Active thin film variation in OPV cells and analysis through external and internal quantum efficiency

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ABSTRACT

Here is reported an analysis of the external and internal quantum efficiency (EQE and IQE) and, its correlation with the power conversion efficiency (PCE) of organic photovoltaic (OPV) cells, as a function of the active layer thickness, ranging from 40 to 165 nm. OPVs cells configuration was ITO/PEDOT:PSS/PTB7-Th:$PC_{71}BM$/PFN/Field's Metal (FM: an alternative top electrode). IQE spectra were determined from EQE and net internal absorption spectra; net absorption was estimated through the transfer matrix method (TMM).

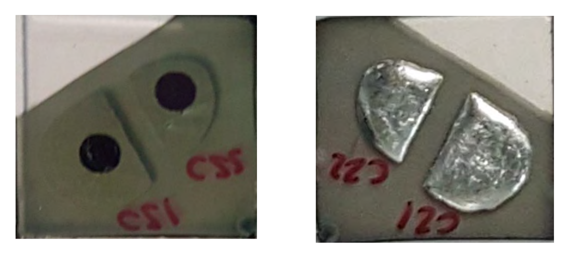
INTRODUCTION

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

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

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

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



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

$\boldsymbol{\eta_A}$: 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

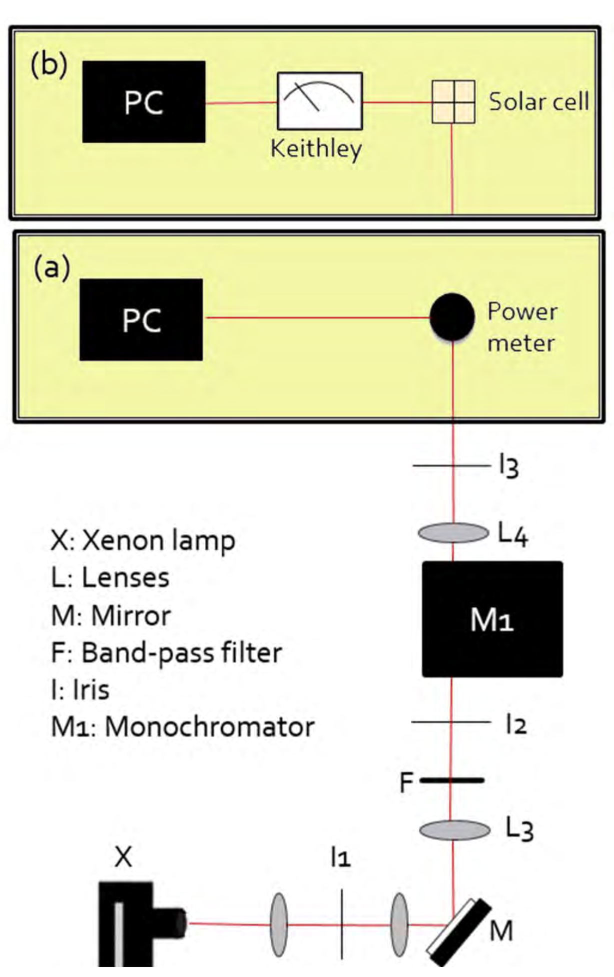


Fig. 1: EQE scheme: a) Power measurements, b) solar cell current measurements

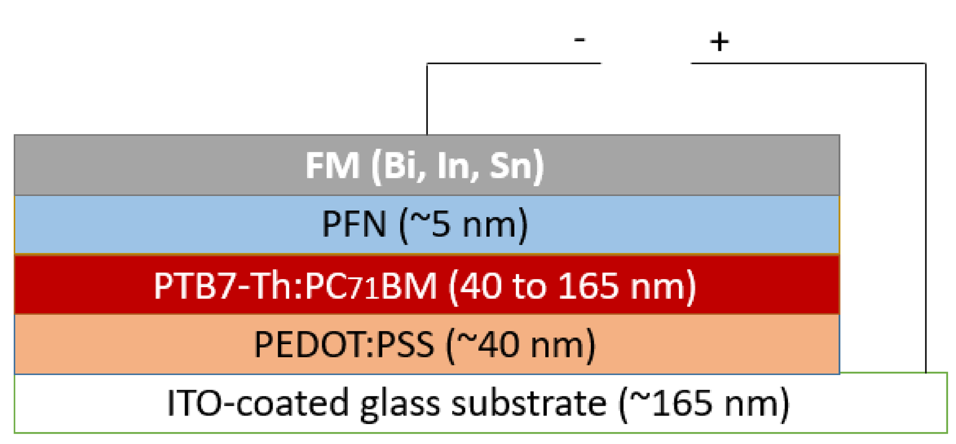
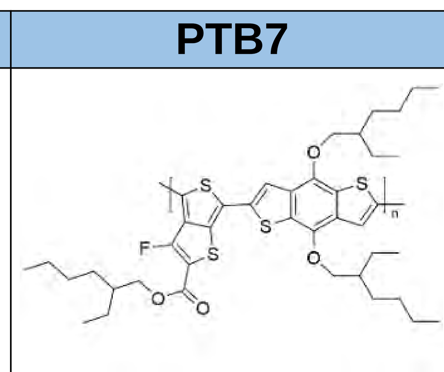
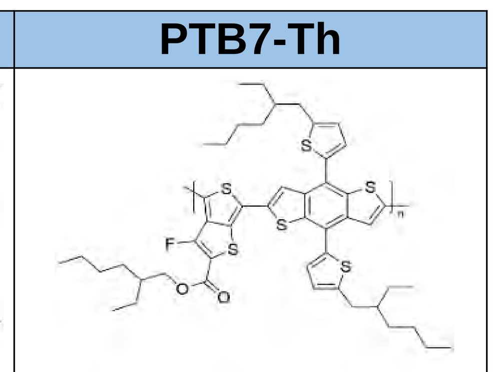


Fig. 2: *Scheme of OPV's*

Field's Metal (FM):
Alternative top electrode. Is an eutectic alloy, composed by 32.5% Bi, 51% In and 16.5% Sn, that melt at 65°C.

PTB7 vs PTB7-Th

Tab. 1: *Comparative data of PTB7 and PTB7-Th [5,6]*

Parameters:	PTB7	PTB7-Th
Chemical structure		
Hole mobility	$5.8 \times 10^{-4} cm^2V^{-1}s^{-1}$	$2.83 \times 10^{-3} cm^2V^{-1}s^{-1}$
Bandgap	1.64 eV	1.58 eV
Absorption coefficient	$1.9 \times 10^4\ cm^{-1}$	$2.5 \times 10^4\ cm^{-1}$

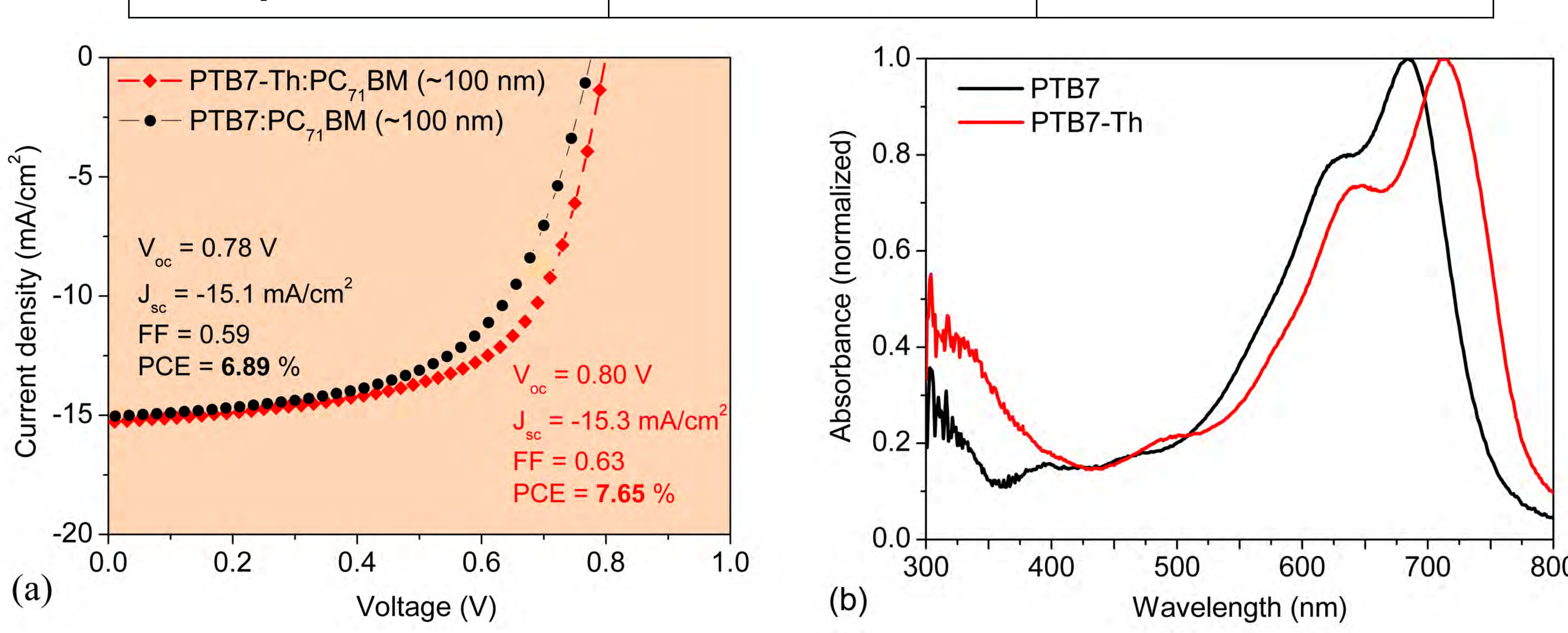


Fig. 3: *(a) Best efficiencies obtained with PTB7 and PTB7-Th; (b) Absorption spectra of PTB7 and PTB7-Th films.*

RESULTS

ITO/PEDOT:PSS/PTB7-Th:$PC_{71}BM$/PFN/FM

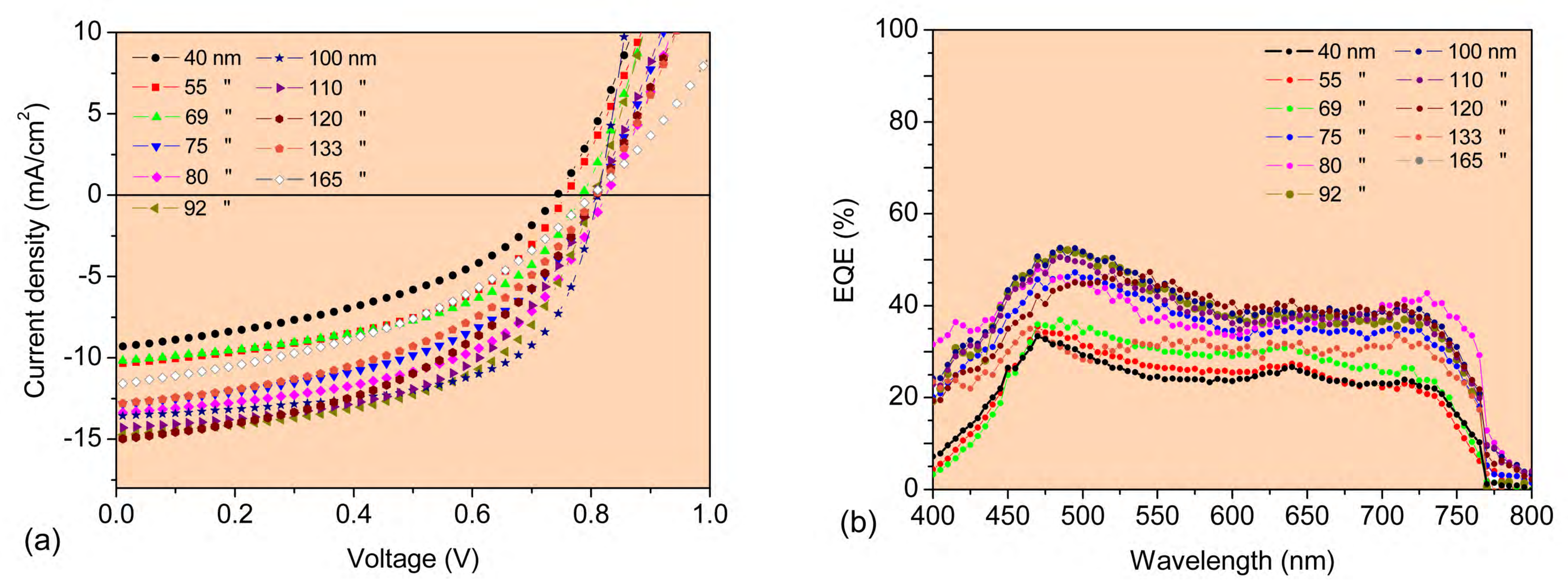


Fig. 4: *(a) J-V and (b) EQE curves of solar cells with different active layer thicknesses*

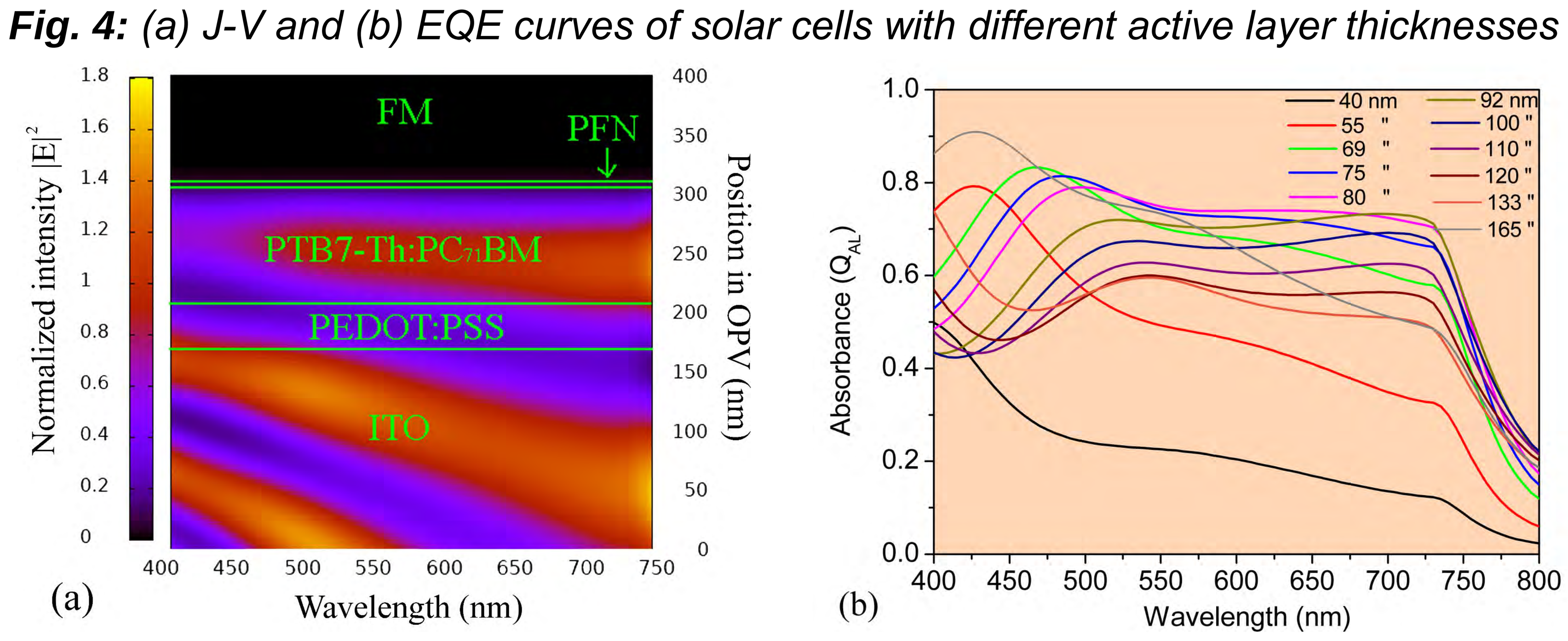


Fig. 5: *(a) Optical electric field intensity estimated by TMM considering a unitary incoming intensity passing through these layer thicknesses: 165 nm of ITO, 40 nm of PEDOT:PSS, 100 nm of PTB7-Th:$PC_{71}BM$ and 5 nm of PFN; (b) PTB7-Th:$PC_{71}BM$ absorbance determined by TMM by taking into account all the OPV layers for each active layer thickness*

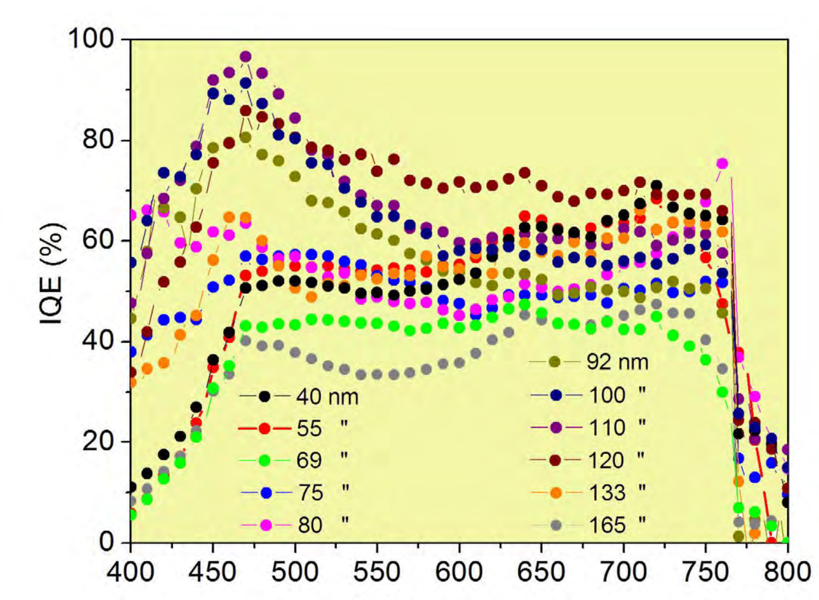


Fig. 6: *IQE obtained from EQE and the PTB7-Th:$PC_{71}BM$ absorbance (from TMM) from 40 to 165 nm thickness*

CONCLUSIONS

The highest IQE took place for the active layer thickness range 92 to 120 nm. IQE spectra showed a significant reduction with the increasing of active layer thickness (> 120 nm), and also if it was very thin (< 75 nm), it is because of the losses for recombination and trapping, and poor absorption, respectively. If an OPV cell exhibits a low EQE but a high absorption, then the reduction in efficiency arises from either poor transport or poor interfacial kinetics (or both).

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