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# Semi-Transparent Organic Photovoltaic for Agrivoltaic Applications



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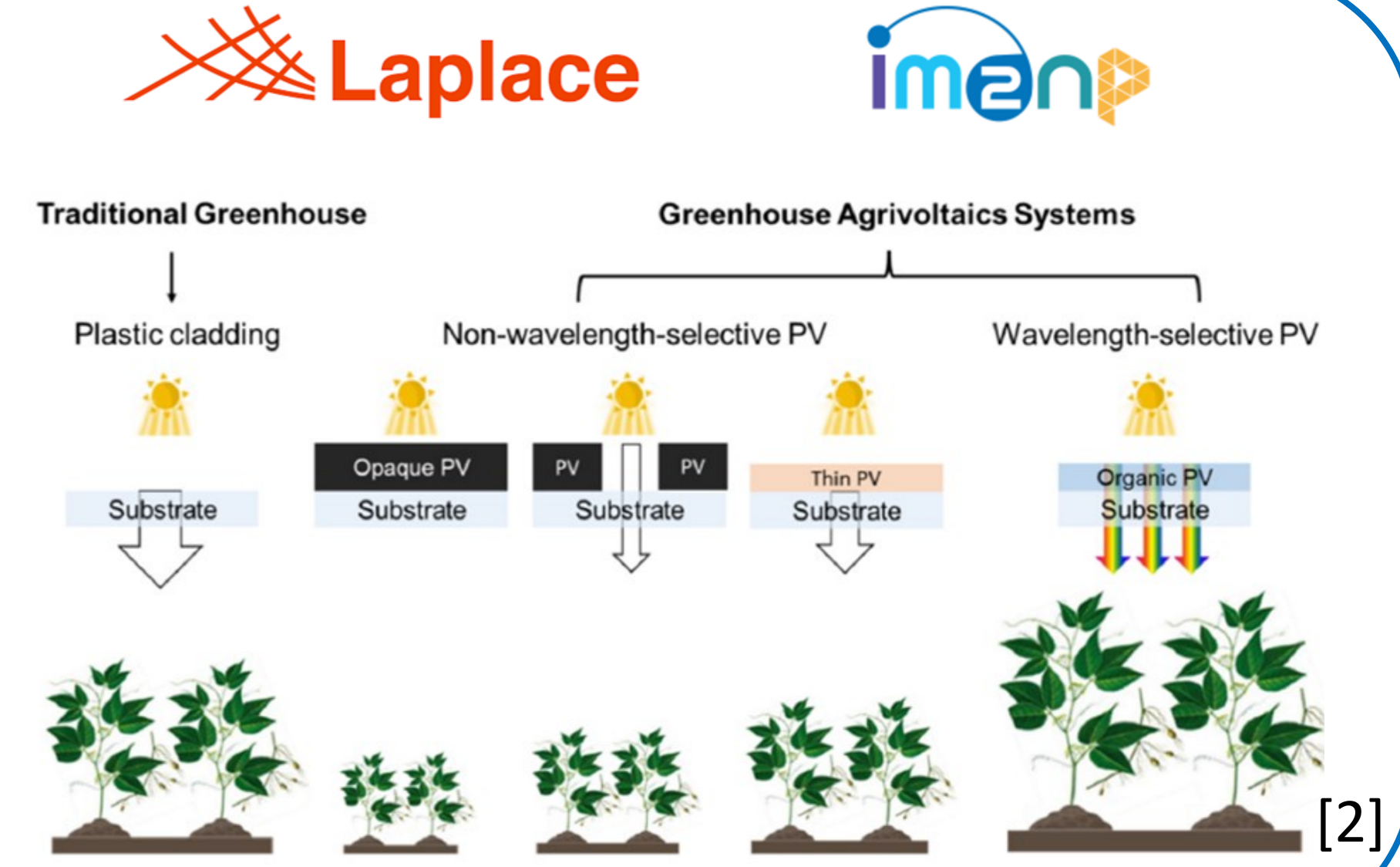
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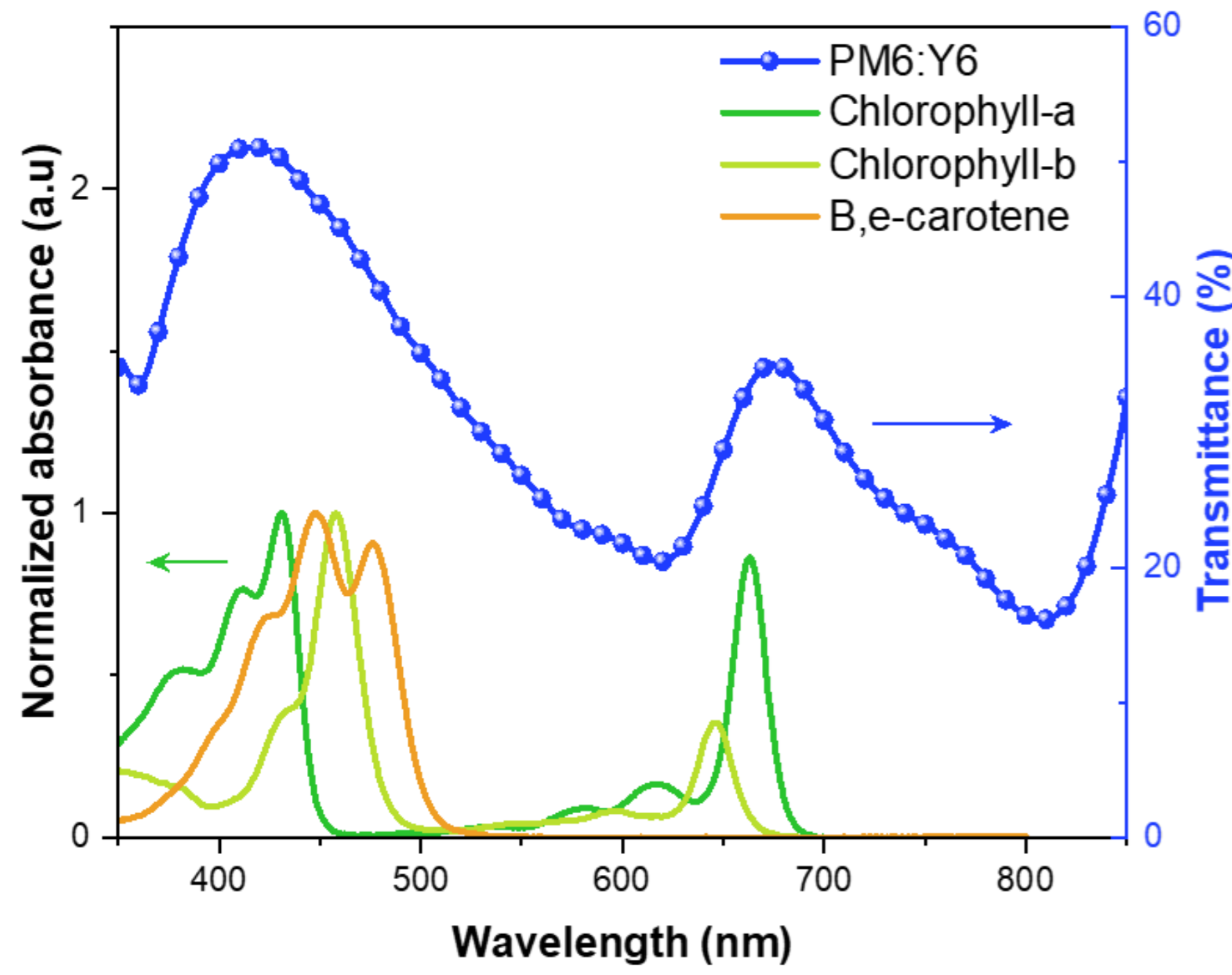


This work is the result of the collaboration involving four laboratories: XLIM Research Institute (Limoges), CINaM (Marseille), IM2NP (Marseille), and Laplace (Toulouse) as part of the SMART4MODULE project in the PEPR TASE program. The objective of this project is to develop aesthetic and transparent photovoltaic solutions. To address this challenge, the project aims to develop low-cost and printable semi-transparent organic photovoltaic (ST-OPV) modules optimized for agrivoltaics (Agri-PV). Agri-PV enables the simultaneous conversion of solar energy and agricultural production on the same surface (arable land or greenhouses). The OPV technology offers constant improving performance, low specific weight, short energy payback time, and high flexibility, making it a promising candidate for integration into small urban greenhouses. This work focuses on the design and characterization of a first generation of reference semi-transparent OPV devices, with light transmission tailored to the wavelengths required for plant photosynthesis, consistent with the standard Photosynthetically Active Radiation (PAR) spectrum. The selected active layer, based on the PM6:Y6 blend, meets this criterion and has been integrated into inverted OPV architectures. [1]

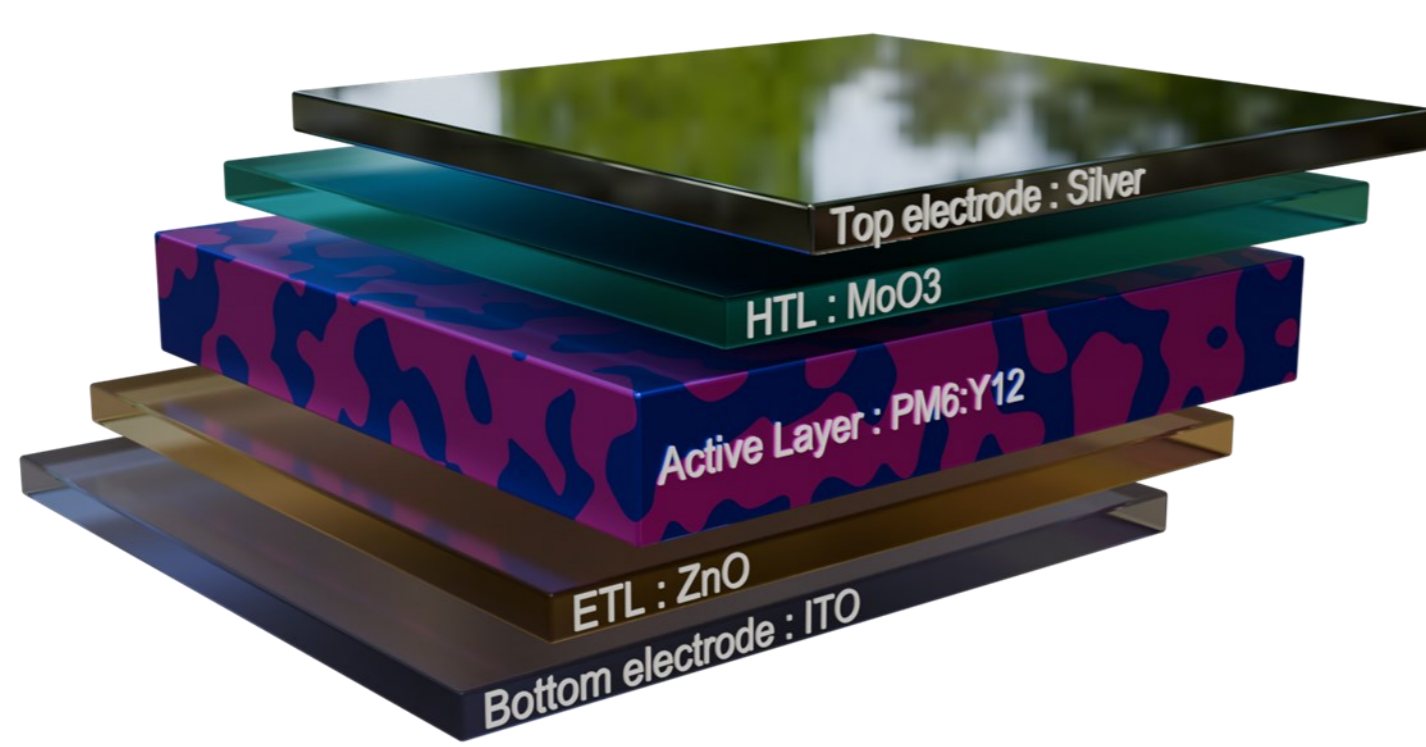
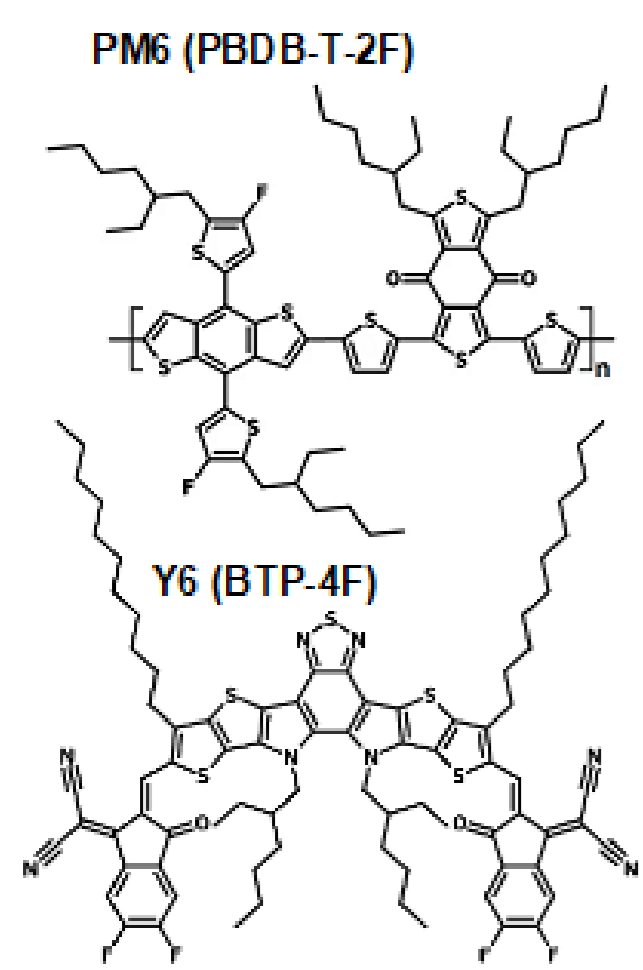
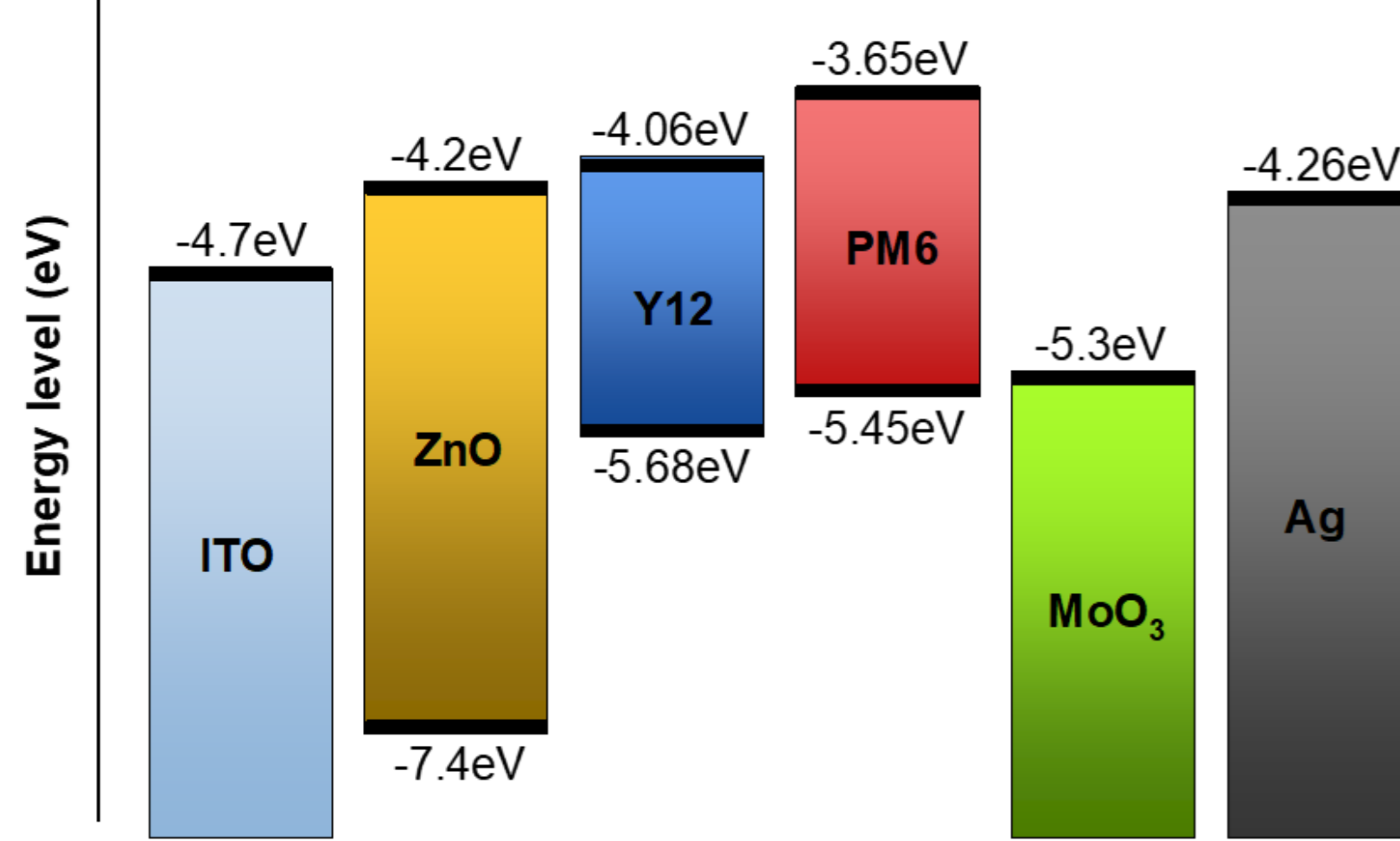


## I. Choosing an active layer tailored for the absorption of photosynthetic systems

The PM6:Y6 active layer exhibits a transmission compatible with the absorption of photosynthetic systems:



Devices fabricated at lab scale (active area 0.10-0.15cm<sup>2</sup>)



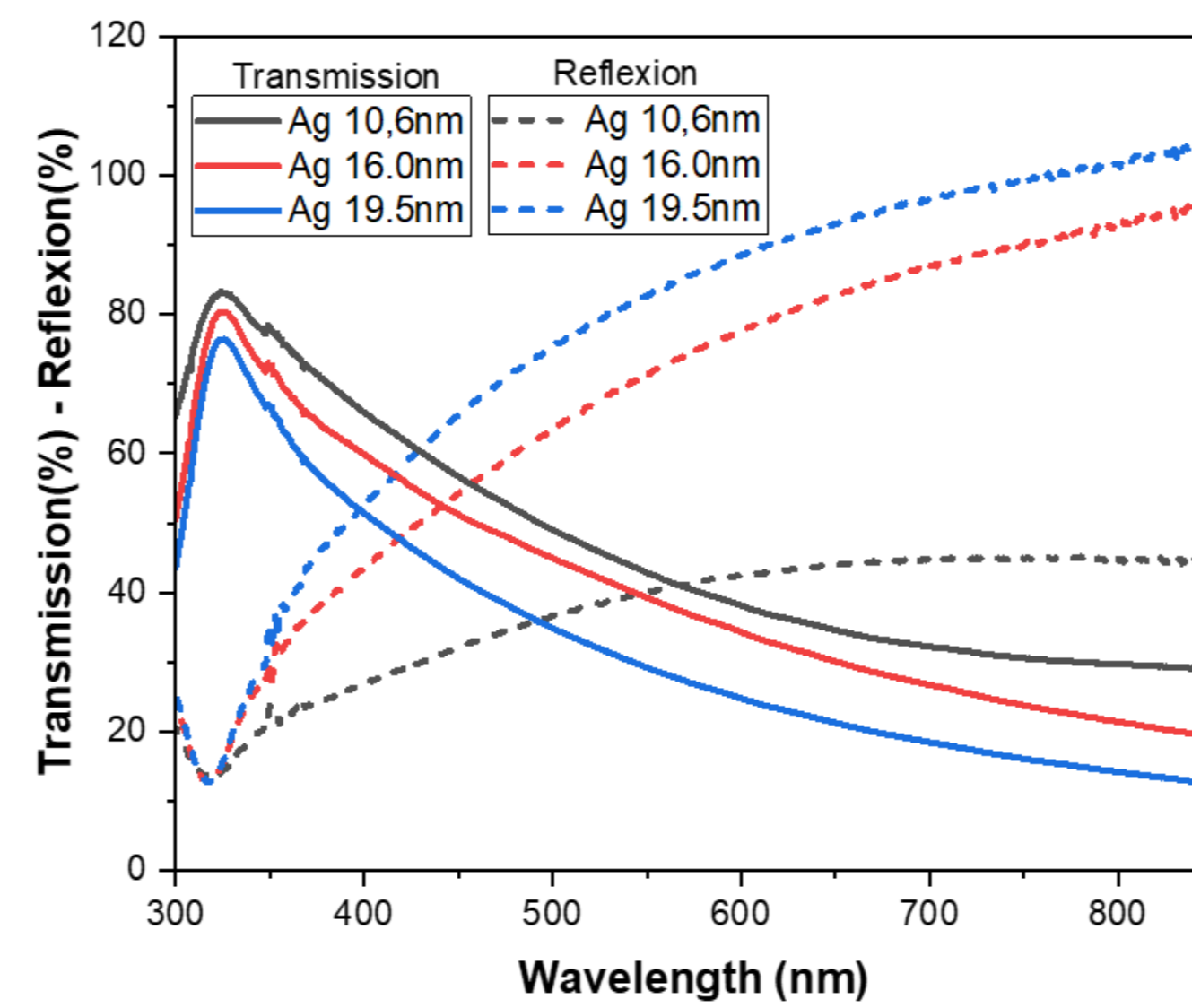
Bulk heterojunction inverted structure

ITO/ZnO(20nm)/PM6:Y6(100nm)/MoO<sub>3</sub>(10nm)/Ag(100, 15 & 10nm)

## II. Obtaining Semi-Transparent devices

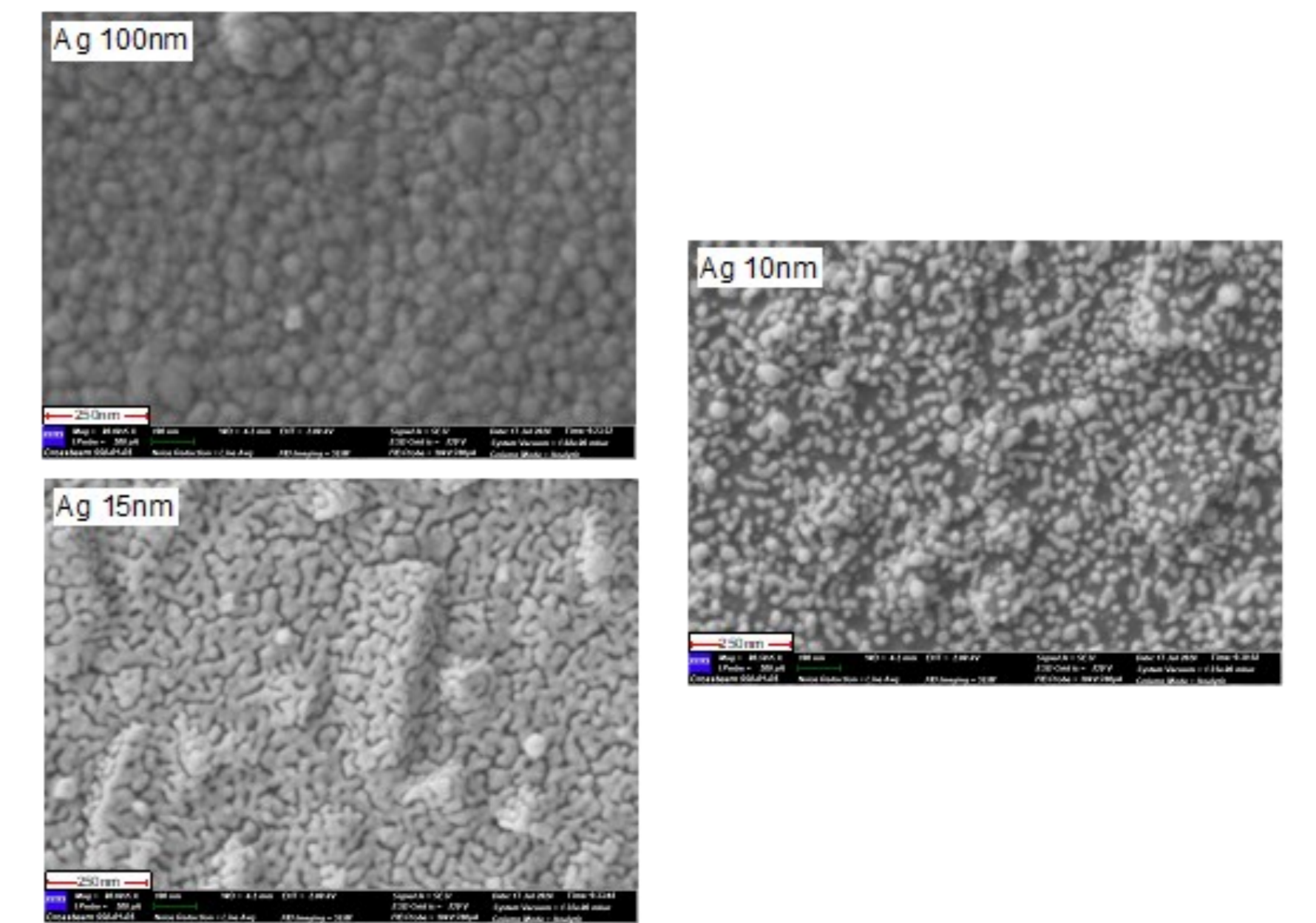
The semi-transparent devices were obtained by reducing the thickness of the silver electrode

- ⇒ Increased transmittance of Silver layer as a function of decreasing thickness
- ⇒ Decreased reflection of Silver layer as a function of decreasing thickness



Silver electrodes deposited by thermal evaporation

## Scanning Electron Microscopy of evaporated Ag electrodes (100nm, 15nm & 10nm)



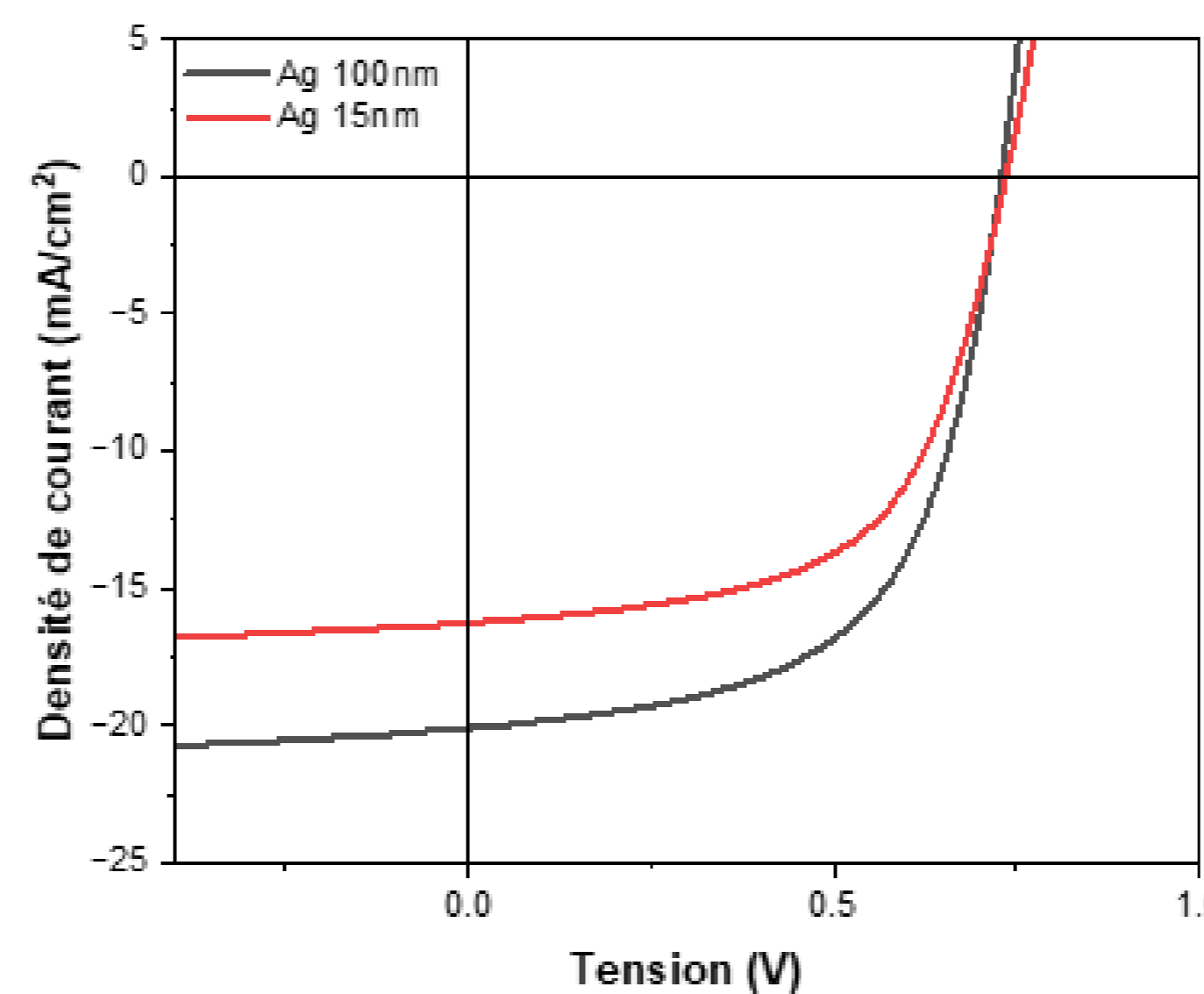
- ✓ Ag 100nm : Percolation threshold reached
- ✓ Ag 15nm : Percolation threshold reached
- ✗ Ag 10nm : Percolation not threshold reached

## III. Photovoltaic performance under AM1.5G

Silver Thickness	V <sub>oc</sub> (V)	J <sub>sc</sub> (mA/cm <sup>2</sup> ) <sup>a</sup>	J <sub>sc</sub> (mA/cm <sup>2</sup> ) <sup>b</sup>	FF(%)	PCE (%)
100nm	0.73 ± 0.01	20.30 ± 1.05	20.03	57.78 ± 1.29	8.55 ± 0.43
15nm	0.73 ± 0.01	16.49 ± 1.50	16.13	58.29 ± 2.93	6.99 ± 0.70
10nm	Devices not working				

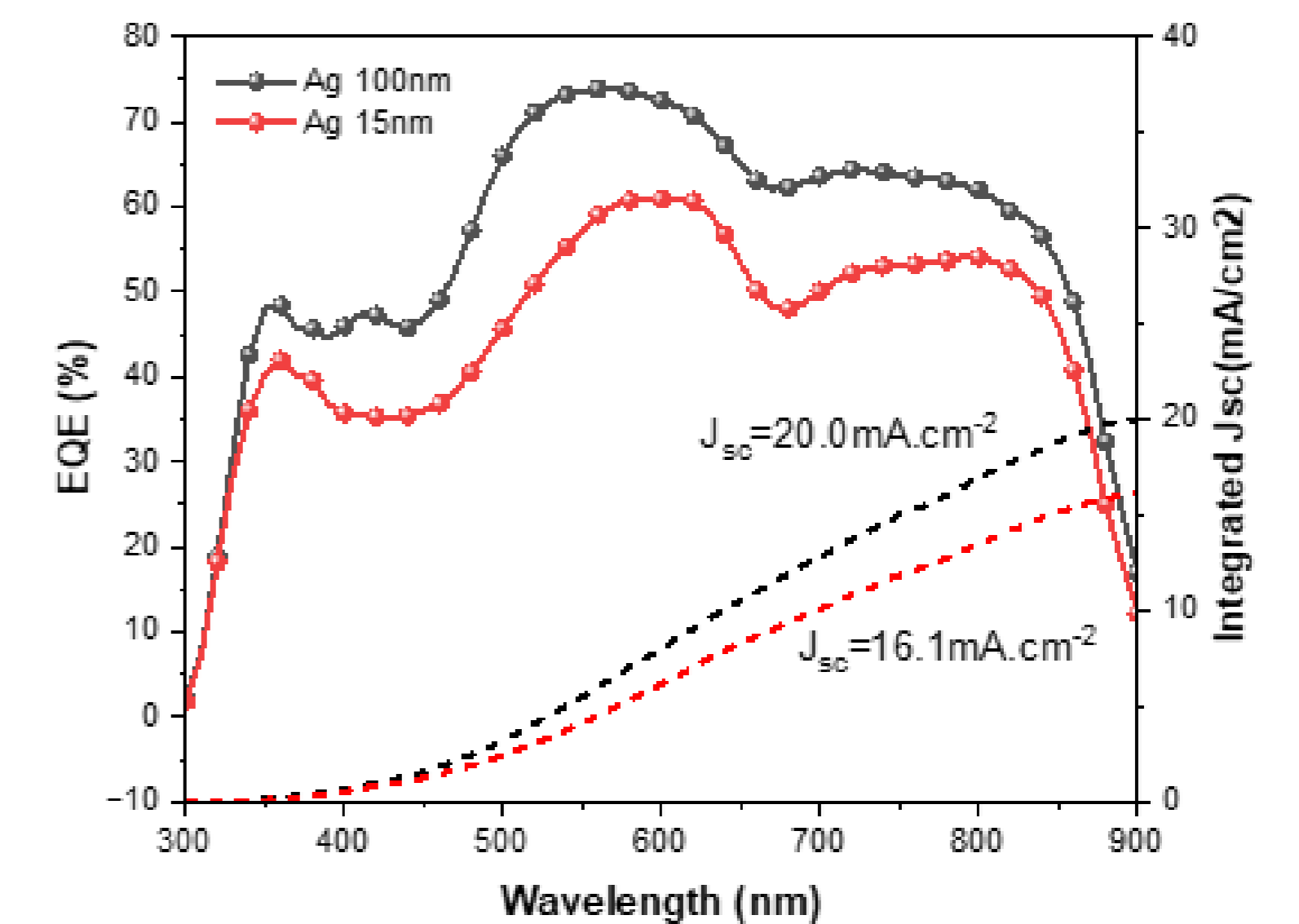
<sup>a</sup> Calculated from J-V curve

<sup>b</sup> Calculated from External Quantum Efficiency curve (EQE)

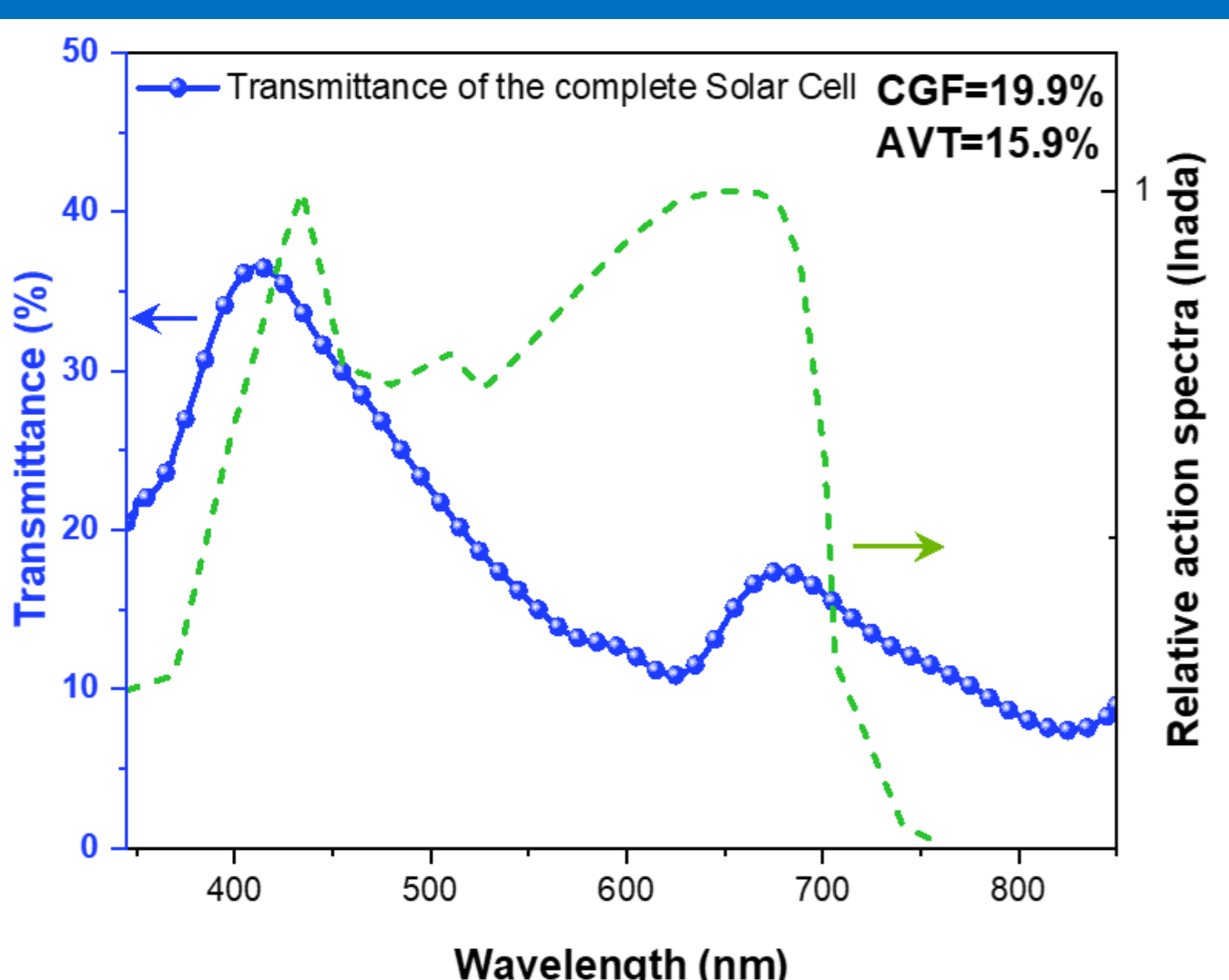


Decreased photocurrent for devices with a 15nm Silver Electrode :

- ⇒ Low reflection of the silver electrode induce less photons absorbed in the active layer
- ⇒ Less efficient charge carrier collection with increased resistance of the silver electrode



## IV. Transmission of the devices



Transmission of the ST-OPV matching with the absorption of photosynthetic systems:

- ⇒ Crop growth Factor (CGF): **19.9%**
- ⇒ Average visible transmittance : **15.9%**

$$CGF = \frac{\int T(\lambda)PAR(\lambda)\Gamma(\lambda)d\lambda}{\int PAR(\lambda)\Gamma(\lambda)d\lambda}$$

$$AVT = \frac{\int T(\lambda)PR(\lambda)\Gamma(\lambda)d\lambda}{\int PR(\lambda)\Gamma(\lambda)d\lambda}$$

λ is the wavelength, T(λ) the transmittance of the OPV, PAR(λ) the photosynthetic action spectrum, PR(λ) the photopic response of a human eye and Γ(λ) the solar spectrum AM1.5G



## V. Perspectives

Optical simulations to find the best compromise between photovoltaic performance and transmission for plant growth

Research on new donor:acceptor systems for the application

Integration of printable semi-transparent electrodes based on silver nanowires

Scaling up to small printable modules (New acceptor Y12)

### References :

- [1] Nannan Yao, ACS Appl. Energy Mater 4 (2021) 14335-14341
- [2] Song, Nano Energy 116 (2023) 108805