Grant Agreement no.: 248678

Project acronym: HIFLEX

Project title: **Highly Flexible Printed ITO-free OPV Modules**

Instrument: Collaborative Project

Thematic Priority: **FP7-ICT-2009-4**

Milestone 2.3: First series of prototypes ITO-free S2S processed OPV modules (size >50 cm^2) available as an intermediate step towards (D2.2)

Date of preparation: march 2011

Author(s): Birger Zimmermann

WP Leader: Birger Zimmermann (WP2)

Organisation name of lead contractor for this milestone: Fraunhofer ISE

Start date of project: 01.01.2010 Duration: 36 months

Project coordinator name: Dr. J.M. Kroon
Project coordinator organisation name: ECN

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination level		
PU	Public	
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)	x

History

Based on the layer stack “substrate/Cr/Al/Cr/P3HT:PCBM/PEDOT:PSS/Au grid” Fraunhofer ISE has manufactured modules with active area ($13.2 cm^2$) efficiencies of up to 2.2% for PET and 2.5% for glass as substrate (ca. 70-80% of the typical small area efficiency of 3%). The aperture area was $19.8 cm^2$ for these devices. The modules comprise two busses and thus the areas are doubled for the complete device shown in the figure below. The organic layers have been processed with the R2R compatible slot die coating. P3HT:PCBM was dissolved in a non-chlorinated solvent (o-xylene).

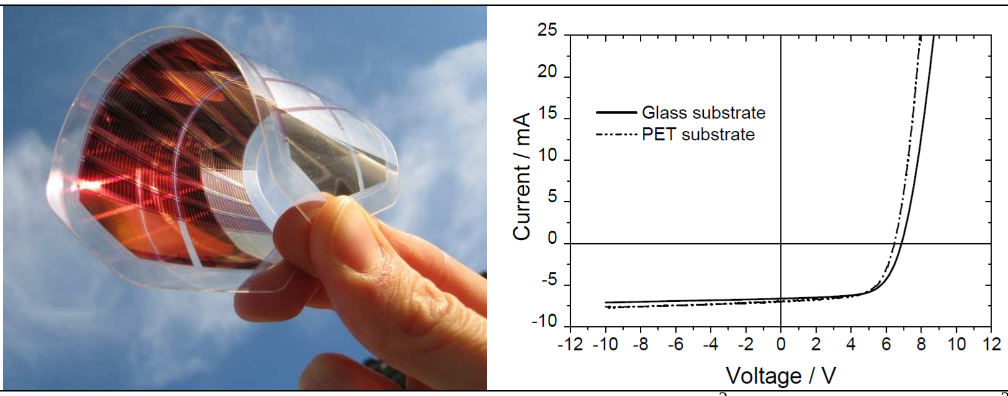

Figure 1: ITO free flexible organic solar module with 2x $13.2 cm^2$ active and 2x $19.8 cm^2$ aperture area.

The transfer of these results to an aperture of >50 cm^2 as was requested in $M^2.3$ was planned for 11./12.2010 but unusual problems with the quality of the laser cut evaporation masks and a breakdown of the cooling system of the evaporation setup delayed the experiments to January 2011.

Device stack and module layout

The ITO-free modules employ the layer stack as shown in Fig. 2 using a PET substrate, which is subsequently coated with the Cr/Al/Cr metal electrode by evaporation, the photoactive layer and PEDOT:PSS by slot die coating and a gold grid by evaporation. The dimensions of the grid and the cell stripes have been determined from numerical calculations as presented in the annual report. The modules have a quadratic shape with an aperture area of 100 cm^2 and consist of six serially connected cell stripes (16.6 mm X 100 mm each). For the serial interconnect ca. 2 mm are necessary, such that the active area is 6 x 14.6 mm X 100 mm or 87.6 cm^2.

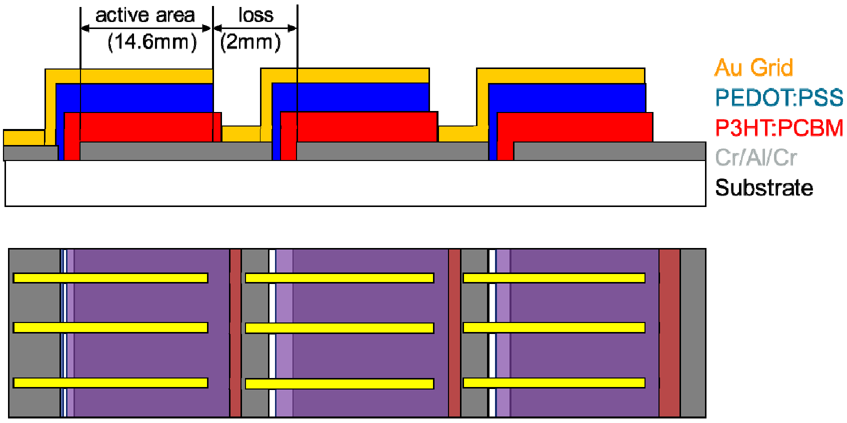

Figure 2: Schematic drawing of the series circuitry for a module with three cell stripes. The modules presented below employ 6 cell stripes connected in series.

Experimental details

First 5nm Cr/100nm Al/ 5nm Cr have been evaporated by e-beam (Cr) and thermally (Al) on a 50µm thick PET RNK foil from Mitsubishi. A shadow mask was used to form the individual cell stripes. Underneath the interconnects, 5nmCr /100nm Au were evaporated. Prior to the deposition of the photoactive layer, the substrates have been cleaned with ethanol. The photoactive layer consisted of P3HT (4002EE (batch BS19-79) from Rieke metals and PCBM 99% (Solenne) dissolved in o-Xylene in the ratio 15mg:10.5mg per millilitre of solvent. All materials have been used as received. The solution was slot die coated with a speed of 0.6 m/min under ambient conditions and dried. After soaking in butanol and drying off the samples the PEDOT:PSS (CPP105 DM) layer was slot die coated on top of the photoactive layer. Both layers have been structured by wiping with solvent. After transfer to inert gas atmosphere the modules have been annealed at 80°C for 10 minutes. The Gold grid was evaporated (450-500nm) on top. The comparably large thickness was necessary to achieve a sufficiently high conductivity of the 100 µm wide and 1.5 cm long grid lines. A final annealing at 120°C for 10 minutes was done prior to the measurement of the I-V curve.

Results

The modules have been characterised on a solar simulator (Steuernagel SolarcellTest575) adjusted to 1000 W/m^2 using a KG3 filtered silicon reference Solar cell and accounting for spectral mismatch. The criteria of M2.3 are an active area > 50cm^2 and an efficiency referenced to the active area of >70% of the average efficiency for small area (1cm^2) devices with the same cell stack and materials. For devices of this type typically around 3% are achieved (V_{OC} ca. 600-620 mV, J_{SC} ca. 8-9 mA/cm^2, FF ca. 0.6-0.65) on 1cm^2 active area. The active area is 87.6 cm^2, thus nearly twice as large as requested. An efficiency of 2.5% referenced to the active area was obtained, being ca. 80% of the small area value (Fig. 3). <u>Therefore the requirements of M2.3 are met and we consider M2.3 to be achieved</u>. A remarkable feature is the high ratio of the aperture to active area efficiency, being close to 90%.

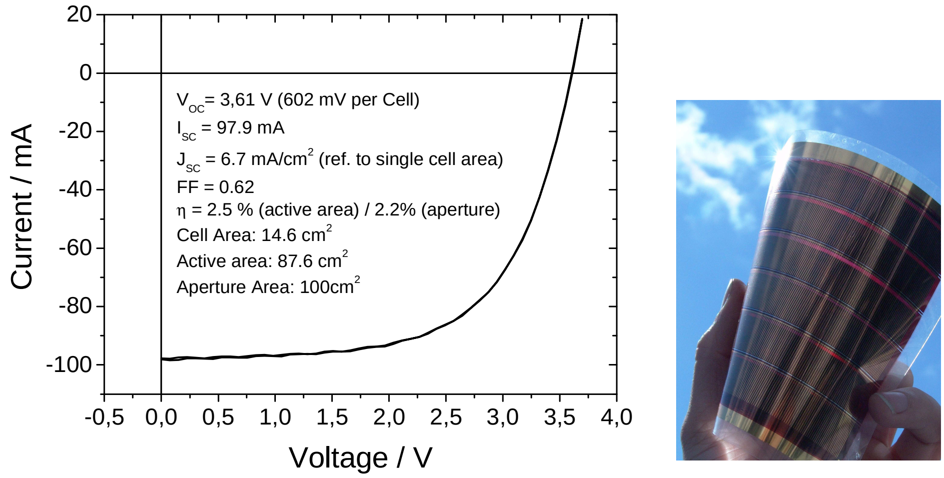

Figure 3: I-V curve and photo of the ITO-free flexible module with 87.6 cm^2 active area (criterion > 50 cm^2) and 100 cm^2 aperture area. Open circuit voltage and fill factor are in the range of the average values obtained for small area cells, while the short circuit current is slightly lower, even if referenced to the active area of a single cell stripe. Nevertheless the module fulfils the criteria of M2.3, as the efficiency is more than 80% (criterion > 70%) of the small cell efficiency (on average 3%).