Non-Fullerene Tandem Organic Solar Cells with High Open-circuit Voltage of 1.97 V

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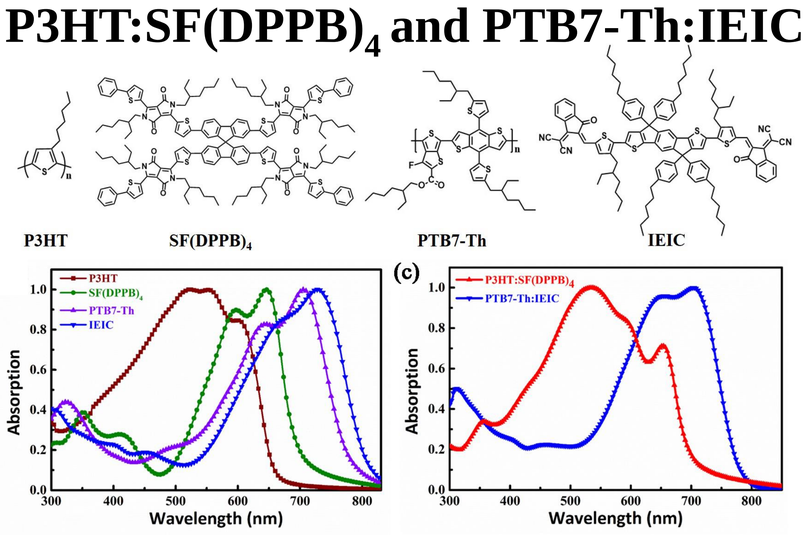
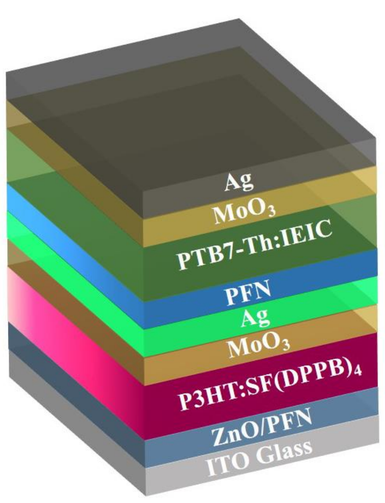
Abstract

In this work, the non-fullerene molecule based inverted tandem organic solar cells (OSCs) have been demonstrated for the first time, wherein P3HT:SF(DPPB)$_4$ and PTB7-Th:IEIC bulk-heterojunctions (BHJs) are used as the front and back sub-cells, respectively. A high power conversion efficiency (PCE) of 8.48% is achieved, accounting for ~30% improvement to that of the individual cells (~ 6.3% PCE). Moreover, we demonstrated that the delicate engineering of interconnection layer (ICL) and the active layer thicknesses leads to the optimized optical field distribution in cell and thus a matched current density between the two sub-cells. More interestingly, an ultra-high Voc of 1.97 V is obtained in such devices, which is the highest voltage value reported to date among the efficient tandem OSCs. Such tandem OSCs can drive water splitting of an electrochemical cell under 100 mW cm^{-2} AM1.5G illumination. These results would provide new insights for tandem OSC development by employing new material systems, and reveal the great potential for high voltage nonfullerene tandem cells used in solar-to-fuel research.

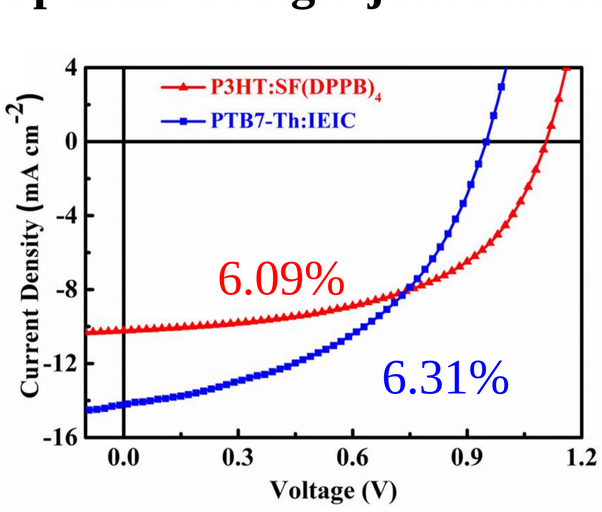
Materials and single-junction device information

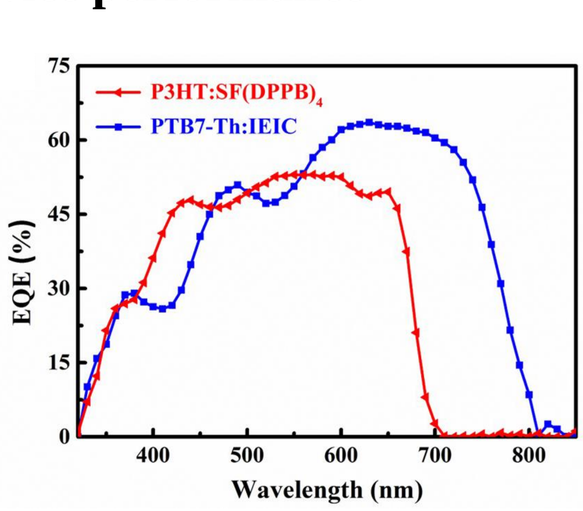
P3HT:SF(DPPB)$_4$ and PTB7-Th:IEIC





Optimized single-junction device performance



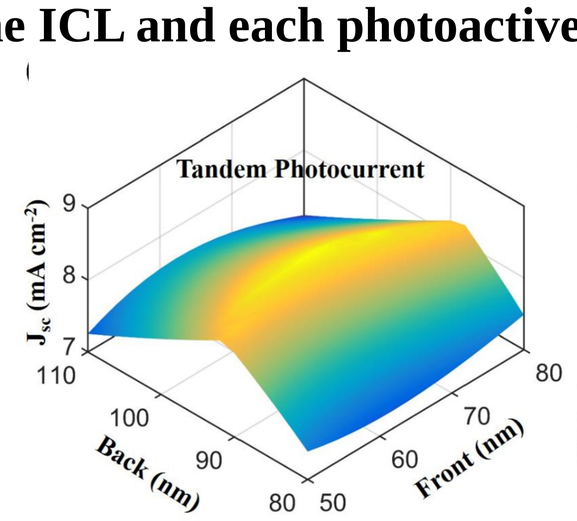


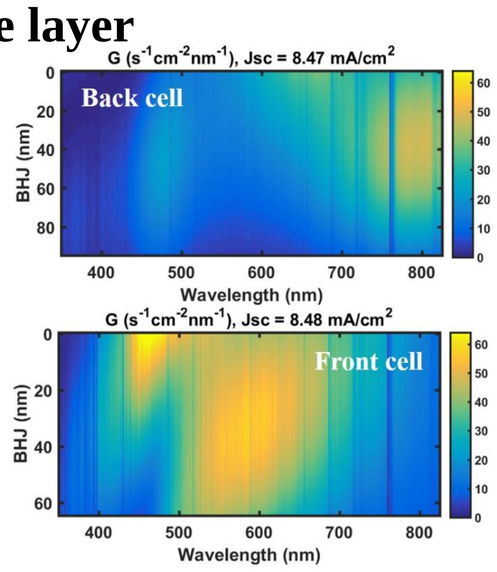
Optimizing of the tandem devices

We carefully tuned the thicknesses of the ultrathin Ag layer in the ICL and each photoactive layer

Ag thickness	V_{oc} (v)	J_{sc} (mA cm^{-2})	FF	PCE(%)
2[a]	1.88	4.57	0.43	3.71
5[a]	1.94	6.31	0.49	6.05
8[a]	1.97	7.49	0.50	7.42
10[a]	1.97	7.84	0.51	7.95
10[b]	**1.97**	**8.28**	**0.52**	**8.48**
15[a]	1.97	7.10	0.52	7.22

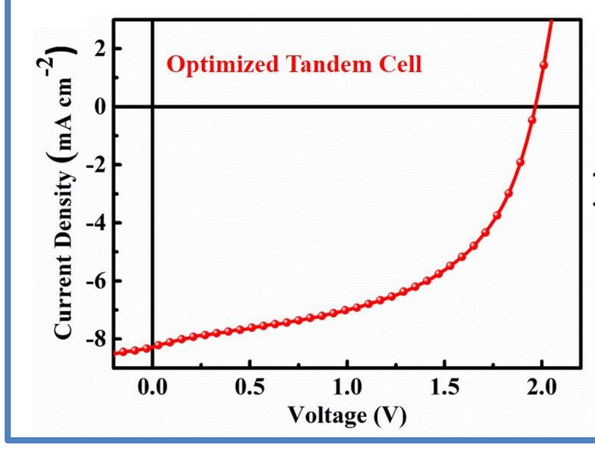
a, the thicknesses of the front and back cells were 73 nm and 99 nm; b, the thicknesses of the front and back cells were 64 nm and 99 nm.

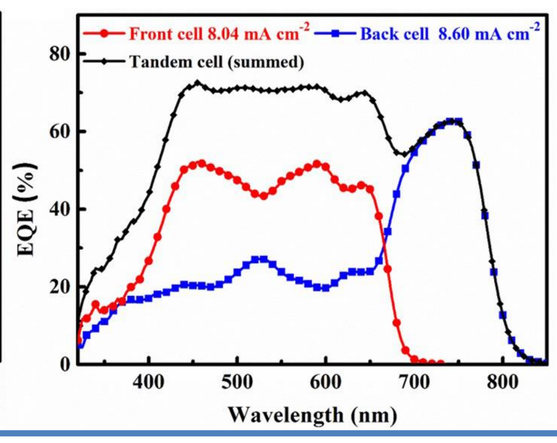


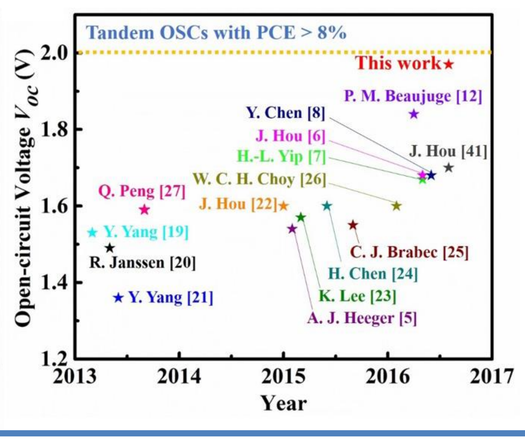


Device performance of the optimized tandem devices

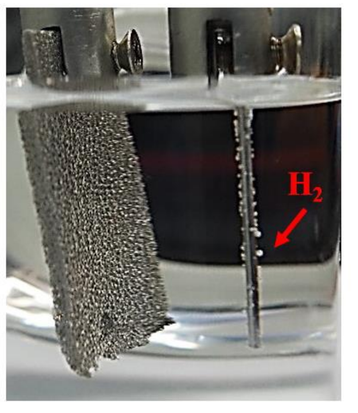
The Voc of 1.97 V achieved here is the highest value for the state-of-the-art reported tandem OSCs with PCEs > 8%







Solar-energy-driven water splitting was successfully demonstrated



Conclusions: An efficient nonfullerene based tandem devices with a high PCE of 8.48% and an ultra-high open-circuit voltage of 1.97 V was achieved and further be explored for water splitting of an electrochemical cell, revealing great potentials for solar-to-electricity and fuel research with non-fullerene tandem OSCs.

References:

[1]T. Ameri, N. Li, C. J. Brabec, Energy Environ. Sci. 2013, 6, 2390.

[2]Liu, W.; Li, S.; Huang, J.; Yang, S.; Chen, J.; Zuo, L.; Shi, M.; Zhan, X.; Li, C.-Z.; Chen, H. Adv. Mater. 2016, DOI:10.1002/adma.201603518.