REDOUBLED EFFORTS IN SOLAR CELLS

Solar energy is obviously one of the key renewable energy resources available to us. At the same time researchers are hitting against a glass ceiling. A famous 1961 paperby William Shockley (who co-invented the transistor) and Hans Queisser comes to the conclusion that for a semiconductor such as silicon the maximum conversion efficiency of solar energy into electricity will never be more than about 30%.

Dye-sensitized solar cells. A design similar to these solar cells is now used to demonstrate the creation and extraction of multiple charge carriers per photons.

One reason for this limit is that each light particle only excites one electron. Even if the electron has enough energy to excite two electrons, all this energy is lost and only one electron is excited. And this is the case for pretty much all present commercial solar cell technology. Fortunately, however, there are possible exceptions.

Bruce Parkinson and colleagues from the University of Wyoming in the USA have now built a photovoltaic cell that at certain wavelengths of light can generate more than one electron per photon of light. Their approach promises to beat the Shockley-Queisser limit and could lead to solar cells with considerably enhanced efficiency.

In silicon and other semiconductors, if a photon excites an electron all excess energy is predominantly lost as heat. Of course, there are attempts to harvest the heat generated in solar cells, and such approaches could beat the Shockley-Queisser limit. And so could nanostructured materials that use for example plasmonic effects. But a more direct solution would be if the excess energy could be used to excite more than one electron in the first place.

Indeed, such schemes have been proposed for nanoscale semiconductor structures such as quantum dots. These are tiny particles of only a few nanometers in size. The quantum dots used by Parkinson have a diameter of about 4.5 nanometers, so that the electrons are highly confined to a small space. This confinement means that the interaction between electrons is strong, and the process of heat generation may suddenly not be the only option during light absorption. Instead, it is now likely that the excess energy from high-energy photons is used to excite a second electron.

This idea of such multiple carrier generation has been around for decades. In particular advances in the synthesis of semiconductor quantum dots during the past decade have led to a revival of experimental studies, and consequently with a number of claims of multiple-electron-generation by single photons. But some of these experiments are controversial whereas others remain inconclusive. None have conclusively demonstrated such an effect in a functioning solar cell. It is Parkinson and colleagues who now demonstrate for the first time a photovoltaic cell where more than one electron per photon of light is extracted.

The design of their photovoltaic cell follows largely that of a dye-sensitized solar cell. Lead sulfide (PbS) quantum dots with 4.5 nm diameter are placed on a titanium dioxide (TiO_2). Light is absorbed by the quantum dots and the electrons created are extracted to the titanium dioxide anode. An electrolyte liquid that covers this titanium surface is used to close the electric circuit and to transport the electrons' positively charged counterparts, the holes, to the cathode. For light energies above the threshold required to excite two electrons, the authors find that on average up to 1.7 electrons are created.

While these results are indeed a significant advance towards beating the Shockley-Queisser limit, we won't be seeing such devices on our rooftops quite yet. For once, multiple electrons are only generated for the high-energy part of the spectrum, namely green and blue light.

For red colors the absorption efficiency remains the same. Moreover, the overall efficiency of these cells is not documented, and the increase in performance that can be achieved remains unclear. Nor is this kind of architecture really suited for record-breaking efficiencies.

The best dye-sensitized solar cells presently achieve about 11% efficiency, less than half of what the best silicon cells can deliver. Instead, the advantage of dye-sensitized solar cells is their cheap fabrication. Significant enhancements in efficiency could therefore still translate into a commercial benefit, even though consumer devices probably better use quantum dots not made from toxic heavy metals such as lead.

Nevertheless, this study seems to settle a long-standing debate on the issue of multiple charge carrier generation and could lead to more intensive research into solar cells based on light absorption in quantum dots.

Source: http://allthatmatters.heber.org/2010/10/04/redoubled-efforts-in-solar-cells/