SUNFLOWER

"Sustainable Novel Flexible Organic Watts Efficiently Reliable"

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Deliverable 6.4: Demonstration kit including manuals and background information with different levels of complexity

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Abbreviations

OPV	Organic Photovoltaics
PCE	Power Conversion Efficiency
BHJ	Bulk Heterojunction
ITO	Indium Tin Oxide
FF	Fill Factor
V_{oc}	Open Circuit Voltage
J_{sc}	Short Circuit Current
Ba	Barium
Ca	Calcium
Al	Aluminum
MoO_3	Molybdenum Trioxide

1 Introduction

For public engagement activities of the Sunflower consortium partners like conference and exhibition attendance, product and training workshops, school visits at primary and secondary schools, and other dissemination events a demonstration kit is developed in the course of the Sunflower project.

The demonstration kit visualizes the unique features of OPV and shows the basic principles of converting sun light into electrical and mechanical energy. The demonstration kit also includes corresponding information on how the demonstrator works (manual) accompanied by background information with different levels of complexity.

Each consortium partner involved in work package 6 (dissemination and training) will receive a demonstration kit.

The following sections of this deliverable report introduce the demonstration kit.

2 Demonstration Kit

2.1 Outline

The demonstrator kit is developed to communicate the basic operating principle of a solar cell and the design freedom as a key advantage of OPV technology for dissemination purposes. The demonstrator kit consists of three parts: first the OPV module, second the instrument to visualize the conversion of light into mechanical and electrical energy and third the manual describing the principles of PV and OPV for various recipients in different complexity.

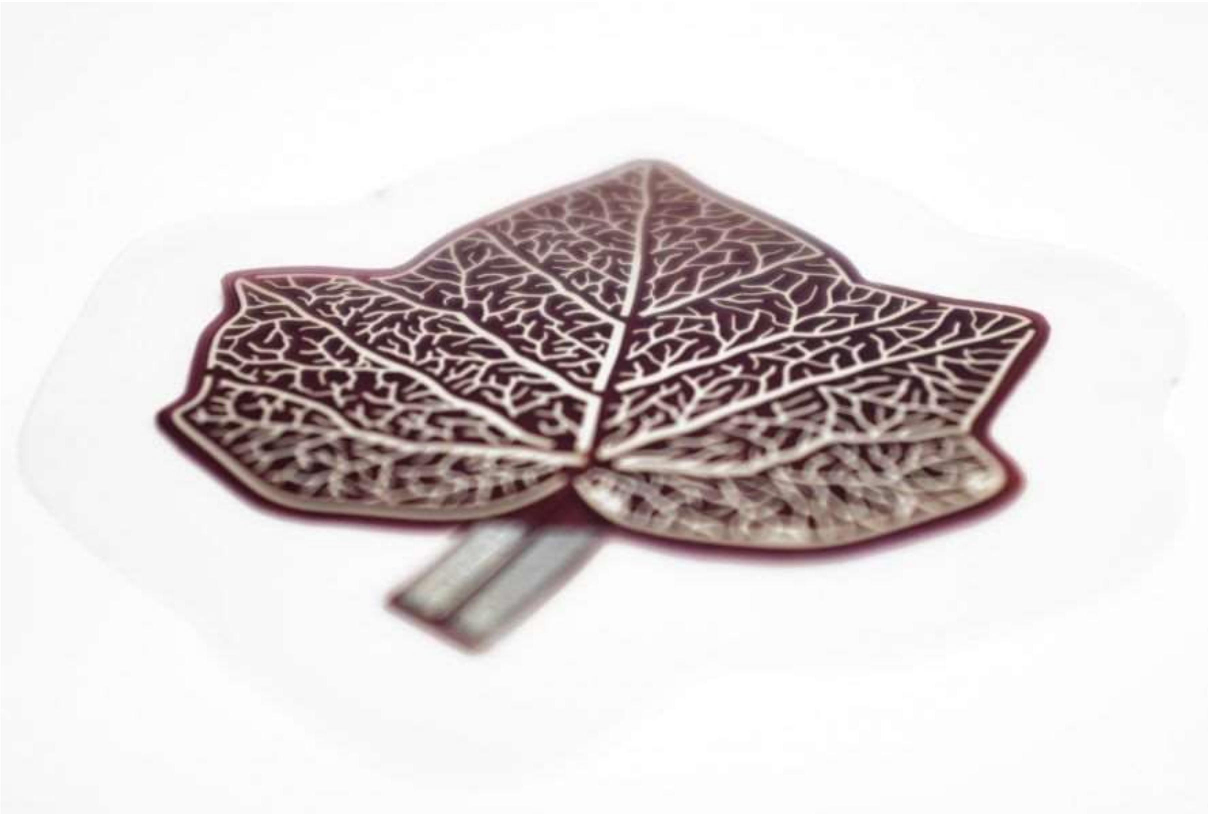

Figure 1. Belectrics OPV module

The employed organic solar cell was designed and built by Belectric and illustrates nicely that in principle any module layout can be realized thanks to the design freedom in the employed printing technology as shown in Figure 1, which is a key differentiator compared to traditional crystalline silicon solar cell technology. The chosen leaf layout of the cell ideally conveys the message that mankind successfully mimicked, in an appealing way, nature’s ability to convert sunlight into energy for consumers.

The instrument to visualize the conversion into electrical and mechanical energy was designed by the Bayerisches Zentrum für Angewandte Energieforschung e.V.in Würzburg, germany (ZAE).

The background information explains the working principle of PV and OPV for various audiences using respective level of complexity.

2.2 Demonstration Kit Manual

The device, shown in Figure 2, shows how a solar module can produce electrical energy. It can either charge a capacitor or directly power an electric motor, which then moves a fan to demonstrate the conversion from solar to mechanical energy. The voltage of the solar module or the capacitor can be measured with the voltmeter in the lower left. The current passing through the motor is measured with the ammeter in the top right. The gauge in the middle shows if the capacitor is being charged or not.

The design of the circuit board can be seen in Figure 2 and Figure 3. The parts list is given in Table 1.

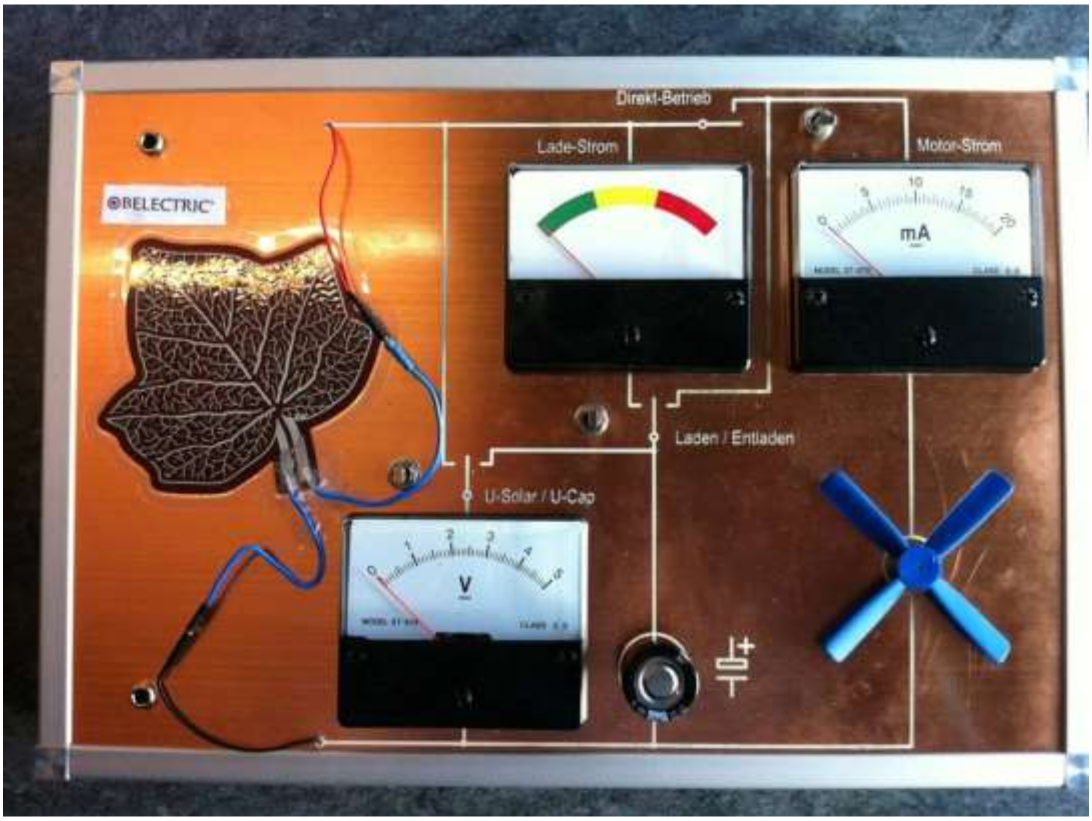

Figure 2. View of the Demonstrator from the top

Figure 3. View of the demonstrator from the bottom

1x switch on/on single phase
2x switch on/off/on single phase
2x Analog Ammeter ST-670 0-20mA
1x Analog Voltmeter ST-670 0-5V DC
2x Schottky Diode 6A
1x Voltage reference
1x Low Power Motor
1xTrimmer Resistor T93 YA 5K
1x polarised capacitor 1F
1x polarised capacitor 100nF

Table 1. Overview on used electrical parts

3 Technical Background Information

3.1 Functionality of an Organic Solar Cell (Beginner Level)

With the help of renewable energies, we can be able to supply the increasing global demand for energy needs. The sun supplies our planet with enormous amounts of green energy, therefore covering small part of the earth's surface with solar cells would help us satisfy present electrical needs. Organic solar cell is a novel and promising technology to harvest electricity from sunlight, which can be made on a transparent and flexible substrate, applied to low-cost and light panels (Figure 4).[1] Compared to crystalline silicon-based solar cells commonly used now, one appealing advantage of organic solar cells is their efficient production and environment-friendly manufacture. Organic solar cells can be easily fabricated via many solution processes like spin-coating, ink printing and roll-to-roll technology, which enable them easy to make thin and large-area devices cost-effectively.[2] This significant advantage is one of the reasons that organic solar cells have received tremendous interest from academic and industrial communities during the past decade.[3]

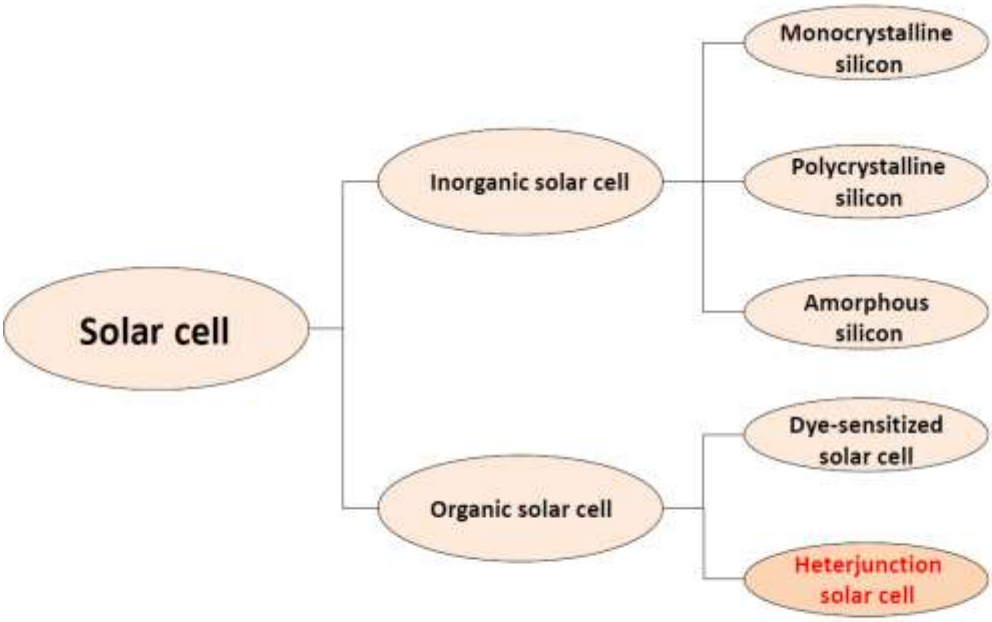

Figure 4. Classification tree of solar cells

There are various types of organic solar cells, including single layered and multi-layered structures. The most common one is called bulk heterojunction (BHJ) organic solar cell, using a solution-processed active layer composed of an electron-donor and an electron-acceptor organic material, sandwiched between the metal anode and cathode, which have been intensively investigated in research labs and small-area industry applications.[4] In general, the active materials of organic solar cells are typically made of carbon-based small molecules and conjugated polymers. These organic semiconductors can absorb light and induce the charge transport between the conduction bands of the electron-donor molecules to the conduction bands of the acceptor molecules. Finally, the hole and electron can be connected separately by anode and cathode, and thus affords electricity in the external circuit (Figure 5).

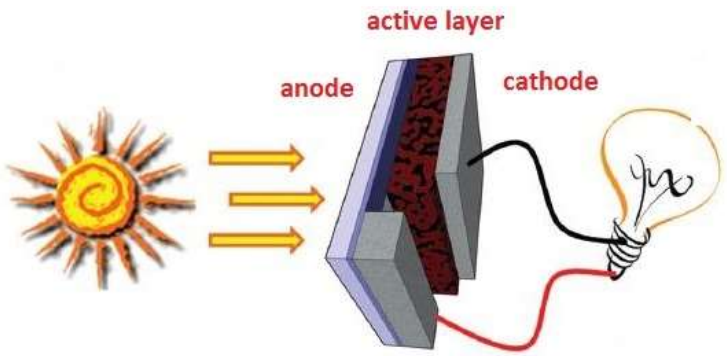

Figure 5. Architecture of organic solar cells

However, organic solar cells have some disadvantages including their relatively low efficiency and short lifetime. Nonetheless, their numerous benefits can promote the current research and investment in developing more high-efficient materials, device architecture, and fabricating technology to enhance efficiency, low-cost and large-scale production. A commercially viable organic solar cell is the target of the next few years. Working together with engineers and architects, we will soon be able to find organic solar cells in our cell phones, bags, cars and buildings and so on, which would be open to everyone's daily life (Figure 6).

Figure 6. Potential application of organic solar cells in our daily life

3.2 Functionality of an Organic Solar Cell (Intermediate Level)

During the past decade, organic solar cells have attracted growing attention from academic and industrial communities as a potentially viable solar energy harvesting technology by virtue of their ability in providing light weight and large-area devices at low manufacturing costs. The low manufacturing cost is achieved via conventional low-cost solution-based fabrication techniques such as coating and printing.[5] Conventional organic solar cells use a solution-processed active layer composed of an electron-donating and an electron-accepting material sandwiched by a transparent ITO anode and a low work-function metallic cathode.[6-9] Up to now, many conjugated small molecules and polymers are successfully used as electron-donating materials.[10] Small molecules can make post purification and structure characterization more convenient, while conjugated polymers exhibit better solution processing ability. For optimum cell performance, broad absorption, narrow band-gap and efficient hole-transporting materials it would be highly desirable for the electron-donating materials, since they are more efficient in capturing solar energy. In order to obtain narrow band-gap, a conjugated framework is normally constructed with an alternating electron-rich (D) and an electron-deficient (A) repeating unit, This conjugated D-A system can offer us an opportunity for tuning the band-gaps and energy levels via the strengths of D-A units and nature of π-conjugation (Figure 7). In addition, the targeted materials should possess reasonable solubility in organic solvents to ensure their solution processing ability. To date, many structurally diverse systems of narrow band-gap materials have been synthesized with the power conversion efficiency (PCE) reaching up to 8-9%.[11-13] For electron-accepting materials, the electron-transporting ability, complementary absorption spectrum and compatible energy levels with electron-donor counterpart should be considered as well.[14] Up to now, the most widely used electron-accepting materials are soluble fullerene and its derivatives, and a few electron-deficient molecules also exhibit their potential applications.

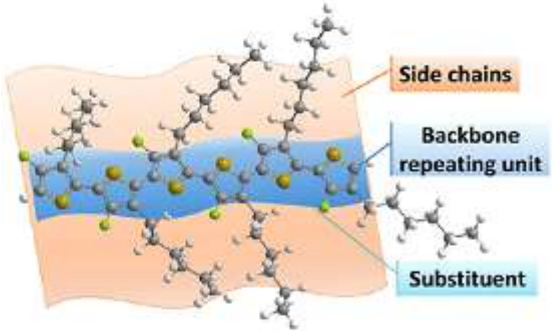

Figure 7. Molecular engineering for organic solar cells [10]

For architectural design of organic solar cells, the early devices used separate electron-donating and electron-accepting bilayers as the active layers. However, the performance of bilayer devices is limited by the small length of exciton dissociation and charge generation between donor and acceptor interface. To overcome this difficulty, a promising bulk heterojunction (BHJ) structure using an interpenetrating blend of an electron-donating and electron-accepting materials start to attain major breakthrough and rapid development. The working mechanism for BHJ organic solar cells includes (a) photo excitation of the electron-donating material to generate an exciton. (b) exciton diffusion to the D-A interface. (c) bound exciton dissociation at the D-A interface. (d) free charge transportation and collection at each electrode (Figure 8).

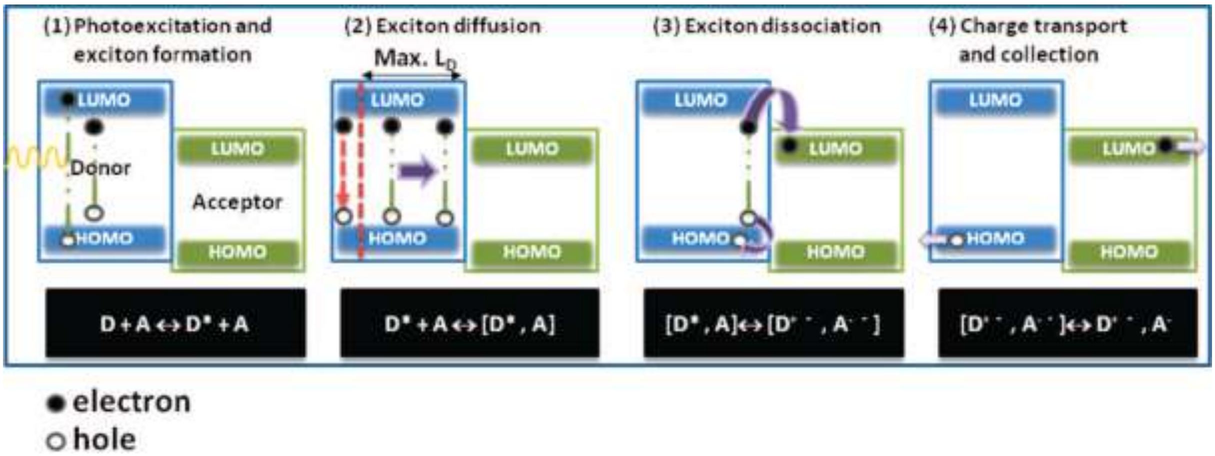

Figure 8. Working mechanism for donor-acceptor heterojunction solar cells [8]

An ideal BHJ organic solar cell requires a high open-circuit voltage (V_{oc}) and a short-circuit current (J_{sc}), which would benefit from matched energy levels and maximum light absorption of the blended active layer. In addition, the electron-donating and electron-accepting materials should afford continuous nanostructures with maximum interfacial areas and proper domain size (10-20 nm) for efficient exciton diffusion, since the morphology has a profound influence on the fill factor (FF), and thus the power conversion efficiency (PCE) of devices.[15] Likewise, interfacial modification between the active layer and electrodes can also facilitate extraction of charge to respective electrodes, which would lead to further improvements in photovoltaic performance.[16-17] Moreover, BHJ organic solar cells can be fabricated in either conventional or inverted device configuration (Figure 9). In a conventional structure, indium tin oxide (ITO) deposited on a substrate typically works as the anode for hole collection; while a thermally deposited metal (Ba, Ca, Al) is used as the cathode for electron collection. On the contrary, an inverted organic solar cell can use the ITO as the cathode and the vacuum-deposited metal (MoO_3, Al) as the anode. Recently, inverted organic solar cells have received much attention because of their high PCEs as well as better device stability than conventional PSCs.[18] To use solar radiation more effectively, one approach is to stack two active layers in series to construct a tandem organic solar cell. A tandem structure typically consists of a front cell with a high band-gap material, an interconnecting layer, and a rear cell comprising a narrow band-gap material.[19] Compared to a single-junction device using one narrow band-gap material, this tandem structure has a reduced photo voltage loss. The V_{oc} of organic solar cell with single active layer is limited by the band-gap of electron-donating material. On the contrary, each cell of a tandem structure can capture different parts of the solar spectrum, the V_{oc} and PCE is therefore increased.

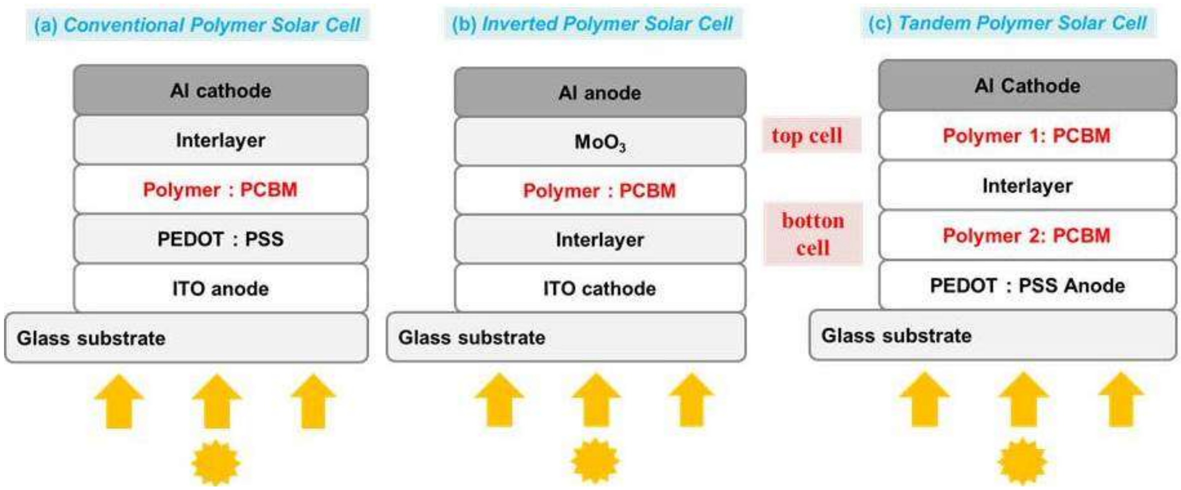

Figure 9. Architectures of organic solar cells.

In summary, the rational design of novel D-A conjugated materials with good photovoltaic properties remains a key interest in synthesis. Driving organic photovoltaic efficiency up to an economically viable level would require further development both in electron-donating and electron-accepting materials. In addition, by exploring new device architecture, nanostructure engineering and interfacial optimization, we believe the future development of organic solar cells will ensure their key role in bringing high-efficiency and low-cost plastic solar cells closer to successful commercialization.

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