Active thin film variation and analysis of OPV cells through External Quantum Efficiency (EQE) technique

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ABSTRACT

Here is reported the analysis of the external quantum efficiency (EQE or IPCE) and, its correlation with the power conversion efficiency (PCE) of organic photovoltaic (OPV) cells, as a function of the active layer thickness. OPVs cells configuration was ITO/PEDOT:PSS/Active layer/PFN/Field's Metal (FM). The active layer was PTB7-Th:PC71BM blend. Active film thickness range was 40-165 nm. Internal quantum efficiency (IQE) was also estimated.

INTRODUCTION

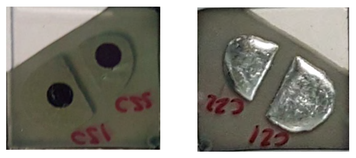
External Quantum Efficiency (EQE): Measure of how efficiently the device converts the incident light into electrical energy at a given wavelength.

$$\boldsymbol{EQE} = \frac{n(generated\ e^-)}{n(total\ incident\ photons)}$$

$$\boldsymbol{IQE} = \frac{n(generated\ e^-)}{n(abs.\ photons\ in\ act.layer)} = \frac{EQE}{Q}$$

$$\boldsymbol{Q} = \frac{n(abs.\ photons\ in\ act.layer)}{n(total\ incident\ photons)} = \frac{EQE}{IQE}$$

$$\boldsymbol{\eta_{EQE}} = \eta_A \times \eta_{IQE} = \eta_A \times \eta_{CG} \times \eta_{CT} \times \eta_{CE}$$



Field's Metal (FM): Eutectic alloy, composed by 32.5% Bi, 51% In and 16.5% Sn, that melt at 65°C.

$\boldsymbol{\eta_A}$: the exciton generation efficiency (Q), $\boldsymbol{\eta_{CG}}$: is the CC photo-generation efficiency, $\boldsymbol{\eta_{CT}}$: is the CC transport efficiency, $\boldsymbol{\eta_{CE}}$: is the subsequent charge extraction efficiency across the interface to the external circuitry.

EXPERIMENTAL SET UP

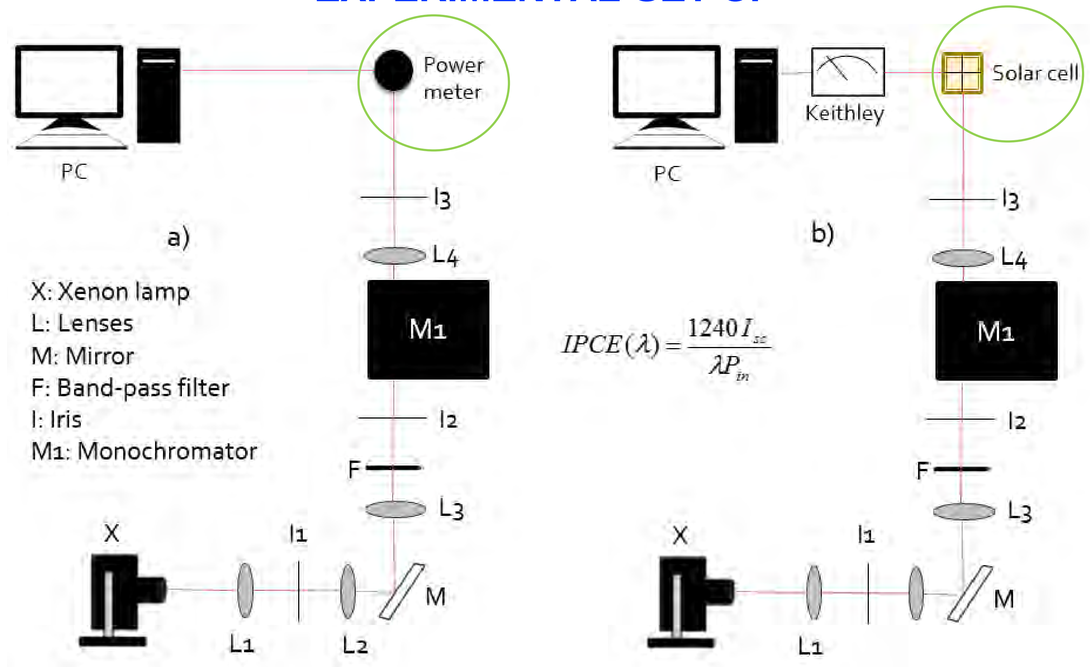
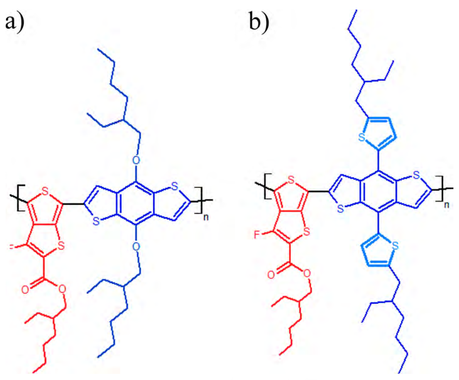


Fig. 1: *IPCE scheme: a) Power measurements, b) solar cell current measurements*

PTB7 vs PTB7-Th



FM (Field's Metal)
PFN (~5nm)
PTB7-Th:PC71BM (variable)
PEDOT:PSS (~40nm)
ITO-coated glass substrate (~165 nm)

Fig. 2: *(Left) Chemical structure of (a) PTB7 and (b) PTB7-Th, (Right) Scheme of OPV's*

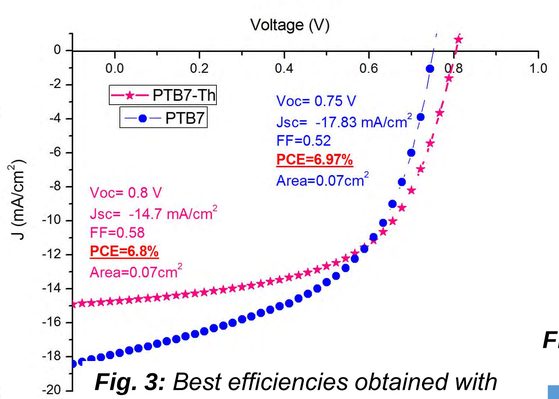


Fig. 3: *Best efficiencies obtained with PTB7 and PTB7-Th*

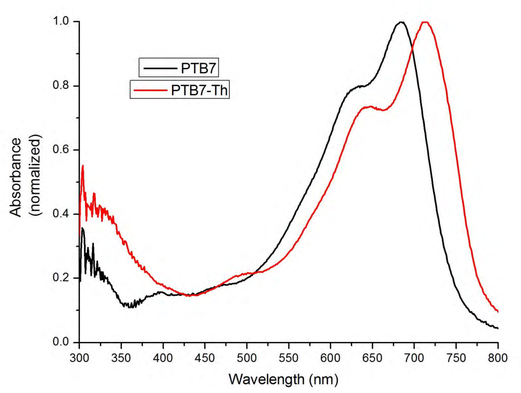


Fig. 4: *Absorption spectra of PTB7 and PTB7-Th films*

Tab. 1: *Comparative of PTB7 and PTB7-Th [7,8]*

	PTB7	PTB7-th
PCE(%)	9.2	10.3
Band gap (eV)	1.8	1.58
H. Mobility ($cm^2V^{-1}s^{-1}$)	$1x10^{-3}$	$2.8x10^{-3}$

RESULTS

ITO/PEDOT:PSS/PTB7-Th:C71/PFN/FM

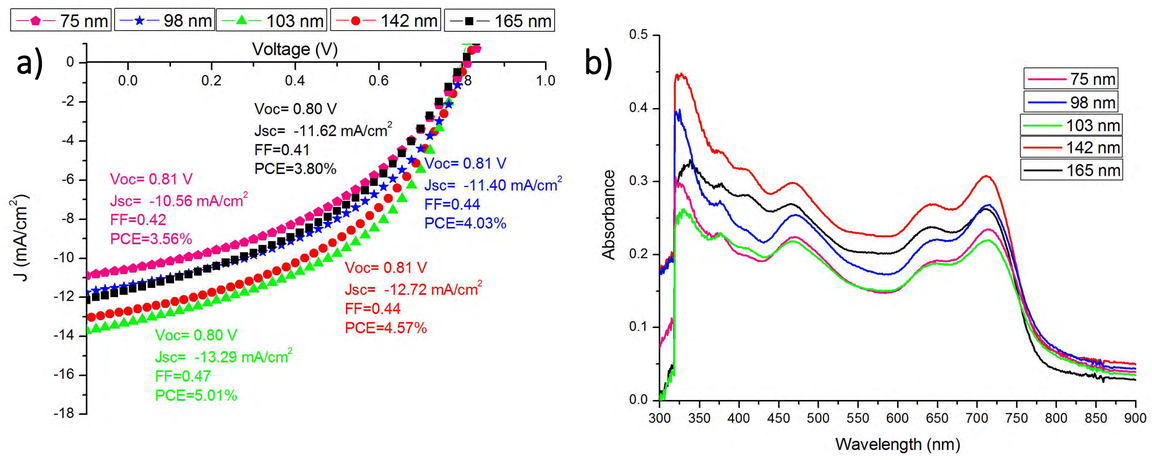


Fig. 5: *(a) J-V curves of solar cells with different active layer thicknesses, (b) Active layers absorbance*

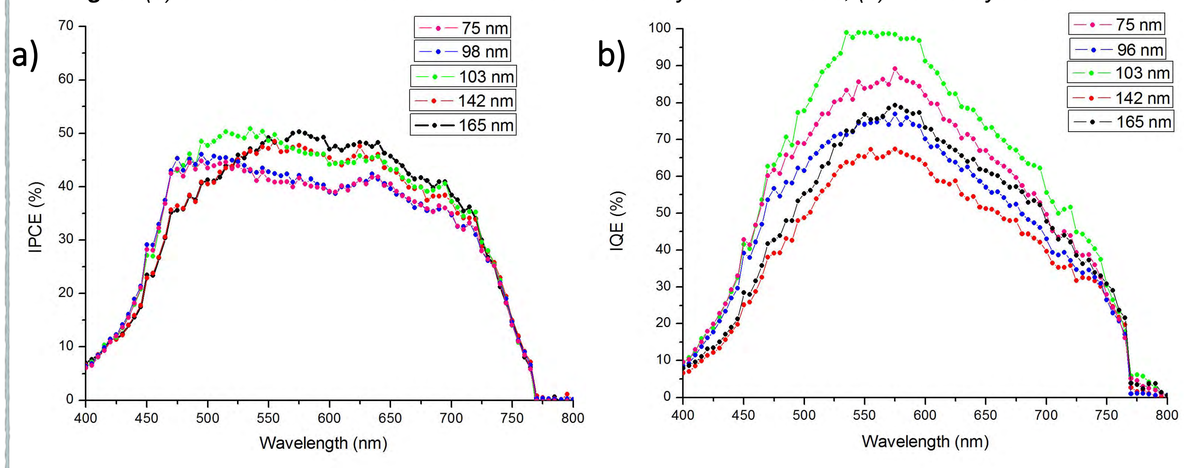


Fig. 6: *(a) IPCE and (b) IQE curves of solar cells with different active layer thicknesses*

Photocurrent estimation from IPCE and comparison with those measured from the J-V plots:

$$J_{sc}(mA/cm^2) = \int \frac{P_{in\lambda}\,\lambda}{1240}\,\frac{IPCE_\lambda}{100}\,d\lambda$$

Tab. 2: *Jsc estimated from IPCE*

Thickness (nm)	Jsc (mA/cm^2) J-V curve	Jsc (mA/cm^2) IPCE
165	-11.62	-11.66
142	-12.72	-11.30
103	-13.29	-11.86
98	-11.40	-10.85
75	-10.56	-10.69

CONCLUSIONS

It was observed a significant reduction of IQE with the increasing of the active layer thickness (above 120 nm). It could mean that there exist more non-geminate recombination losses. On the other hand, when the active layer thickness have a significant decrease (under 70 nm) PCE is reduced too because not enough charge carriers are generated. There exist a good agreement of the Jsc measured from the J-V curves and the estimated from EQE measurements.

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Ce-MIE-Sol 207450/27 and CONACyT-SENER grant 245754 (Mexico)

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