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Repair of retina now in sight

Solar cell material may help the visually impaired to see, says S.Ananthanarayanan.

Solar cells create electricity when sunlight falls on them. The cells of the retina in the eye do the same thing, sending pulses of electricity to the optic nerve when exposed to light. While there has been no way to repair damaged retinas, it is tempting to think of using solar cell material to take their place.

The trouble is that solar cells have traditionally used metallic components, like silicon or germanium crystals, materials that cannot be integrated with living tissue in animals. The discovery of organic materials that could work as solar cells raised hopes that synthetic materials, which are known to interface with biological tissue, may find a place in the eye. ***Diego Ghezzi, Maria Rosa Antognazza, Rita Maccarone, Sebastiano Bellani, Erica Lanzarini, Nicola Martino, Maurizio Mete, Grazia Pertile, Silvia Bisti, Guglielmo Lanzani***, scientists in Geneva, Milan, L'Aquila and Negrar, Italy, report in the journal, ***Nature Photonics***, that a popular synthetic material is shown to efficiently stimulate nerve cells and restore light sensitivity in a damaged retina. "Interfacing organic electronics with biological substrates offers new possibilities for biotechnology…" say the authors of the paper.

The photocell

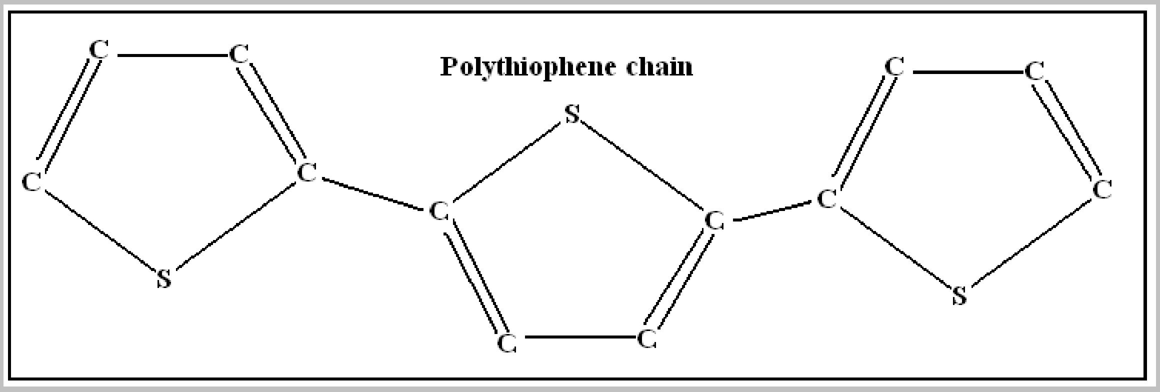
Photo cells and solar cells work thanks to the ***photovoltaic effect***, a property of some metals, discovered by in 1839 by ***Edmund Becquerel***, a 19 year old French scientist. In metals that form a balanced crystal lattice, like silicon, where the 4 outer shell electrons of each atom 'holds hands' with a similar electron of a neighbouring atom., the forces that bind the electrons to the atoms get diluted and the outer electrons can be nudged to escape the parent atom and 'float', to conduct electricity. In metals like silicon, the 'nudge' can be gentle and photons of light can provide the necessary energy. But this effect is not of use by itself, as the atom that has yielded an electron would be left with net positive charge, which would rapidly bring the fugitive electron back.

The way the electrons that are freed by a photon are made to do work, as an electric current, before they go back to where they belong, is to trap the free electrons behind a 'one-way' gate, so that they need to flow through an electric circuit to return. The one-way gate is created by using silicon in two modified forms of lattice, in conjunction. The silicon atom forms a balanced lattice because it has four outer shell electrons. Now, if the lattice is '***doped'*** with, or impurities added of, other atoms which have either 3 or 5 outer electrons, like phosphorus or boron, then, at each of these atoms, the lattice would have one electron 'short' or 'too many'. Such 'extra' electrons, or the lack of one, which are called '***holes***', equally help carry electricity and materials that have been treated in this way are called ***semiconductors***. And, when there is a junction of the two kinds of semiconductors, then, the electron carriers on one side of the junction can pass into the next one, but the 'holes' on the other side cannot move to the 'extra' electron side. The junction is thus '***one way'***. In a stack of these two kinds of semiconductors, electric charge builds up on the opposite sides of the 'gate' and this can drive a current through a device or charge a battery.   We can see that it is a '***donor-acceptor'*** mechanism that is in action..

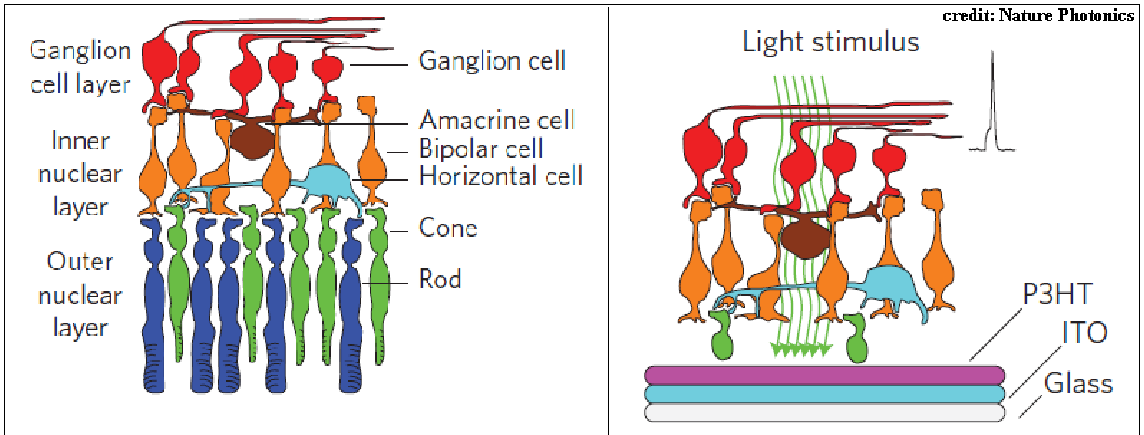
Organic photo-material

Just like silicon and germanium have 4 outer shell electrons, which gives them special properties, the simpler element, carbon also has this 4-electron structure. And, thanks to its lower mass, carbon is able to easily form a variety of compounds with oxygen, hydrogen and other elements, like sulphur, chlorine, nitrogen. These compounds are stable and engage in reactions at normal temperature and pressures and hence all life, vegetation and animal, is carbon based – which gives this class of compounds the name, ***organic***. As organic compounds arise from chemical combinations, where the outer electrons of atoms engage with other atoms, the electrons are not usually free to conduct electricity and organic materials have not been of great use in this area, except as insulators.

An exception is the class of conducting polymers, which are organic molecules with a long, repeating structure, with bonds that allow electrons to get free. Important work on these compounds was done by Alan J. Heeger, Alan MacDiarmid, and Hideki Shirakawa and they received the Nobel Prize for Chemistry for the year 2000 for their work. In this\ work, they developed a class of compounds, the ***polythiophenes (PTH)***, which occur as chains of units of five sided rings, each with one sulphur and four carbon atoms at the corners, with the bonds between atoms being the 'sharing of outer shell electrons. The carbon atoms participate in the ring by sharing one electron with one neighbour, two electrons with the next and the last electron with some chemical group outside the ring. This combination of single and double bonds allows an electron to become free to conduct and also allows 'doping' where there can be an 'extra' or a 'one short' electron, although it the 'extra' that is common.

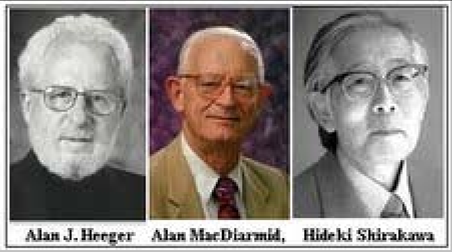


This class of compound has marked response to exposure to light and has given rise to the field of organic or ***polymer solar cells***. These consist of a optically active layer sandwiched between an electron or hole blocker, mounted on a conducting glass surface, and a metallic electrode. The device is much lighter and cheaper than silicon based devices, apart from being flexible, so that it can be rolled into sheets. The material can also be customized, during preparation, to suit the kind of light source it is to be used with. But the disadvantage is that it is only 1/3 as efficient as silicon based devices. But the promise of cheap and large scale deployment has led to huge research effort and improvements in efficiency that have been achieved are perhaps more than what has been reported.



Optic nerve cells with natural light detectors **Optic nerve cells with synthetic detectors**

One of the most successful materials for this kind of application is the blend of a PTH, an electron donor, and a Fullerene molecule, which has a shape like a geodesic dome or a football, which acts as an electron acceptor – thereby enabling the proven ***donor-acceptor*** mechanism. Apart from a high figure of efficiency in its use in solar cells, this blend has also proved successful in stimulating nerve cells cultured on a substrate, or platform, of the blend. The authors of the paper point out that the manner of working, when in contact with biological material, may be different from the electron exchange mechanism in the usual solar cell design. With biological material, it may be a case of charges on one side of the interface inducing corresponding effects on the other side, rather than a physical current.



The Italian team carried out detailed studies with the electron donor, or PTH part of the blend, alone, and the retinal nerve cells extracted from albino rats. The light sensitive layer of the retina was degenerated and the depleted cells were placed on specially treated glass coated with PTH. Trials then showed that levels of low illumination, which had no effect on retinal cells placed on just the prepared glass, had marked effect when the cells were place on glass coated with PTH. As a sequel, the team tried out the PTH layer not with nerve cells but with the retina itself of albino rats, where the photoreceptors of the receptors had been damaged. The exciting discovery was that the level of response was as good as with a normal retina – which holds out the possibility of using light sensitive polymers for sight restoration of the visually impaired!