Charge Mobility Determination in Cyanine/C_{60} Bilayer Solar Cells Using Photo-CELIV Technique

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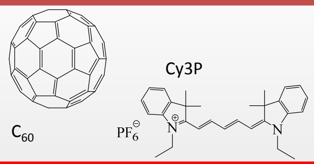
Abstract

The possibility of large-scale and low-cost fabrication of organic photovoltaics became more and more interesting in research and industry. To further improve the performance of these devices it is important to obtain material properties of the used components.



The “Carrier extraction by linearly increasing voltage” (CELIV) is a recently developed technique. It enables to measure the mobility and the charge carrier density in thin film devices, such as our solar cells. The influence of different solvents for spin coating on the performance was investigated.

Experimental

A trimethine cyanine with PF_6 as a counter ion (Cy3P) was spin coated from two different solvents. The influence on the IV characteristics, mobility and recombination was analysed.

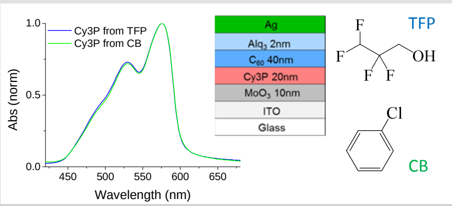


Figure 1: *Left: Normalised absorbance spectra of Cy3P coated from different solvents. Middle: Device structure of the solar cell used in this work. Right: Tetrafluoro-1-propanol (TFP) and chlorobenzene (CB) were used as a solvent to coat Cy3P.*

Photo-CELIV

The cell was illuminated for 30 µs with a blue LED to produce charge carriers in the active layer. After a certain delay time a voltage ramp *A* is applied to extract the produced charge carriers. The measured current shows a current overshoot Δj on top of the constant displacement current j_0.

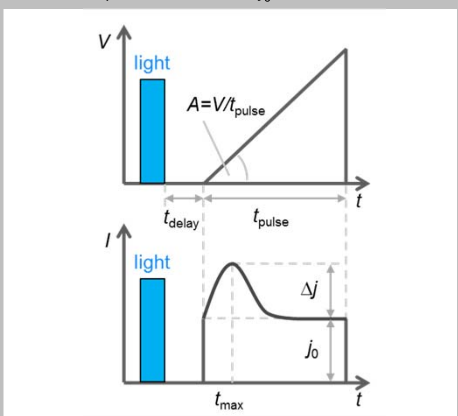


Figure 2: *Schematic illustration of Photo-CELIV technique. A triangular voltage ramp A is applied to the sample.*

From the peak position in the current (t_{max}) the mobility (μ) can be calculated using the film thickness (d) and the variables shown in figure 2.

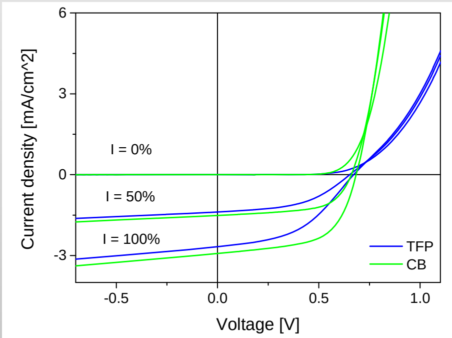
$$\mu = \frac{2d^2}{3At_{max}^2}\left(1 + 0.36\frac{\Delta j}{j_0}\right)^{-1} \quad [1]$$

The peak area is proportional to the charge carrier density which can be used to investigate the recombination of charge carriers.

Results and Discussion

Current-Voltage (IV) characteristics

IV curves were measured using the same blue LED with variable light intensity. For the characteristic numbers shown in figure 3 the cells were also measured using a solar simulator.



Average numbers from a former work show the same trend. [2]

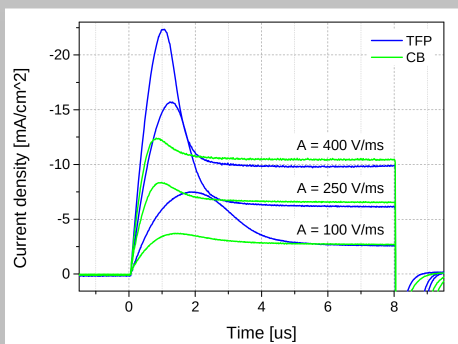
Solvent	V_{oc} (V)	J_{sc} (mA/cm^2)	FF (%)	η best (%)
CB	0.67–0.92	5.9–6.6	48.5–52.1	3.6
TFP	0.86–0.95	5.9–6.5	39.9–52.4	3.2

The cells show a much lower fill factor (FF) when the Cy3P was spin coated from TFP. A mobility difference of orders of magnitude could explain this behaviour.

Figure 3: *IV curves at different light intensities. For characteristic numbers a solar simulator was used. The Cy3P was either spin coated from TFP (black) or CB (red, green).*

Mobility determination

The Photo-CELIV curves of the three representative cells from figure 3 are shown below. The average mobility values calculated from all measurements are shown on the right.



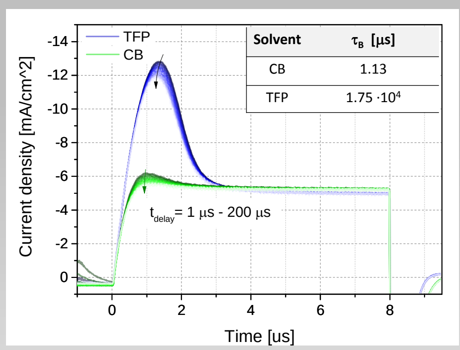
Solvent	µ ·10^{-5} [cm^2/Vs]
CB	
TFP	

The hole mobility is a factor of ~ 2 times lower in cells that were coated from TFP than with CB. This difference is to small to explain the difference seen in FF.

Figure 4: *Photo-CELIV measurements of the same cell as in figure 3. The voltage ramp A were 100, 250 and 400 V/ms respectively and the delay time was set to zero.*

Recombination

The recombination was monitored by increasing the delay time logarithmically. An effective bimolecular lifetime was calculated from the evolution of the peak area which is shown in the inset of figure 5.



Solvent	τ_B [µs]
CB	1.13
TFP	1.75 ·10^4

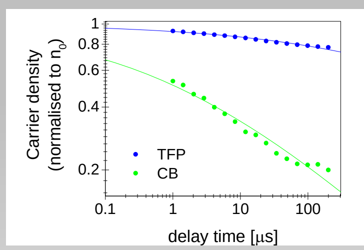


Figure 6: *Normalised charge carrier density as calculated by integrating the peak area. Fit from the bimolecular recombination model. [3]*

Figure 5: *Photo-CELIV measurements with varied delay times.*

Summary and Outlook

- Cell performance, especially the FF, depends on the solvent used for spin coating
- A factor of ~2 in mobility cannot explain the difference in IV characteristics
- Other reasons for different FF have to be investigated

References

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[3] A. J. Mozer *et al.*, Phys. Rev. B, 2005

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