A Solution-Processed n-Doped Fullerene Cathode Interfacial Layer for Efficient and Stable Large-Area Perovskite Solar Cells

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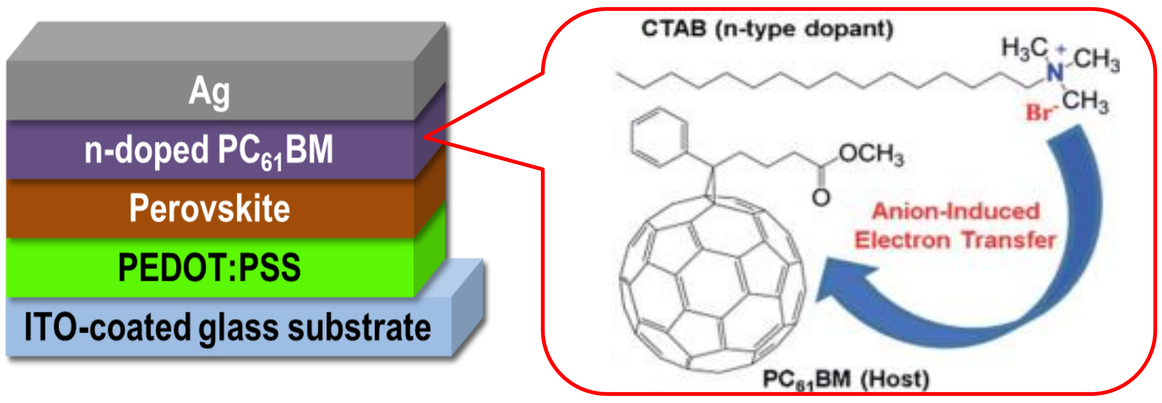
A novel solution-processed cetyltrimethylammonium bromide (CTAB)-doped [6,6]-phenyl-C_{61}-butyric acid methyl ester ($PC_{61}BM$) film prepared by an extremely facile method is demonstrated as an effective cathode interfacial layer for perovskite solar cells (PSCs). This doped layer also exerts multi-positive effects for use in PSCs, including efficient interfacial charge transfer ability, superior charge selectivity, good film coverage on the perovskite layer, relatively weak thickness-dependent performance properties, general applicability to different perovskite materials, and good ambient stability. With this n-doped $PC_{61}BM$ layer, the device delivers high power conversion efficiency (PCE) up to 17.1%. The application of the CTAB-doped $PC_{61}BM$ layer in large-area solar cells (active area = 1.2 cm^2) is also demonstrated, and a remarkable PCE of 15.4% is achieved, which represents one of the highest PCE values for PSCs with a similar active area. More significantly, the resulting devices possess good ambient stability without the need for rigorous encapsulation.

Introduction

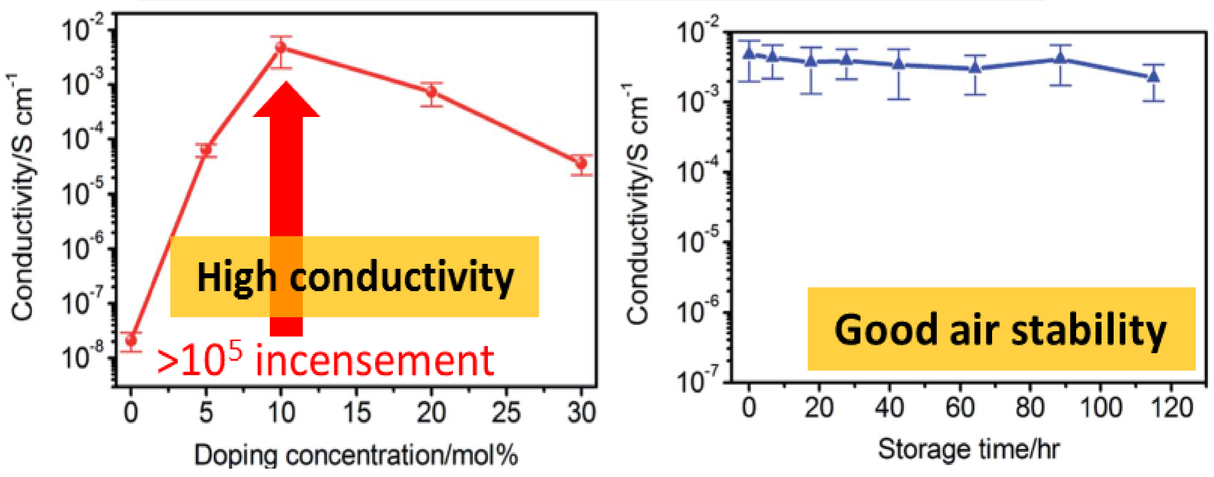
- Hybrid organic–inorganic lead halide perovskite solar cells (PSCs) hold much promise for cost-effective solar energy.
  - ✓ Commonly used planar heterojunction device configuration: ITO-coated glass/PEDOT:PSS/perovskite/$PC_{61}BM$ ETL/cathode
- Main challenge in PSCs: poor stability due in part to the use of low work-function (WF) metals (e.g. Ca or Al) as the cathode.
  - ✓ High WF metals (e.g. Ag or Au) ⇒ existence of energy barrier at metal/$PC_{61}BM$ interface ⇒ low power conversion efficiency (PCE)
- An effective strategy is to incorporate an additional cathode buffer layer (CBL) between $PC_{61}BM$ ETL and high WF cathode.
  - ✓ This certainly increases fabrication complexity due to the requirements of additional steps and accurate layer thicknesses
  - ✓ Deposition of uniform and ultrathin CBL (5-25 nm) on rough $PC_{61}BM$/perovskite surface without pinholes remains challenging
- This work : we demonstrate an effective strategy to improve PCE & stability through facile chemical doping (n-doping) of $PC_{61}BM$:
  - ✓ The doped film is capable of serving as both ETL & CBL in PSCs

Experimental

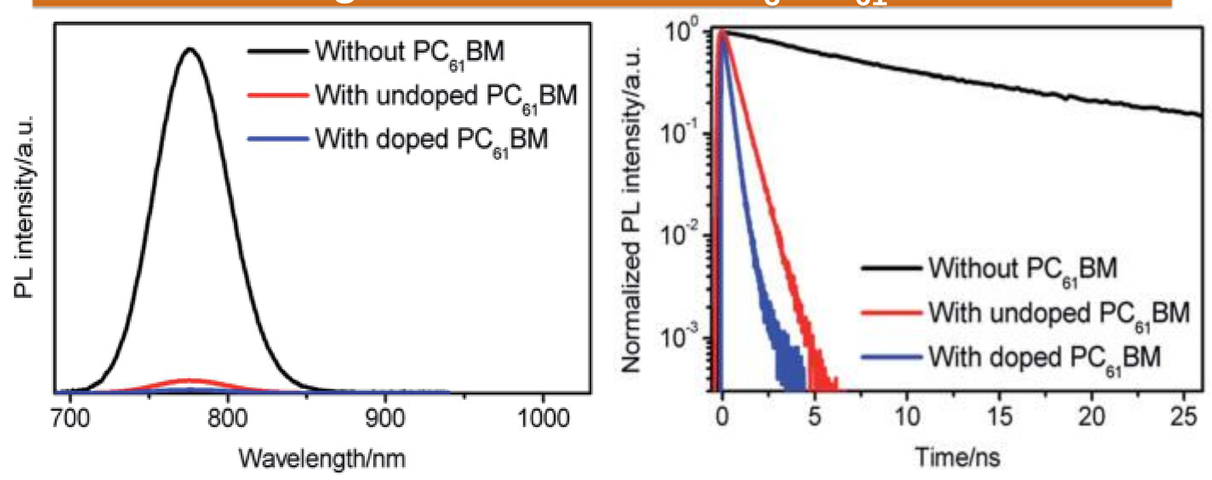


Result and Discussion

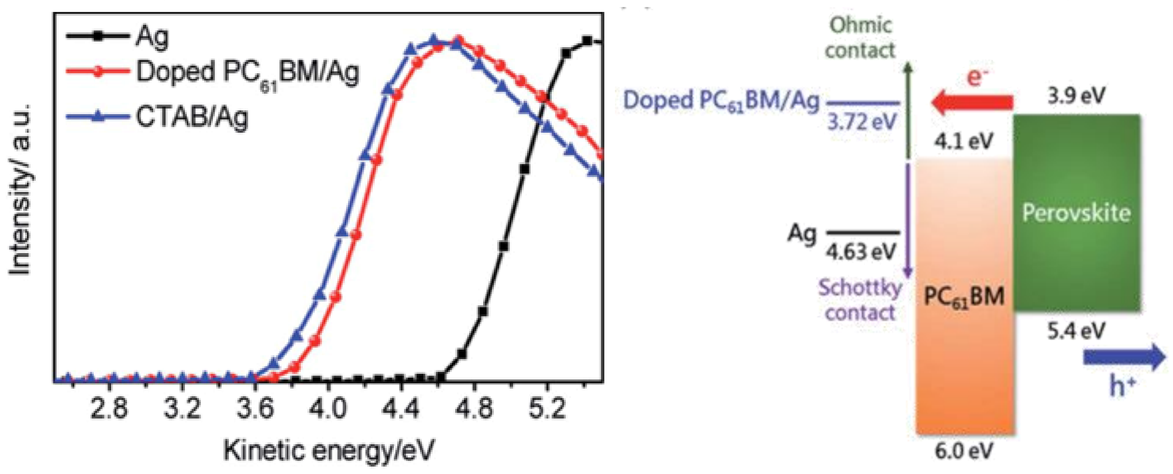
Conductivity & stability of doped films



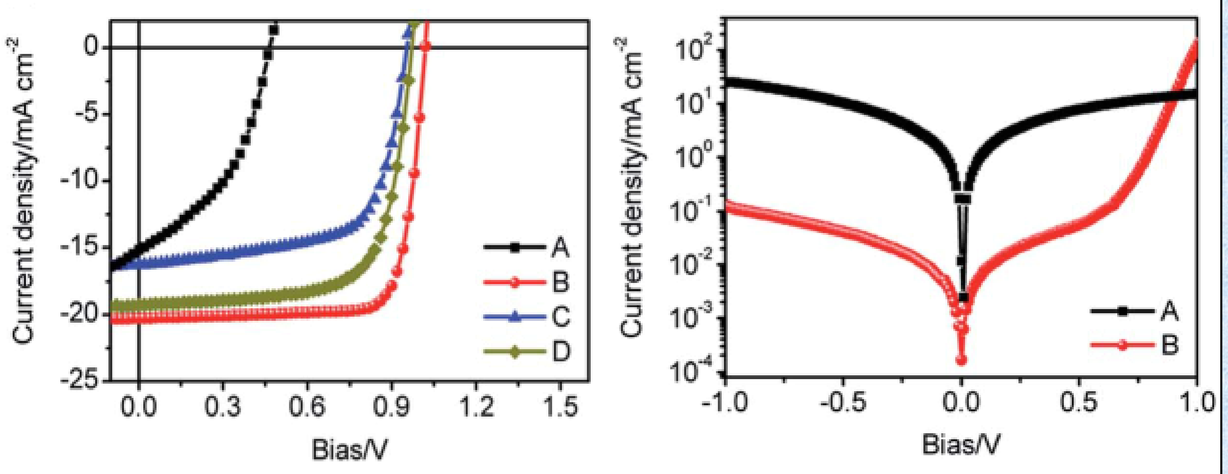
Efficient charge transfer at $MAPbI_3/PC_{61}BM$ interface



WF modulation of Ag electrode

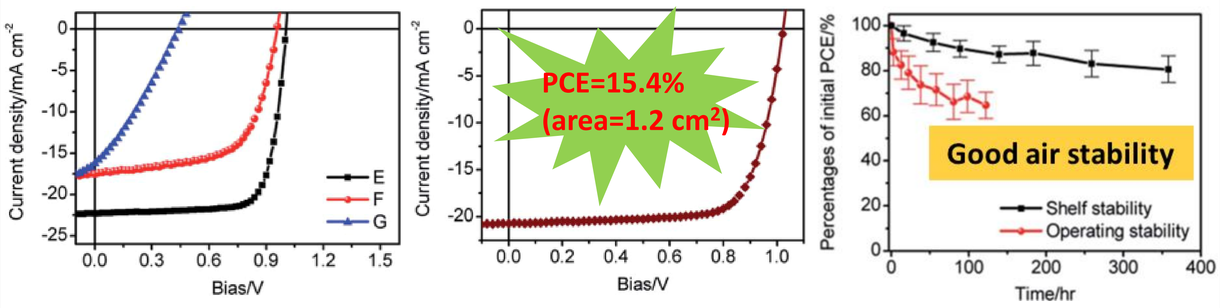


J-V characteristics of $MAPbI_3$-based devices



Device	Interfacial layer	V_{oc} [volt]	J_{sc} [mA cm^{-2}]	FF [%]	PCE [%]
A	$PC_{61}BM$	0.47	15.14	42.60	3.0
B	Doped $PC_{61}BM$	1.01	20.27	78.75	16.1
C	$PC_{61}BM$/ZnO	0.95	16.29	66.13	10.2
D	$PC_{61}BM$/CTAB	0.97	19.27	70.16	13.1

J-V characteristics & stability of $FAPbI_3$-based devices



Device	Interfacial layer	V_{oc} [volt]	J_{sc} [mA cm^{-2}]	FF [%]	PCE [%]
E	Doped $PC_{61}BM$	1.01	22.41	75.60	17.1
F	$PC_{61}BM$	0.45	16.28	29.27	2.2
G	$PC_{61}BM$/ZnO	0.95	17.55	62.67	10.5

Conclusion

- ➢ A promising method to improve PCE & stability of PSCs is demonstrated by using CTAB-doped $PC_{61}BM$ as CBL and ETL:
  - Remarkable PCE up to 17.1% is demonstrated
  - Record-high PCE of 15.4% is obtained for large device (1.2 cm^2)
  - Good ambient stability is achieved without encapsulation

Reference

➢ Chih-Yu Chang, Wen-Kuan Huang, Yu-Chia Chang, Kuan-Ting Lee, Chin-Ti Chen, *J. Mater. Chem. A*, 2016, 4, 640–648.