Near Infrared Absorbing Cyanine Dyes for Visible Transparent Organic Solar Cells

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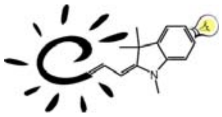
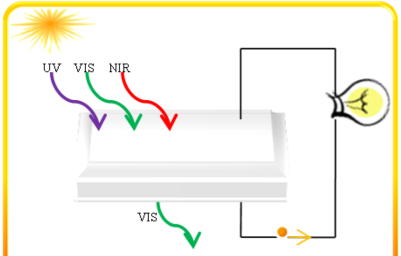
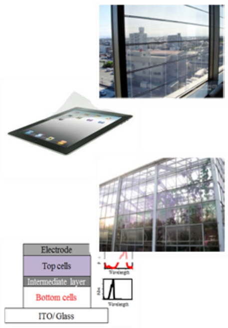


Introduction

Organic photovoltaic (OPV) cells are attracting interest in research and industrial laboratories due to their potential as low-cost, flexible and lightweight devices for solar energy conversion [1,2]. In addition to the pursuit of high device efficiency, solar cells have also been intensively investigated for their potential in making advances for unique applications. The rather weak Van der Waals interaction holding together the molecular building blocks in organic semiconductors results in narrow absorption spectra that are uniquely distinct from very broad absorption band of their inorganic counterparts. Therefore, OPV is considered to have important advantages for the development of truly transparent solar cells.

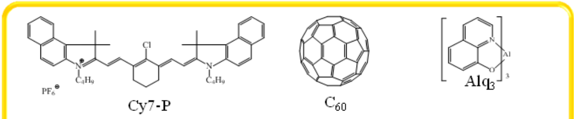


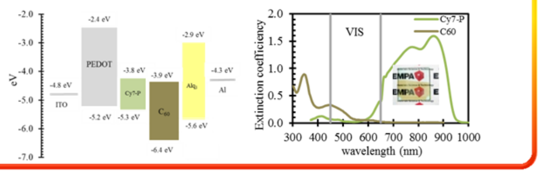
Transparent solar cells are devices through which the visible (VIS) light is transmitted while ultraviolet (UV) and near infrared (NIR) light is selectively harvested and then transformed to electrical energy



Experiment

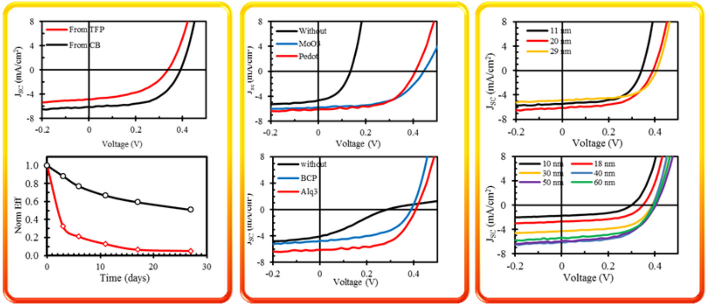
In this work, we used a selective near-infrared absorbing heptamethine cyanine dye (Cy7-P) electron donor for the fabrication of bilayer solar cells with the acceptor C_{60}. Using a reflective aluminum top electrode, and Alq3 as cathode buffer layers. Highly transparent devices were then fabricated by using silver/Alq3 cathodes.





Results and discussion

Performance optimization: Using a reflective aluminum top electrode, the performance of cells are optimized by using different spin coating solvent, anode and cathode buffer layers and active layer thickness



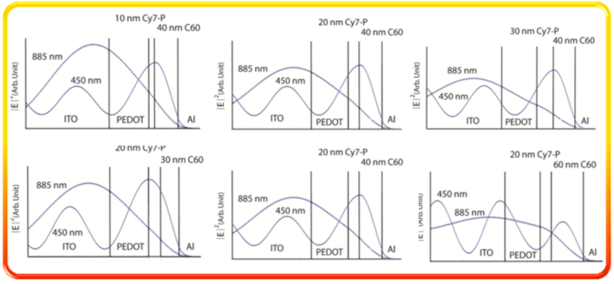
Solvent selection | Buffer layer selection | Active layer thickness

References:

[1] Lloyd, M.T., et al. materialstoday. 2007, 10(11), 34-41
[2] Walker, B., et al. Chem. Mater. 2011, 23(3), 470-482

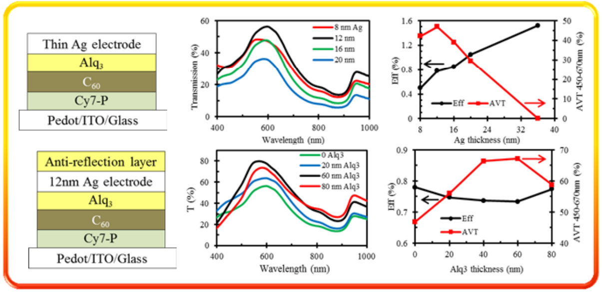
Optical simulation

The spatial distribution of the squared optical electric field strength was calculated for wavelengths at 885 nm, the absorption maximum of Cy7-P, and at 450 nm where C_{60} has a local absorption maximum. The optical field at 450 nm was maximized exactly at the junction for a C_{60} layer of 40 nm, confirming that this thickness optimizes the desired light absorption able to reach the heterointerface where charge generation takes place.

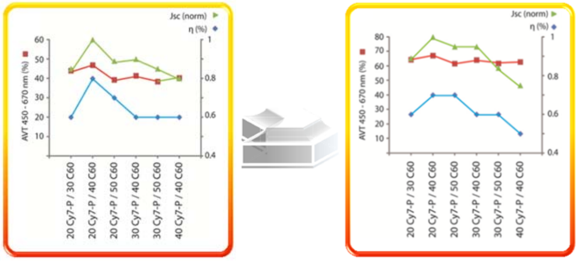


Towards transparent solar cells

Transparent solar cells were fabricated by replacing the reflective cathode with thin layers of Ag. To increase the transmission, Alq_3 was used as an additional external dielectric coating on top of Ag. Due to interference effects in semitransparent metal films, the additional Alq_3 capping layer showed the beneficial influence of increasing AVT strongly with only small losses of efficiency.



Transparent solar cells with fixed top cathodes but different thickness combinations of Cy7-P and C_{60} layers. Performance data showed again highest values for J_{sc} and η for layer thicknesses of 20 nm cyanine and 40 nm C_{60}, in agreement with results found for cells with an Al top contact.



Thin Ag top electrode | Ag/Alq_3 top electrode

Conclusions and outlook

Conclusion

- Using reflective top electrodes, solar cell optimization resulted in an efficiency of 1.5% for the configuration of ITO/PEDOT:PSS/20nm Cy7-P /40nm C60 /Alq3/Al, using CB as spin coating solvent
- Using 12nmAg /60nmAlq3 as transparent top electrode, AVT (450–670 nm) = 67%, T_{max}=80% at 568nm

Outlook

- For the further increased visible transmittance: replace C60, use cyanines with improved NIR absorption
- For the efficiency improvement: bulk heterojunction, tandem cells

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