Donor/acceptor heterojunction organic solar cells

P. Cusumano

Dipartimento di Energia, Ingegneria dell'Informazione e Modelli Matematici (DEIM)

University of Palermo, Viale delle Scienze, Edificio 9, Palermo, I-90128, Italy

pasquale.cusumano@unipa.it

Organic solar cells (OSCs) have made very good improvements in recent years, reaching power conversion efficiencies above 10% [1]. This have been achieved through chemical synthesis of new organic materials with improved properties and also by new and more or less complex structures such as donor/acceptor (D/A) or bulk heterojunction OSCs. Here we report the results of initial development of OSCs based on the simple D/A heterojunction [2].

Copper phtalocyanine (CuPc) is used as donor organic material, whereas *perylenetetracarboxylic dianhydride* (PTCDA) and *fullerene* (C60) as acceptor organic materials. Moreover *bathocuproine* (BCP) is used as exciton blocking layer. Devices are fabricated by vacuum thermal deposition on ITO-coated glass substrates with the layers thickness and structure as follows:
a) ITO/CuPc (45 nm)/PTCDA (40 nm)/LiF (1 nm)/Al (80nm);
b) ITO/CuPc (20 nm)/C60 (40 nm)/BCP (12 nm)/Al (80 nm).
Their band diagram is shown in Fig.1. The BCP layer of the device b), inserted between the acceptor layer and the metal cathode, acts as exciton blocking layer preventing excitons photogenerated in the C60 layer from diffusing towards the Al cathode and being lost by nonradiative recombination.

The OSCs are tested in ambient atmosphere without encapsulation by using a calibrated halide lamp as a light source and varying the incident optical power density by simply changing the distance between the lamp and the solar cells [3]. The illumination condition used is AM1.0, i.e. vertical incidence and a standard value of 100 mW/cm^2 for the optical power density. The J-V characteristics under illumination of the OSCs are reported in Fig. 2 for increasing incident optical power density. The Fig. 2(a) is for the OSC with structure a) and shows that the photovoltaic effect is not very strong. The OSC exhibits an open circuit voltage V_{OC} of 80 mV and a short circuit current density J_{SC} of about 40 $\mu A/cm^2$ at 100 mW/cm^2 incident optical power density. The Fig. 2(b) is for the OSC with structure b). This OSC shows a much better photovoltaic effect as compared to that of the OSC with structure a), due to the fullerene layer used as acceptor and, more important, to the insertion of the exciton blocking layer. The OSC exhibits V_{OC} = 0,43 V and J_{SC} = 2,35 mA/cm^2 (again AM1.0 with 100 mW/cm^2) with a fill factor FF $\approx$ 50%, an external quantum efficiency (electrons/s over incident photons/s) EQE $\approx$ 5% and a power conversion efficiency $\eta \approx$ 0,5%. These results are certainly a good starting point for further improvements.

References

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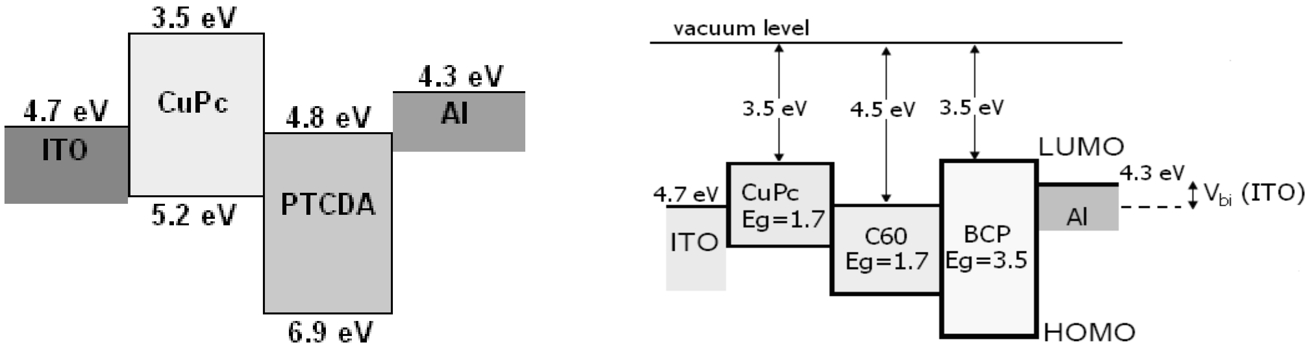
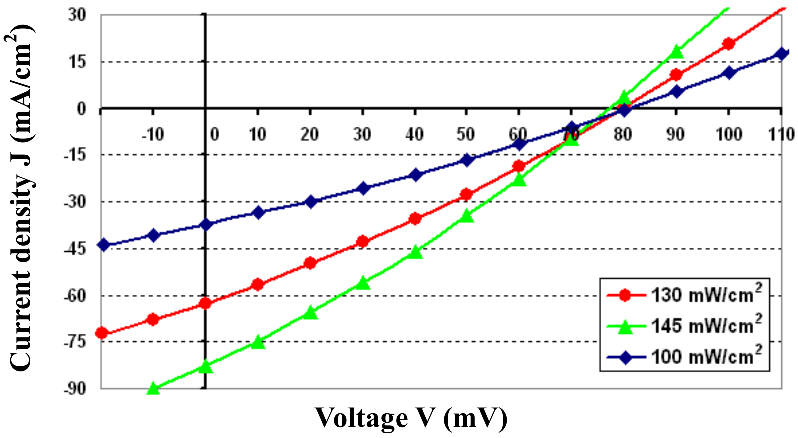
[2] C. W. Tang et al., "Two-Layer Organic Photovoltaic Cell", Appl. Phys. Lett. Vol.48(2), 1986, pp.183-185
[3] P. Cona, "Realizzazione e caratterizzazione fotovoltaica di celle solari organiche", Master Degree Thesis in Electronic Engineering, University of Palermo, A.A. 2005-2006

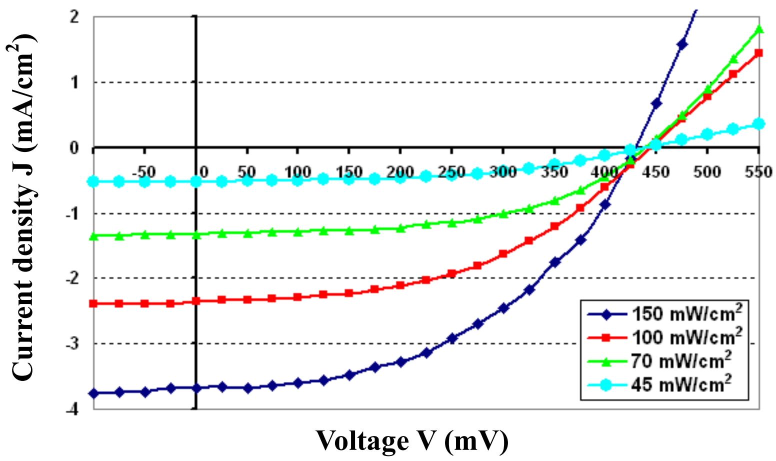


(a) (b)

Figure 1: Band diagrams of (a) OSC with structure a) and (b) OSC with structure b).



(a)



(b)

Figure 2: J-V characteristics of OSCs for increasing incident optical power density. (a) OSC with structure a) and (b) OSC with structure b).