

Influence of molybdenum oxide interface solvent sensitivity on charge trapping in bilayer cyanine solar cells

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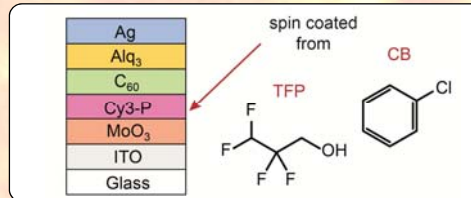
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Abstract

The spin coating solvent in cyanine/C₆₀ solar cells has been identified to be a crucial parameter for device performance¹. When TFP is used a much worse fill factor, associated with an s-shaped *I-V* curve, is measured compared to CB.

Figure 1: Solar cell device structure and chemical structure of the solvents from which the cyanine layer is spin coated.



A variety of electrical measurements (*I-V*, CELIV, C-V) have been performed in order to identify trapped states at the MoO₃/cyanine interface which are present when TFP is used. These states are absent when the cyanine is coated from CB. Using XPS we could directly show that an accumulation of residual TFP at the anode interface causes those traps.

Results and Discussion

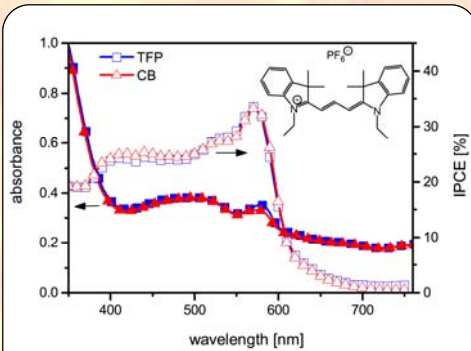


Figure 2: Cell absorbance and IPCE using 20 nm thick Cy3-P layers coated from both solvents. The inset shows the chemical structure of Cy3-P.

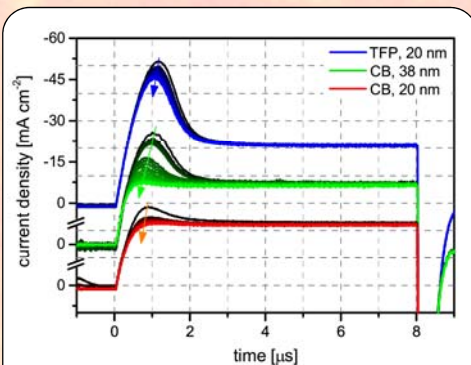


Figure 4: Photo-CELIV transients of the same cells as in figure 3. The delay time was varied between 0 and 200 μs indicated by the arrows.

Absorbance and IPCE

- Cell absorbance and IPCE are independent of the solvent

I-V curves

- For 20 nm thick TFP films *I-V* curve has an s-shape associated with a low FF

Solvent	V _{oc} (V)	J _{sc} (mA/cm ²)	FF (%)	η best (%)
CB	0.67–0.92	5.9–6.6	56.5–63.8	3.6
TFP	0.86–0.95	5.9–6.5	39.9–52.4	3.2

Photo-CELIV

- Hole mobility is similar for both solvents μ_h ~ 4·10⁻⁵ cm² V⁻¹ s⁻¹
- Recombination is much faster for CB cells (20 and 38 nm) compared to TFP
- For TFP cells t_{1/2} > 200 μs

- Trapped states in TFP films

C-V measurements

- For CB cells the capacitance around V_{oc} is increasing with increasing layer thickness
- For TFP cells the opposite is true, indicating a geometrical factor
 - Interface traps, considering also similar IPCE the Cy3-P/C₆₀ interface can be excluded

XPS

- Elemental composition of ITO/MoO₃/Cy3-P (2.5, 10, 40 nm) samples was measured
- The thinner the cyanine the higher the F:P ratio
 - Accumulation of TFP at the MoO₃/Cy3-P interface is trapping holes

Cy3-P	F [at%]	P [at%]	C [at%]	N [at%]	F : P	F : C
2.5 nm	3.4	0.38	23	--	8.9	0.15
10 nm	11	1.6	45	--	6.9	0.25
40 nm	19	3.6	71	5.4	5.3	0.27

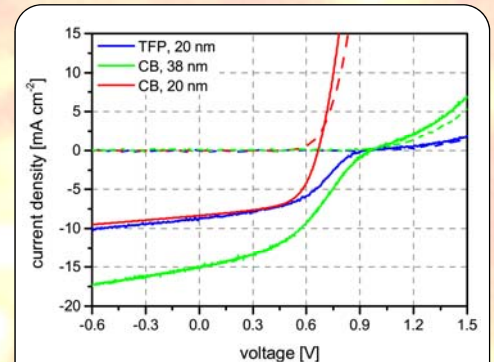


Figure 3: *I-V* characteristics of cells with 20 and 38 nm thick cyanine coated from both solvents.

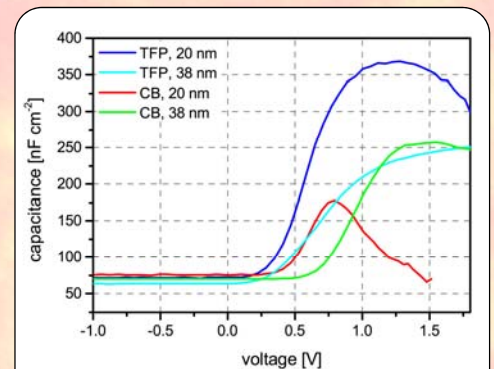


Figure 5: Capacitance-voltage measurements of cells with 20 and 38 nm thick Cy3-P coated from both solvents.

Experimental

Photo-CELIV²

- Photogenerated charge carriers are extracted by a linear voltage ramp *A*
- Mobility can be calculated from peak position, the area is proportional to charge carrier density

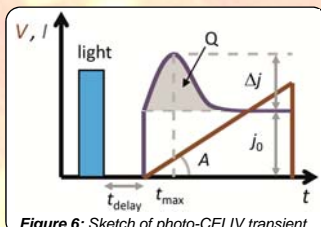


Figure 6: Sketch of photo-CELIV transient.

Capacitance-voltage

- By using the principles of impedance spectroscopy one gains insight into charge distributions

Conclusion and Outlook

- Solar cell performance depends highly on the spin coating solvent
- Various measurements were combined to identify trapped states at the MoO₃/Cy3-P interface
- Using XPS, trapped states in TFP cells could be attributed to residual solvent that accumulates at the interface
- Pre-treatment of MoO₃ or post-treatment of Cy3-P (TFP) could reduce this effect

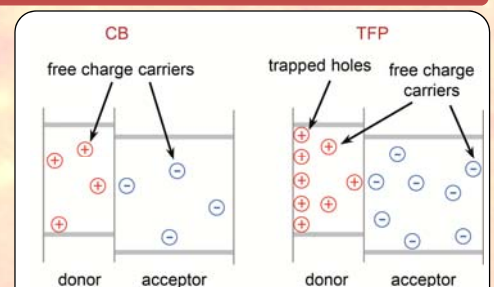


Figure 7: Sketch of the charge carrier situation in donor and acceptor for both spin coating solvent.

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References

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