Plastic PV with emphasis on the electron acceptor side

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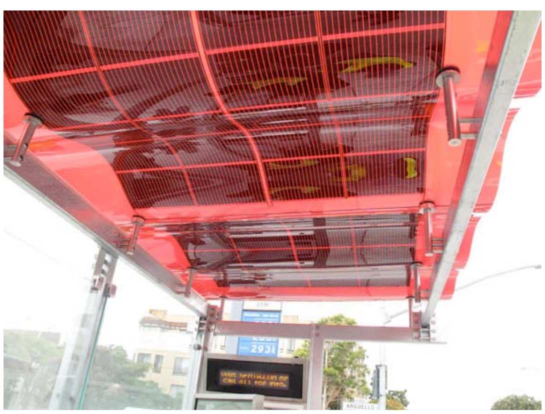
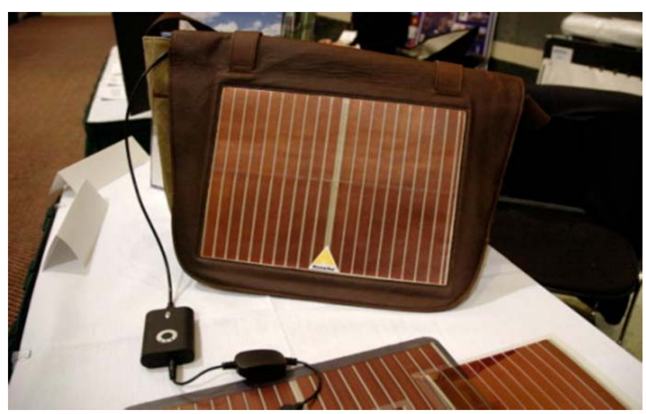
One way to lower the cost of PV cells is to make the manufacturing process cheaper. In the production of silicon and in the manufacturing processes for silicon solar cells, high temperature processes and steps in which (high) vacuum is needed are part of the chain. Making layers by simple printing techniques can be much cheaper than making layers by evaporation methods. Another advantage of printing is that products can be made on very large scale, and that is exactly what is needed for a future in which PV products provide 25% or more of the world's need for electrical energy. In 2008, some tens of km^2 of solar panels were installed worldwide. In 15-30 years from now, this should grow to something like ten thousand km^2 or more per year! While it is certainly not the only option, plastic PV technology can be regarded as a good candidate to supply the world with those numbers of solar cells at highly competitive cost, because it beautifully combines the thin film aspect with that of low energy, low cost, and large scale fabrication methods. Last but not least, there is plenty of supply material for organic (plastic) solar cells on our planet. First, a few pictures of real plastic solar cells, and then let us explain how plastic PV works.





Left: Bus stop with plastic PV roof top in San Francisco by 3Form / Konarka; © Matthew Roth (2009).
Right: a prototype solar bag with an integrated plastic PV module by Noon Solar / Konarka.

Plastic PV is called plastic because that is a nice and popular name for one of the constituents of the active layer in the mainstream of bulk heterojunction-type active layers in 'organic' (molecular) photovoltaic devices. 'Plastic PV' sells because it sounds like low cost, flexible, mass product, and potentially applicable in many ways that are less obvious for the common crystalline silicon-based 'solar panels'. Plastic PV can be considered as member of the class of molecular PV, more generally known as organic PV (OPV). Molecular PV – as we know it today- is really different from the more classical inorganic PV. I say 'as we know it today', because we might be able to develop molecular semiconductors in the future that have properties that come closer to those of inorganic semiconductors than the ones we can presently make. For now, molecular semiconductors have the disadvantage that no free charges are formed directly upon absorption of a photon. Instead, an excited molecule (or exciton in the solid state) is created in which the hole and electron are still bound significantly. A second, either more or less electronegative material is needed to really separate the hole and the electron by charge transfer in one or the other direction. Hence, OPV is based on the combination of two materials (or two functionalities combined in a single material) that have a electronic donor-acceptor relationship. I will explain this situation and the relevant processes in detail in the introduction. This leads to the introduction of the principle of the bulk-heterojunction.

I will then focus on the developments regarding the materials that are being used in the active layer in bulk-heterojunction PV active layers. The most commonly used materials are conjugated polymers as donor materials and fullerene derivatives are acceptor materials. The two main points to improve in OPV are efficiency and lifetime. In order to increase the efficiency, much effort has been done to design better polymer donor materials in terms of absorption spectrum, charge carrier mobility, processability, and lifetime. But improving the same properties of the acceptor materials is just as important! I will discuss the historical development of both.

I will explain how we recently unraveled the dynamics of the second charge generation process in bulk-heterojunction PV. This hole transfer process really forms a twin with the more commonly known electron transfer. In present day world record cells, the two processes simultaneously lead to the total photocurrent.

Finally, I will discuss some variations on the theme of (bulk-heterojunction) PV and I will end with some thoughts about the future of OPV in particular and of organic electronics in general.