Keys to improve flexible organic bulk-heterojunction solar cells

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The soldier of the future will be carrying many electronics. From sensors, communications, weapons control, augmented reality aids, etc, they all need to be powered. In spite of the predictable impact of nanotechnologies on the efficiency and lightweight on the combat gear, weight carried by the individual soldier will be significant. Current batteries need to be frequently charged or replaced in the theater of operation with spares and chargers contributing to the total weight to be carried and, on the second case, they need a power source to plug in. Solar energy is present in most of the actual and predicted near future “war zones” and the use of solar chargers may be an attractive source of power to charge the electronics of the future soldier. However the actual solar harvesting technologies are cumbersome, with a rigid form and heavy, not ready to be easily carried by the soldier or easily deployed in the battle field. This is where organic photovoltaic’s (OPVs) may have an impact since they can be flexible (bendable, foldable), thin, light weighted and very cheap to produce.

OPVs emerged as a “low-cost” solar cell technology being the optimization of the sun light absorption and electrical carrier generation, in order to increase the OPV efficiency, one of the most important fields concerning such new technology. The usual polymeric bulk heterojunction solar cell (BHSC) structure employs an active layer formed by a mixture of a polymer and a carbon based nanostructure. Although some important results have been obtained, still many questions have to be overcome before a real application can be made. In this work, an active BHSC layer composed by MEH-PPV (poly(2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene) and PCBM ([6,6]-phenyl-C61-butyric acid methyl ester) was studied by absorption spectroscopy and photoconductivity, as a function of MEH-PPV:PCBM ratio (in mass). A flexible OPV based on such active layer is then fabricated and analyzed in order to correlate the figures of merit with the morphology revealed by atomic force microscopy (AFM).

Absorption data shows, besides the well-known UV organic structures absorption, a difference on the visible region of the spectrum as the MEH-PPV / PCBM ratio changes. Both MEH-PPV and PCBM absorb light in the visible spectral region, although the donor (polymer) exhibits a larger absorption in the bluish-green region due to its gap near 2 eV. The cumulative effect from both species is studied aiming the light absorption maximization. When the PCBM concentration increases, new photocurrent bands in the blue / green spectral region appears. As the spectral region of photocurrent generation becomes wider, this leads to an improvement on the solar cell electrical carrier generation. The photocurrent increases as the PCBM concentration increases only up to 80% (in mass). For both absorption and photoconductivity data, the best compromise for maximize the sun light absorption and further electrical carrier generation, points to a MEH-PPV:PCBM ratio of 1:4 (in mass). Considering both data, the maximum efficiency can be obtained by the product of the normalized absorption and photoconductivity behavior with the MEH-PPV:PCBM ratio. Figure 1 shows the overall data.

Concerning the OPV (figure 1), one important point is the electrical charge collection at the electrodes, after the exciton formation and separation. Due to the complex nature of orbital hopping electrical transport, and the usual high density of intrinsic defects in the organic layers, trapping and recombination of the electrical charge is one of the most important factors that diminishes the efficiency. Since such intrinsic defects are related with the local morphology of the films, a detailed work relating these two points must be done. It is observed that the most relevant parameter (influencing the efficiency) is the fill-factor (FF), as both the open circuit voltage and short circuit current are not significantly affected by the microscopic morphology. Different local conformation of the active films can change the FF from near 25% to more than 65%, having a strong impact in the efficiency. These results are modulated by an equivalent circuit, were the serial and parallel resistances are related with the physical behavior of the organic cells, in a direct relationship with the morphology. The best results obtained with this photovoltaic structure are shown in figure 2, where the fundamental figures of merit are presented. The efficiency is about 3.5% with a FF over 65%.

Finally, it is tried to develop a model that comprises the physical nature of the observed results, considering the donor – acceptor interaction and the electrical charge formation, dissociation and transport, related with a study of different parameters for the device fabrication in order to understand the active layer conformation.

Although this technology is on his beginning the expected characteristics of a near future device may be a helpful aid for the equipment of the soldier of the future, alloying to lower the individual carried weight and facilitate mass deployment on the theatre of operations without cost concerns.

Figures

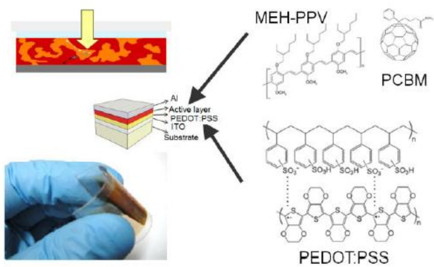

Figure 1 - General solar cell scheme and organic semiconductors structures. A device picture is shown.

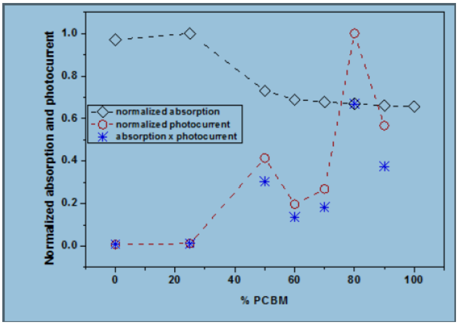

Figure 2 - Relative variation of absorption and photoconductivity between 1.5 – 3 eV

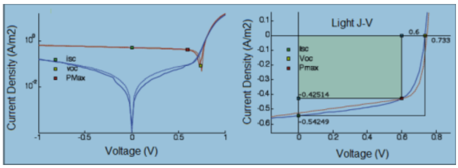

Figure 3 - Current Density – Voltage (J-V) data for a solar cell in dark conditions (blue) and under illumination (red). Broken lines: experimental data; full lines: theoretical modulation. The shadow area represents the fill factor FF.