need power? Just print out a solar cell.Michael Grätzel / Science/AAAS

A type of solar cell first discovered 20 years ago could finally become commercially viable thanks to improvements reported in Science today[1]. This alternative design could lead to cheap, printable cells that would massively boost the worldwide use of solar power.

Electrochemist Michael Grätzel at the Swiss Federal Institute of Technology in Lausanne devised the dye-sensitized nanocrystal cell (DSC) in 1991. It uses organic dye molecules to absorb sunlight, the energy of which then kicks electrons onto tiny nanoparticles of the ceramic titanium dioxide (titania) on which the dye sits. These electrons are collected by electrodes to generate an electrical current.

Titania is itself very cheap: in a larger-grained form, it is the pigment in white paint. And the cells themselves should be easy to mass produce. Grätzel and others have developed methods for 'printing' arrays of nanocrystal solar cells onto glass panels and metal foils.

This all makes DSCs look like an attractive alternative to conventional photovoltaic cells, which are usually made from thin films or wafers of silicon and are relatively expensive to produce.

Upping efficiency

DSCs have previously achieved efficiencies of up to 11%, slightly better than commercial silicon photovoltaic cells, and are already being marketed in small amounts. The company G24 Innovations, based in Cardiff, UK, sells them in flexible, plastic-mounted modules, and several other companies, particularly in east Asia, are marketing them on glass panels that can be integrated into buildings.

But use of the technology has been restricted so far. The dyes used to harvest sunlight contain atoms of ruthenium, an expensive metal. And because of their conversion inefficiencies, DSCs also tend to produce only low voltages (less than 0.8 V).

To complete the electrical circuit and replace the electrons ejected from the dye, DSCs use a chemical compound to ferry electrons from the second electrode. Earlier cells use dissolved iodine, which picks up an electron to form tri-iodide ions. The ions diffuse through the liquid between the electrodes until they reach the dye-coated titania particles.

But tri-iodide ions aren't a good match for the electron energies in the dye molecules: they waste energy transferring their electrons, resulting in a low cell voltage and thus low power. The trouble is, alternative electron carriers that are better matched for transferring electrons suffer from the fact that electrons can jump back onto them from the dyes, squandering the absorbed solar energy.

Now Grätzel and his colleagues have found good alternatives both to the expensive ruthenium dyes and the voltage-limiting iodide mediators. "It's a very nice paper, and a significant advance," says Jenny Nelson, a specialist in polymer and nanocrystal solar cells at Imperial College in London.

For the dyes, Grätzel's team uses complex three-part molecules consisting of a group that readily loses electrons, a group that readily accepts them, and a bridging unit containing a light-absorbing group related to that in chlorophyll.

For the electron mediator, the researchers use organic molecules bound to cobalt atoms, which can switch between two states by the gain or loss of an electron. They tailored the dye by attaching bulky chemical groups that act as barriers, preventing unwanted back-hopping of electrons from the mediator to the dye.

The resulting DSCs have achieved record-breaking voltages (up to 0.97 V) and efficiencies (up to 12.3%). If efficiency can be pushed up to about 15%, the devices should become cost-effective competitors to silicon photovoltaic cells.

Remaining problems

There are other problems to solve first, however. In particular, Grätzel's cobalt mediator is dissolved in acetonitrile, a highly volatile solvent not suitable for use in practical devices, according to Gerrit Boschloo, an expert on DSCs at Uppsala University in Sweden, who first reported cobalt mediators in 2010[2]. He adds that the mediator currently used by the Lausanne team is probably not stable enough for long-term use.

Grätzel says he is working on these and other improvements – for example, adapting the dyes to capture more of the red component of sunlight, and testing new cobalt mediators that boost the voltage still further.

- # References

1. Yella, A. *et al.* Science 334, 629-634 (2011). | Article | ChemPort |
2. Feldt, S. M. *et al.* Journal of the American Chemical Society 132, 16714-16724 (2010). | Article | PubMed | ISI | ChemPort |