

## Electric power from light and plastics

It is expected that organic solar cells on flexible substrate films will be used in the future as portable sources of electric power. Today, such solar cells are already being integrated into functional jackets, for example, to charge smartphones.

This would likely be very uncomfortable with the rigid solar cells. Organic solar cells promise some other advantages: for instance, low weight and low-cost production. By early 2016, organic solar cells had already achieved efficiency of about 13 percent. However, the service life of approximately 5 to 12 years is still inadequate.

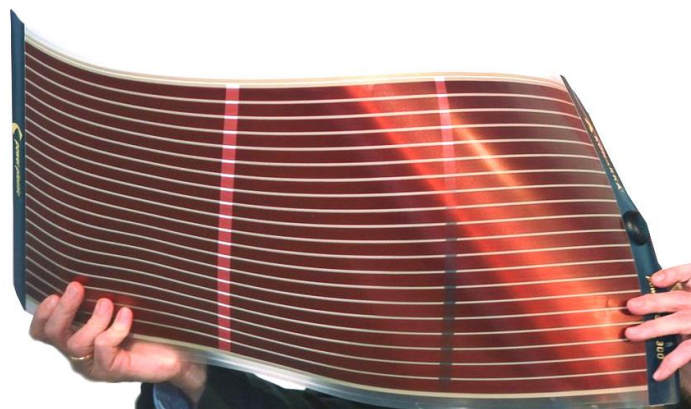


Figure 1: The organic solar cell

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## Structure and operating principle of the organic solar cell

### Layered structure of donor and acceptor material

Organic solar cells generally consist of an electron-donating layer (“donor”) and an electron-absorbing layer (“acceptor”), arranged between two electrodes, the anode (positive pole) and cathode (negative pole). A macromolecule (“polymer”) with alternating single and double bonds (conjugated polymer) that readily emits electrons is frequently used as the donor. Fullerenes are used for the acceptor that receives the emitted electrons. These are spherical molecules made up of 60, 70, 76, or 84 carbon atoms.

Research and production methods based on oligomers are also being pursued, with the expectation of greater efficiency and, in particular, a longer cell service life. (Oligomers are also macromolecules, but unlike the polymers, they consist of fewer monomer components, so they are shorter.)

### Operating principle

The light impinging through the transparent anode is absorbed by the donor molecules, which are thereby electronically excited. When light is absorbed, free electrons do not form immediately. Instead, “excitons,” which are pairs with one negative charge (electron) and one positive charge (so-called “hole”) each, are created. These pairs have to be separated in order to release the electrons. This takes place at the boundary layer to the acceptor, where the exciton in the donor transfers one electron to the acceptor (see Fig. 2). This electron is then diverted through the cathode and can flow back to the anode via an external circuit. The module thus delivers electric power. If separate donor-acceptor layers are used, generation of electrons is limited only to the thin boundary region between the donor and acceptor layer. For this reason, the donor and acceptor material are often blended together in a joint layer (see Fig. 3 below). That allows electron generation to take place over the entire volume and the electricity yield increases.

Thanks to the long-chain conjugated system of the polymer donor, it can absorb light at many different wavelengths. By contrast with conventional silicon solar cells, which absorb light only in a narrower spectral range, organic solar cells therefore convert a considerably broader spectrum of light. For example, artificial light can also be converted to electric power. Despite the broad absorption spectrum and the theoretically high efficiency, the actual efficiency of the organic solar cells technically realizable at present is only approximately half as high as the efficiency of silicon cells (see section “Success factors of the organic solar cell”).

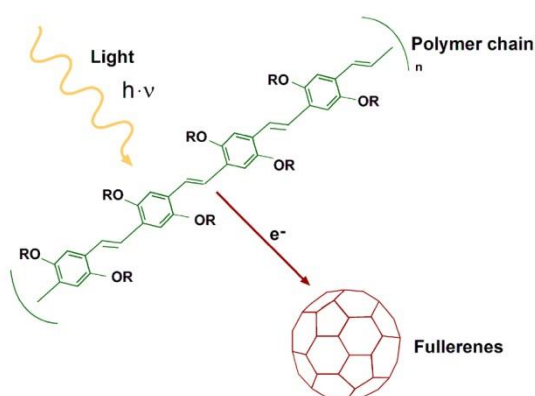


Figure 2: Schematic diagram of the charge transfer in the donor-acceptor system: Polymer chain (donor) and fullerene molecule (acceptor).

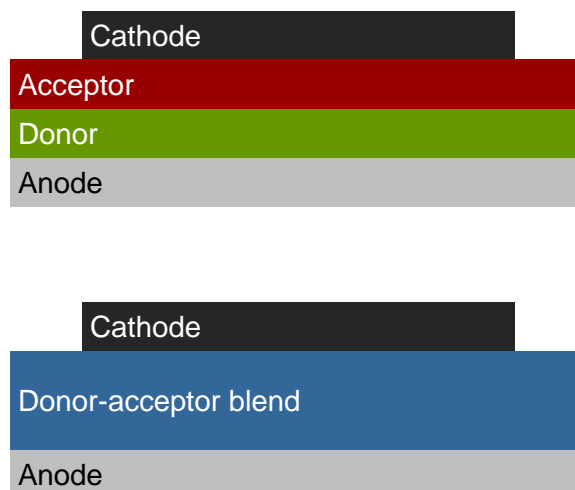


Figure 3: The top graphic shows the structure of an organic solar cell based on a two-layer structure with a donor and an acceptor layer. In the bottom graphic, the photoactive layer consists of a donor-acceptor blend.

## Organic solar cells can be produced without high-temperature processes

The individual layers of relatively low-cost materials are applied one on top of the other on a substrate film using a straightforward printing technique. A major advantage compared with conventional silicon cells is that these films (for example, made of PET plastic) are flexible and also considerably lighter. The photoactive layer is about 100 nm thick, equivalent to about a two-hundredth of the thickness of a hair. However, particles of dirt could result in short-circuits in these thin layers, so extremely clean work conditions are therefore a must.

In addition to the printing technique, a method in which the reactive layers are applied by means of a vacuum process at low temperatures (and without solvents) has recently become established; it has also proved to be successful in the manufacture of OLED displays.

## Wide spectrum of potential applications

Organic solar cells are extremely flexible and can therefore be formed into almost any shape. They also have a low weight and can be colored as well as transparent. The unusual properties of organic photovoltaics open up a broad range of potential applications. It would be possible, for instance, to integrate organic solar modules in garments in order to supply electric devices carried by the wearer with electric power. Roll-up portable solar films could supply electric power for PDAs, MP3 players, or mobile phones at any time. Entire facades, windows, or blinds could be covered with transparent or colored solar cells in the future.

## Success factors of the organic solar cell

The following factors will crucially dictate the future success of organic solar cells:

- **Environmental compatibility:** The materials used are environmentally compatible and can be produced and disposed of without much pollution of the environment. This fulfills EU Directive 2002/95/EC (RoHS), which governs the use of hazardous substances in electronic devices and components.
- **Low weight, small dimensions:** A typical solar cell film is barely one millimeter thick and weighs approximately 500 g per square meter, while the electrically active materials weigh only one gram.
- **Price:** The materials are cheap in comparison with silicon since there is no need for the complex and expensive process of growing high-purity crystals. The printing process is also fast, simple, and cheap. Producers hope to reach less than 15 eurocents/watt of electrical power (compared to 40 eurocents/watt with conventional silicon-based solar cell technology).
- **Efficiency:** Series production of an organic solar cell with efficiency of 13 percent has been announced. The efficiency of a commercially available inorganic solar module is still considerably higher (25 percent). In addition, in 2007 organic solar cells had achieved efficiency of only about 2 to 3 percent.  
Researchers also point out a relatively high energy yield with diffuse, weak light and at extremely high temperatures – conditions that hamper conventional cells.
- **Service life:** Early organic solar cells had a service life of a few 1,000 hours of sunshine (equivalent to 220 days in the Stuttgart (Germany) area). The issue is the effective encapsulation of the organic materials. Organic solar modules packed in glass last for up to 15 years; the relatively small molecules of the oligomers even last more than 20 years. Currently, flexibly encapsulated modules may achieve a service life of only approximately five years; an increase is expected.