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Organic photovoltaics:solar power from extremely thin tinted films and polymer films

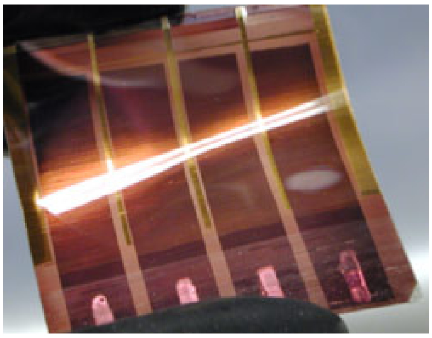
by Rolf Hug
06.09.2007

This new generation of solar cells could be providing environmentally friendly and cost-effective power in fold-up mobile telephone chargers or on car roofs in the very near future. The photovoltaic cells made of organic semiconductor materials are flexible and as thin as plastic films, as well as light-weight and variable in colour. But mainly in the construction industry these organic solar cells are to be utilised as thin, photoactive layer on roofs, façades or even on windows.

German technology initiative centres around organic photovoltaics

Photoelectric effects in organic materials have been known since the 1960's: on the grounds of the success of "conventional" solar cells with organic semiconductors (silicon, amorphous silicon, gallium arsenide, sulphide), however, OPV research was thus far limited to but a few laboratories and universities. In addition, until recently organic photovoltaics were considered by natural scientists as not to be taken seriously and as being of limited potential. But with the Chemistry Nobel Prize having been awarded to the OPV researcher Alan Heeger in 2000, this has changed and is expected to change even more: the German Federal Government and companies such as BASF, BOSCH, MERCK and SCHOTT are following a joint high-tech strategy, are joining forces and are planning to invest a total of 360 million euro into organic photovoltaics (OPV). Solar film is to be manufactured industrially by 2015 already, Bosch Group, that is a part of this initiative, emphasises.

Solar-Report as PDF-Document




Flexible, organic solar cells manufactured at the Fraunhofer ISE. Organic solar cells of the University of California in Santa Barbara (UCSB). Sources: ISE; UCSB

"With organic photovoltaics we want to make available solar energy at reasonable prices," explains Dr Siegfried Dais, Deputy Chairman of the Bosch Board of Management who is responsible for research and future developments. This would only be possible with efficient mass production. Bosch wants to develop the necessary processes to this end. "At

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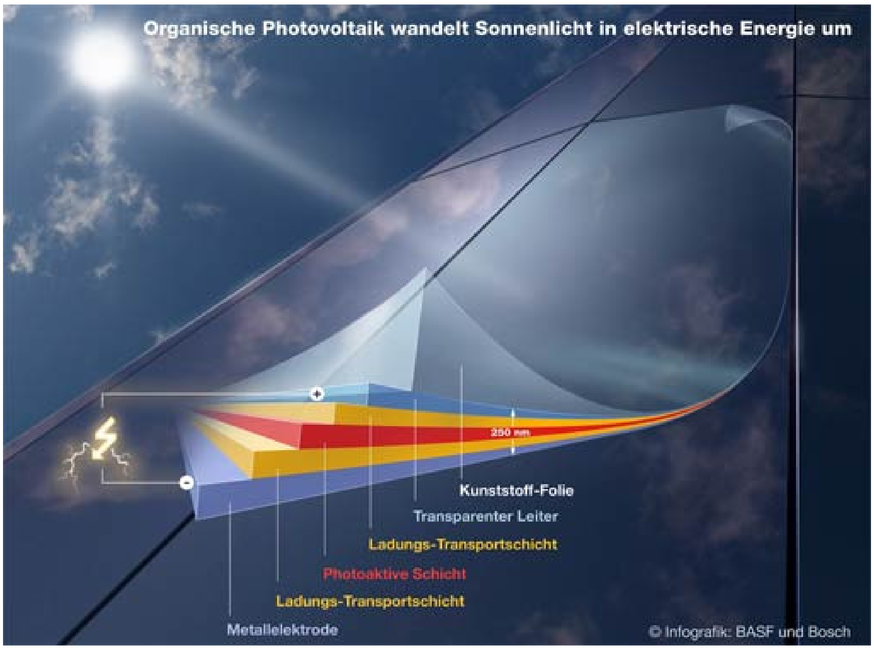
the same time we also want to take a giant step towards our vision of an energy self-sufficient house," Dr Dais adds. The joint goal of all researchers involved was to develop organic solar cells that will transform at least ten percent of all light absorbed into electrical energy and that have a lifespan of over twenty years.

New materials, manufacturing processes and installation technologies are to ensure that organic solar cells are more efficient and cost-effective in the long term. Mainly, however, researchers and companies are expecting lower production costs on the basis of more cost-efficient production technologies and decreased material consumption. Solar cells of the future will be flexible, will weigh even less and will be characterised by their environmentally friendly properties. Furthermore, tinted organic solar cells will open new possibilities in the field of architecture and design.

Solar Report 8/2007 zooms in on the fundamental principles of OPV, as well as on research on organic solar cells and sketches industrial perspectives of the "Third Generation of Solar Technology".



Wording of image: Organic photovoltaics transform sunlight into electrical energy; Polymer film, Transparent conductor, Charge carrier layer, Photoactive layer, Charge carrier layer, Metal electrode] With a photoactive layer of only 250 nanometers, organic solar films can be integrated into building elements, such as windows. Infografik: BASF - The Chemical Company, 2007

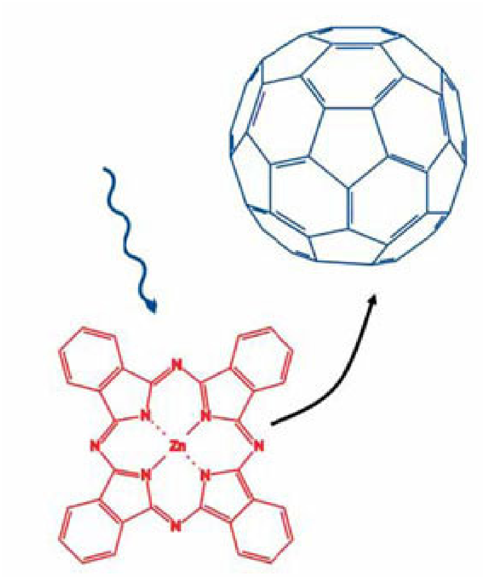
Nobel Prize for the principles of OPV

The awarding of the Nobel Prize for Chemistry in 2000 to Alan Heeger, Professor of Physics at the University of California in Santa Barbara (UCSB), is considered a breakthrough for organic photovoltaics. Heeger received the Chemistry Nobel Prize together with Alan MacDiarmid and Hideki Shirakawa for the discovery and development of conductive polymers. In July 2007 the Nobel Prize winner together with the Korean Kwanghee Lee presented a new, organic tandem solar cell with an increased degree of efficiency. The double solar cell consists of two layers that absorb shorter as well as longer light waves and can thus absorb a broader spectrum of solar radiation than cells with only one layer. "The result is a degree of efficiency of 6.5%. This is the highest efficiency ever achieved with solar cells. And I am convinced that we can further improve the cells that they will meet the requirements of commercial applications," Heeger emphasises. He expects these solar cells to be in the market within three years.

Organic and polymer solar cells function according to the same principles

Organic photovoltaics refers to solar cells on the basis of organic semiconductor materials (mostly dyes) that can generate electric current from light. The Graetzel cell, an electrochemical dye-sensitised solar cell named after its inventor Michael Grätzel of the Swiss Technical University Lausanne, for example, uses the chlorophyll molecule of a leaf with which plants convert sunlight into chemical energy. A variant of organic photovoltaics are electrically conductive polymers (hydrocarbon polymers) used by Alan Heeger. The principle according to which both organic as well as polymer solar cells function is based on a transfer of electrons that is initiated by sunlight, the so-called Donor-Acceptor System (see graph).

The photoactive layers in organic and polymer solar cells usually consist of an electron donor and an electron acceptor material. For organic solar cells, dyes from the group of the so-called phthalocyanines are used as donors and molecules from the hydrocarbon atoms (with fullerene) are used as acceptors. The layers are generally created through the separation of materials from the gaseous phase in vacuum.



Graph: Schematic presentation of the light-induced charge transfer within a donor-acceptor system: the zinc-phthalocyanine molecule (donor, red) gives off electrons. The fullerene molecule (acceptor, blue) accepts these. Source: HMI

In polymer solar cells compound polymers are used as donors and, in some cases, also as acceptors. Often fullerenes are utilised as electron acceptors. The structure of a polymer solar cell is similar to that of an organic solar cell, although its photoactive layer consists of a donor-acceptor combination. Production of the active layer of a polymer solar cell is simple: first the donor and acceptor materials are dissolved in a solvent and are then excited through dropping, spinning or pressing these onto a suitable substrate. After the solvent has evaporated, a homogeneous film of a thickness of approx. 100 nanometer (nm) is formed – this is about one two-hundredth of the thickness of a human hair. The simple printing of polymers onto a film promises low manufacturing costs for "solar cells off the role". Application of existing printing technologies could facilitate large-scale technical implementation.

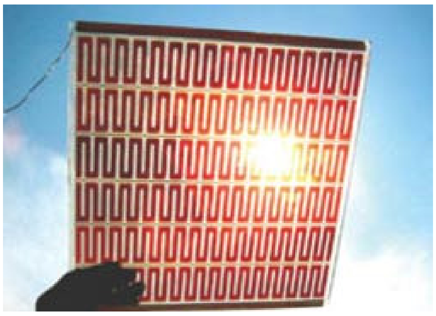
With vacuum thermal evaporation especially thin layers of organic materials can be produced. In order to build solar cells the materials are heated to several hundred degrees Celsius. The vaporised material is deposited as a layer on a substrate, for example on a foil or a glass plate. Source: BASF - The Chemical Company, 2007

OPV research and development in Germany, the USA and in Australia

In 2004 already Siemens researchers achieved a milestone increase in the degree of efficiency of organic solar cells from three to five percent. Even at that time and with the state of technology available they expected a possible degree of efficiency of approximately seven percent. This was enough reason for the Nobel Prize winner Heeger, founder of Konarka Technologies Inc. based in Lowell, Massachusetts (USA), to co-operate with Siemens. Konarka purchased the Siemens know-how and joined research programmes that are driven by Dr Christoph Brabec and Prof. Serdar Sariciftci, both renowned pioneers in the field of conductive polymers. Theoretically polymer solar cells can achieve degrees of efficiency of 20 – 25 % claims Konarka. In laboratories 10 % have already been achieved. Konarka is concentrating its OPV activities in the start-up company Konarka Austria Forschungs- und Entwicklungs GmbH (Linz).

Is it the dawn of the "Decade of organic photovoltaics"?

In Germany, for example, scientists from Oldenburg, Freiburg and Berlin are working for the utilisation of organic photovoltaics. At the University of Oldenburg a research team headed by the physicist Prof. Dr Jürgen Parisi and the born Russian Dr Vladimir Dyakonov is driving the field ahead and Dyakonov is expecting the "Decade of organic photovoltaics". He points out the increase in demand and the willingness to co-operate within the industry. The Fraunhofer Institute for Solar Energy Systems (Freiburg) is also involved in the development of manufacturing processes for dye-sensitised solar cell modules. An important aspect is the sealing of modules. In the years ahead it will only be possible to produce dye-sensitised solar cells with solar degrees of efficiency over 5 % on larger surfaces, if liquid or partially solidified (gel) electrolytes are used. This requires hermetic, durable sealing materials that are compatible with the electrolytes.



Left: Photo of a 30 cm x 30 cm module of dye-sensitised solar cells held against the sun. The module was sealed by a thermal process developed at the Fraunhofer ISE, during which so-called glass soldering (Glaslote) is affixed with screen-printing (glass with particularly low heat distortion temperature). Right: Organic ISE solar cell on flexible substrate (not encapsulated). Source: Fraunhofer ISE

Efficiency and stability of solar cells as the central challenge

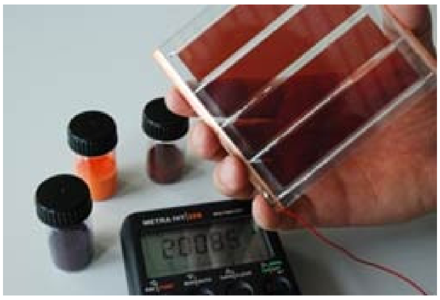
The ISE is tackling manufacturing costs, efficiency and long-term stability which constitute the preconditions for the commercialisation of organic solar cells. The ISE researchers see first potential applications of organic solar cells in the energy supply of mobile small apparatuses. Other possible applications are the supply of micro-systems and sensor networks that are self-sufficient in terms of energy supply, as well as the integration of simple electronic circuits based on organic semiconductor modules. The long-term goal of the Freiburg researchers is to ensure that organic solar cells make a contribution to sustainable energy supply.

The Berlin-based Hahn-Meitner Institute (HMI) is also conducting research in co-operation with the Free University (FU) Berlin in the field of organic solar cells. Efficiency and stability are the main focus points of the Berlin scientists; and they are the preconditions for successful product development. Cost-efficient production based on established thin-layer technology (e.g. printing), an efficiency of 5 – 10 % as well as an increased life span of solar cells are to provide conditions that organic solar cells and/or polymer solar cells will become true competition to the currently utilised PV technologies.

At SCHOTT Solar the well established, crystalline silicon technology (wafer technology) is currently in the foreground. “OPV still has an enormous potential for further development. We at SCHOTT see the realistic chance that it will gain new market segments for photovoltaics in the foreseeable future,” Dr Martin Heming, member of SCHOTT Group Management and Management Director of SCHOTT Solar GmbH comments on the start of this technological initiative. "Should we in our development association succeed in making OPV solutions marketable, industrial manufacturing of OPV components will constitute an interesting future perspective for SCHOTT Solar,” Dr Heming emphasises.

System innovations with thermally and photochemically stable cells

For the further development of organic photovoltaics, BASF and Bosch are co-operating with the Dresden-based company Heliatek GmbH in special research projects. Heliatek has specialised on the manufacturing of solar cells with a role-to-role manufacturing process and is working on a particularly efficient technology that will allow large modules to be manufactured on cost-efficient, flexible substrates. BASF is conducting research on semiconductive organic materials with a high degree of thermal and photochemical stability. According to BASF, they are on the verge of a system innovation and are currently determining crucial properties of the end product. Here the broad know-how of BASF in the field of organic electronics and design, as well as the synthesis and production of complex organic compounds is of great advantage.



Left: Organic solar cells for car roofs and mobile telephones; Right: Purification of an organic dye for utilisation in solar cells. Photos: BASF - The Chemical Company, 2007

One Euro per Watt of output is the target

"Organic photovoltaics is becoming a strategic focus in our growth clusters Energy Management and Nanotechnology,” says Dr Stefan Marcinowske, member of the Board and speaker for BASF Research. The Joint Innovation Lab – Organic Electronics (JIL) of the BASF in Ludwigshafen serves as a co-operation platform for partners from the industry and universities. In the JIL experts of various disciplines are also conducting research on organic light diodes (OLED), another technology that is based on semiconductive organic materials. This new technology is to undercut the cost limit of one euro per Watt PV output under comparable conditions.

Dye-sensitised solar cells from Australia

However, not only in the country of the international photovoltaic champion, the potential of organic photovoltaics is noted: the Australian company Dyesol is working on the commercialisation of dye-sensitised solar cells and reports on progresses of nanotechnology that led to an efficiency increase of its dye-sensitised solar cells to about 8 %. Dyesol is working together with the Queensland University of Technology (QUT) in developing state-of-the-art experimental dye-sensitised solar cell materials. A research project under Prof. John Bell of the Faculty of Architecture and Technology at the QUT is developing new catalyst and electrolyte materials that are to allow a further efficiency increase of dye-sensitised solar cells. Furthermore, research is to be conducted on performance objectives of new material combinations in dye-sensitised solar cells. The new project has set itself a target of a 12% efficiency for commercial dye-sensitised solar cells.

"Solarserver interview with Dyesol Chairperson Sylvia Tulloch on Dye-sensitised solar cells”

Further information on technology initiatives and OPV support can be obtained from the Internet sites of the link Bundesministerium für Bildung und Forschung: http://www.bmbf.de/de/10413.php and http://www.bmbf.de/foerderungen/9757.php

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- An Overview of Photovoltaics in the USA
- The Year 2000: Breakthrough for Solar Technology in Germany
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