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Nano scales up to mega watts

Nano particles may improve the working of photo-cells, says S.Ananthanarayanan.

The photo-cell, which converts sunlight into electricity – without burning any fuel, creating no pollution, and at no operating cost – could be the answer to the world’s energy crisis. The trouble is the high initial cost of the device and its low operating efficiency.

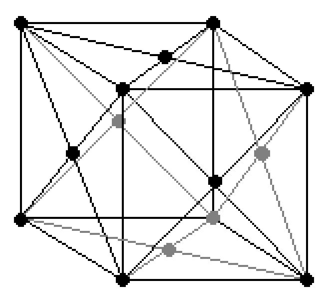
Solar cells can work where the power required is low, like a portable calculator or can be a solution at a remote location, where providing power supply through cables is not possible or economical, but as a source of abundant and cheap electricity, they have not proved viable. The journal of the Optical Society of America reported last week a welcome advance in the efficiency of the photo cell by the use of ***nano-particles***.

Solar Cells

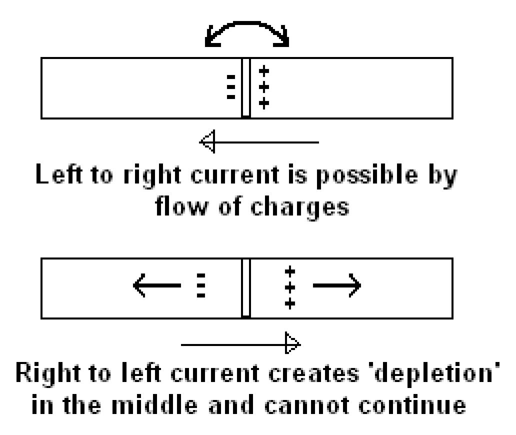
In 1839, A E Becquerel, French scientist, noticed that light falling on some metals could generate electricity. 45 years later, the American inventor Charles Fritts created the first photocell, albeit barely effective, with a sheet of selenium, a semiconductor material, coated with a thin layer of gold. Modern photocells, which use a junction of semiconductors, appeared in 1946 and practical photocells, based on silicon and with an efficiency of 6%, appeared in 1954.

The way the solar cell works is that photons of light of the correct frequencies can knock the electrons in the atoms of some solids out of influence of the atom. This kind of charge cloud at the surface would normally inhibit more electrons being knocked out and put a stop to the effect. But if the freed electrons could be drawn off and the depletion of electrons in the solid replenished, the flow of electrons would be an electric current!

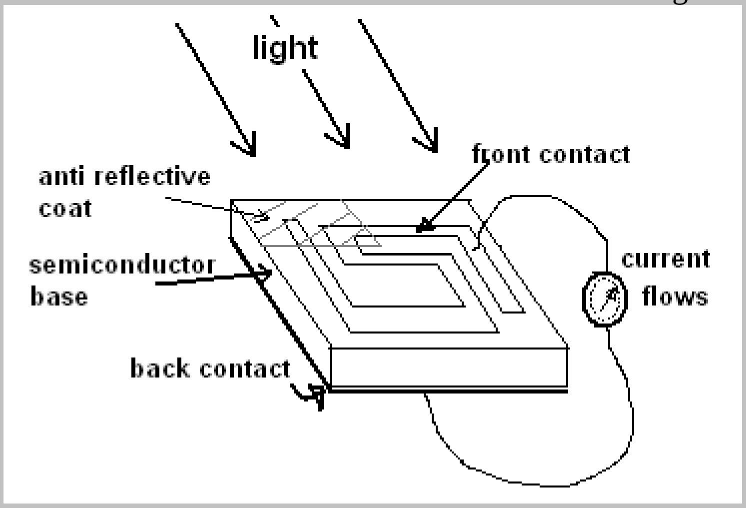
This practical part is achieved using a ***semiconductor junction***. Silicon is the metal that has made the difference. As the silicon atom has 4 electrons in its outermost electron shell, silicon atoms can form a stable, hand-holding network with one another, in the crystalline state, as shown.



Now, if just an occasional silicon atom is replaced with an atom of a different element, which has either 5 or 3 electrons in the outermost shell, then that atom can also be in the hand-holding lattice, except that each such atom would have one electron too many or be one electron short. Treating silicon like this is called ***doping***. This extra electron, or the ***hole***, where there is one electron short, could also jump from atom to atom and become a freely moving carrier of charge if a charge is applied to the crystal. And further, if we formed a junction of these two types of doped silicon, then, the presence of free electrons on one side and free ‘holes’ on the other create an asymmetry – there can be flow of electrons from one side and holes from the other, but there cannot be flow in the other direction – the junction is a one way gate!



The combination of a photovoltaic material and such a semiconductor, which will carry away the electrons knocked out by light energy, but not allow the electrons to go back the same way, then drives the electrons round in a ‘circuit’ - thus creating and electric current.



And in this way, this simple arrangement, once in place, can generate electricity for a long time, without any input other than sunlight and with no emissions or discharge. But, as we said before, the semiconductor junction, the materials and contacts are expensive and worst of all, the device does not generate a lot of electricity for even a lot of sunlight! Great efforts, hence, have gone it to improving the efficiency, so that the device could become useful for large scale electricity generation.

Improving output

An important reason for the conversion efficiency being low is that all the light that strikes the photo cell does not get used and also that the cell cannot convert all the colours of light that are there in sunlight.

Kylie R Catchpole and Albert Polemen, working in the Institute for Atomic and Molecular physics at Amsterdam, have reported in their paper that the nano-particle method they have developed seeks to remedy these two shortcomings of solar cells.

In the normal course, a photon striking a metal would be absorbed, allowed to pass through or reflected. When the metal is in the form of a nano-particle, of the dimensions of the wavelength of light and atomic particles, however, different processes kick in – there is formed on the surface of the nano-particle a wave of electron motion, called a '***surface plasmon***', which can be very intense if the properties of the particle and the light wave should match – resonance, in fact.

The Amsterdam researchers covered a solar cell with a thin coating of nanoscopic (a millionth of a millimeter) metal particles. First of all, the barrier scattered the incoming light and made sure that more of it remained within the solar cell. And then, with careful control of the size of the nano-particles, the capture of different colours of light could be tuned and the performance of poor colours also improved.

It was found that the use of long wavelength (reddish) light improved by a factor of 10. Kylie Catchpole, while working in New South Wales, in Australia, had earlier shown that by using nano-particles, the overall efficiency of solar cells could go up by a factor of 30.

The work if of great interest as improved solar cell construction could answer many baffling questions facing the world today.

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90 % of the solar cell market is based on crystalline silicon wafers, with thicknesses of 200-300 microns. Around 40% of the cost of a solar module made from crystalline silicon is the cost of the silicon wafers. Thin film solar cells, which are only 1-2 microns thick and are deposited on cheap substrates like glass, plastic or stainless steel have been of interest during the last ten years. They use different semiconductors, like cadmium telluride and copper indium diselenide, as well as amorphous and polycrystalline silicon. But in all these technologies, and particularly with silicon, light at the relevant wavelengths is not effectively absorbed.

One method to improve performance, in the case of wafer based cells, is light-trapping, with pyramids of size of 2-10 microns etched into the surface. This method is not practical with thin-film cells whose thickness is in the micron range. With thin films, one way is by forming a wavelength-scale texture on the substrate and then depositing the thin-film solar cell on top. Large increases in photocurrent have been achieved in this way. But a limitation with both is that a rough semiconductor surface affects its performance, and semiconductors deposited on rough surfaces typically have low material quality.

The approach of using noble metal nano-particles of selected sizes appears to be promising and full of potential.