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CTCI Science and Technology Research Scholarship

國立交通大學 National Chiao Tung University

利用具自組裝功能之多甘醇分子於反式高分子太陽能電池作為一製程簡易且具廣泛性之陰極介面修飾層

Self-Assembled Tri-, Tetra- and Penta-Ethylene Glycols as an Easy, Expedited and Universal Interfacial Cathode-Modifier for Inverted Polymer Solar Cells

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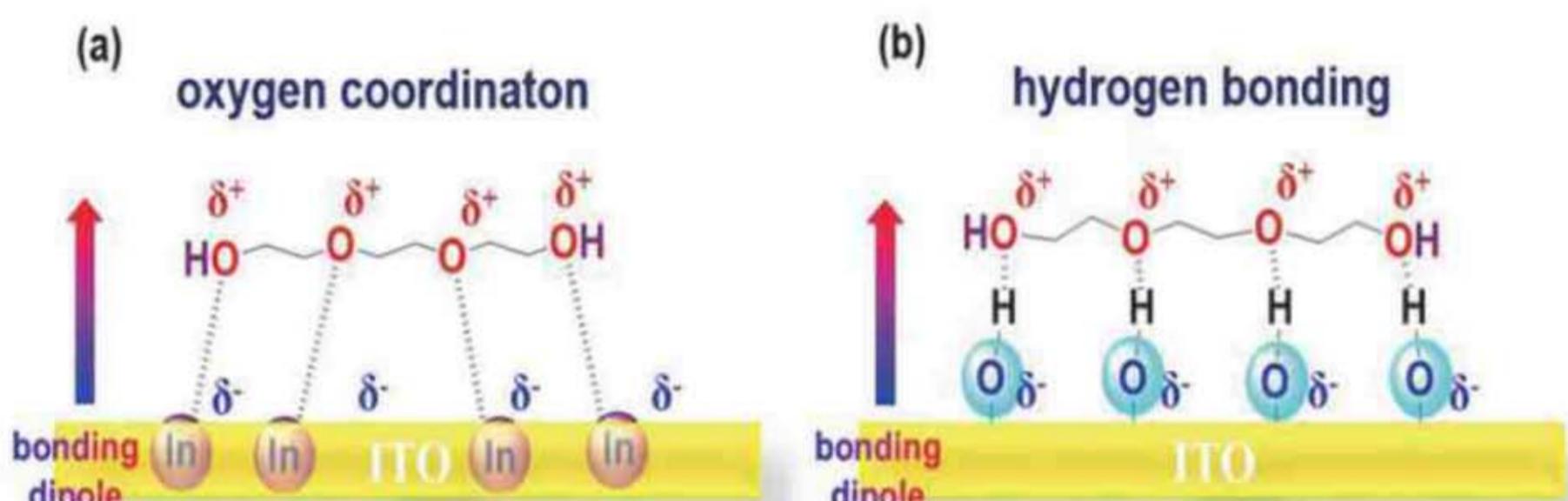
指導教授 鄭彥如 教授

研究重點

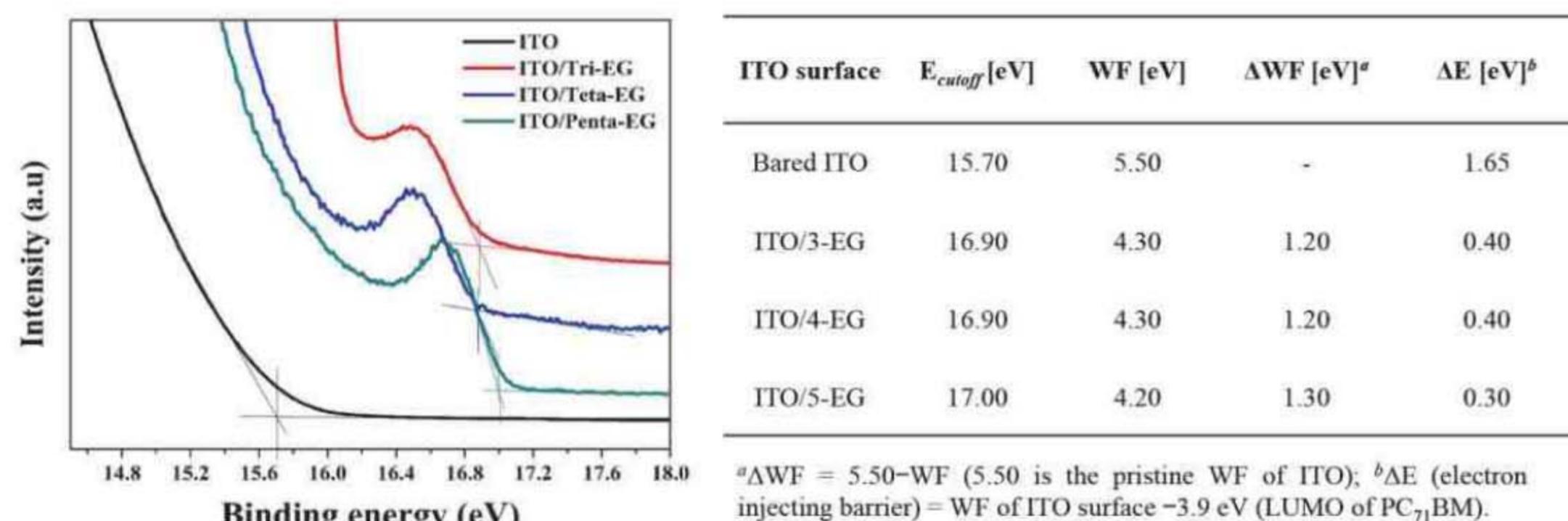
Triethylene glycol (3-EG), tetraethylene glycol (4-EG) and pentaethylene glycol (5-EG) are presented as new cathode modification materials to achieve high-performance inverted-PCPs. By spin-coating from a non-chlorinated solvent, these small molecules can self-assemble on ITO via surface coordination and hydrogen bonding to form an ultra-thin layer. Based on the PBTTT-EFT:PC₇₁BM blend, the bulk heterojunction device using the 5-EG layer exhibited a higher short-circuit current density (J_{sc}) of 15.27 mA/cm², fill factor (FF) of 0.69, and power conversion efficiency (PCE) of 8.46 %. More importantly, this simple and expedited strategy is also demonstrated to be universally effective to various p-type conjugated polymers. The EG oligomers with well-defined chemical structures have the advantages of easy availability, simple processability and good device reproducibility, which are crucial keys for future commercialization using large-scale roll-to-roll production.

研究成果

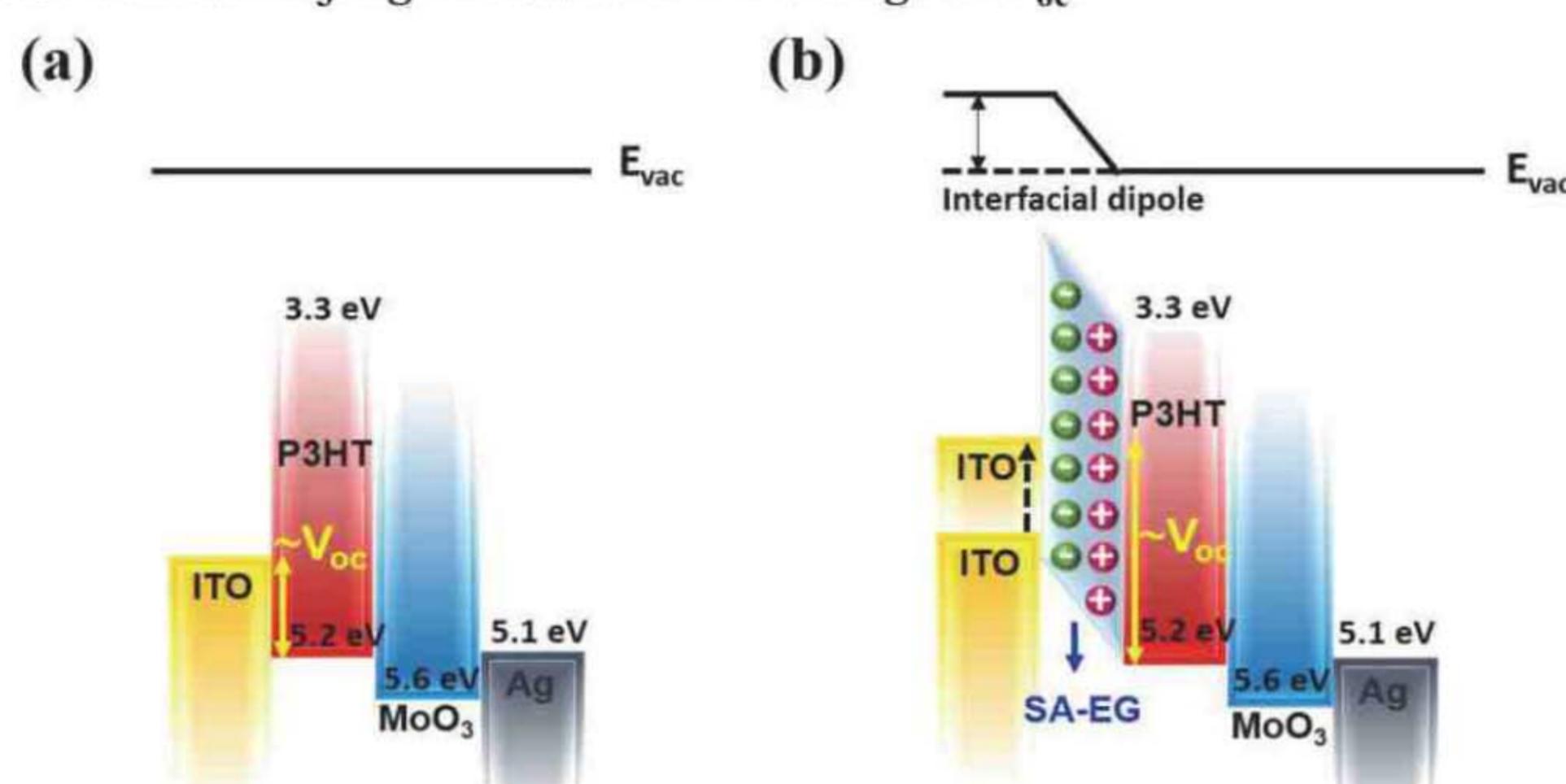
◆ Illustration of a self-assembled 3-EG layer on ITO surface via (a) oxygen coordination and (b) hydrogen bonding mechanisms to induce bonding dipoles.



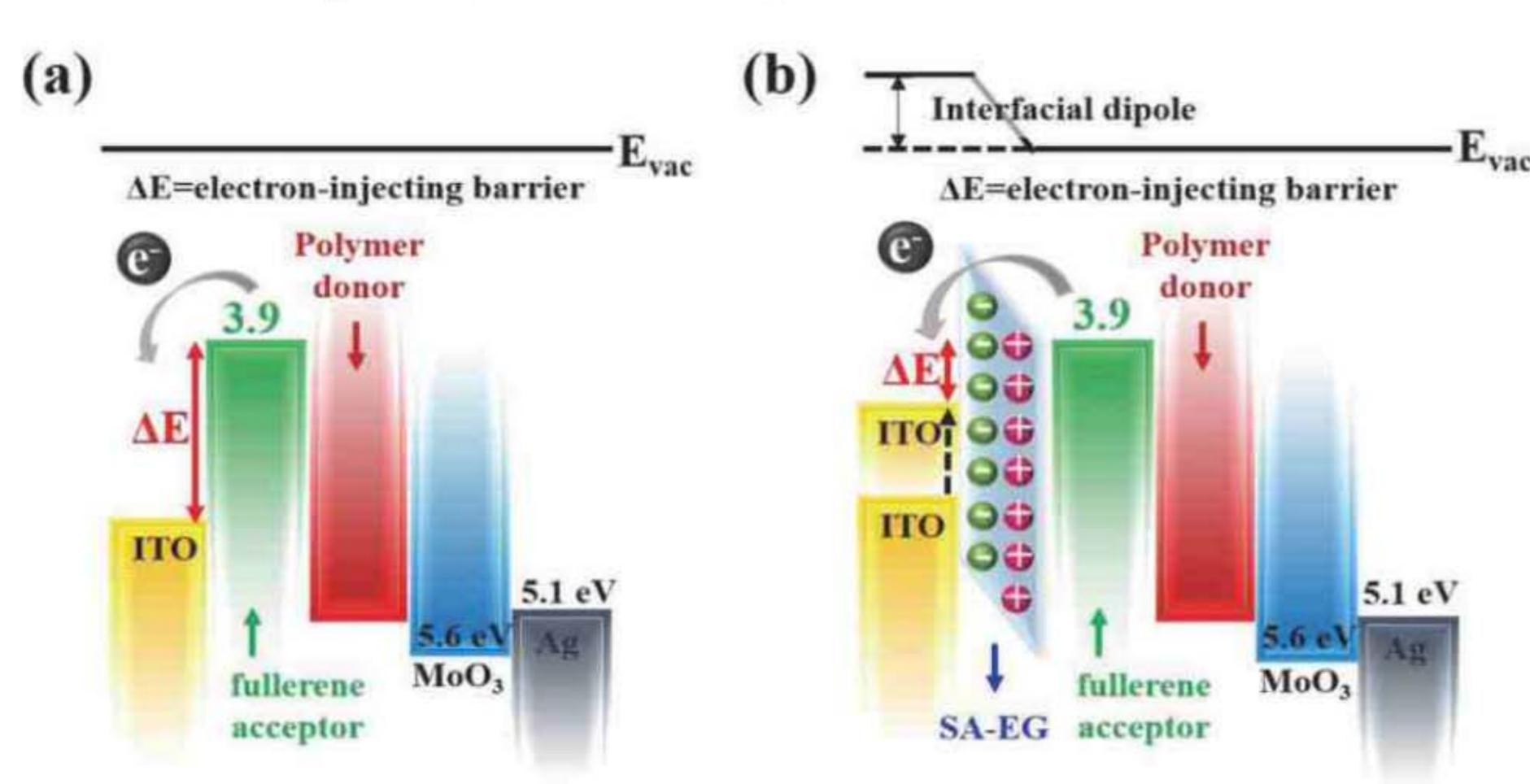
◆ UPS measurements for the ITO, ITO/3-EG, ITO/4-EG and ITO/5-EG surfaces.



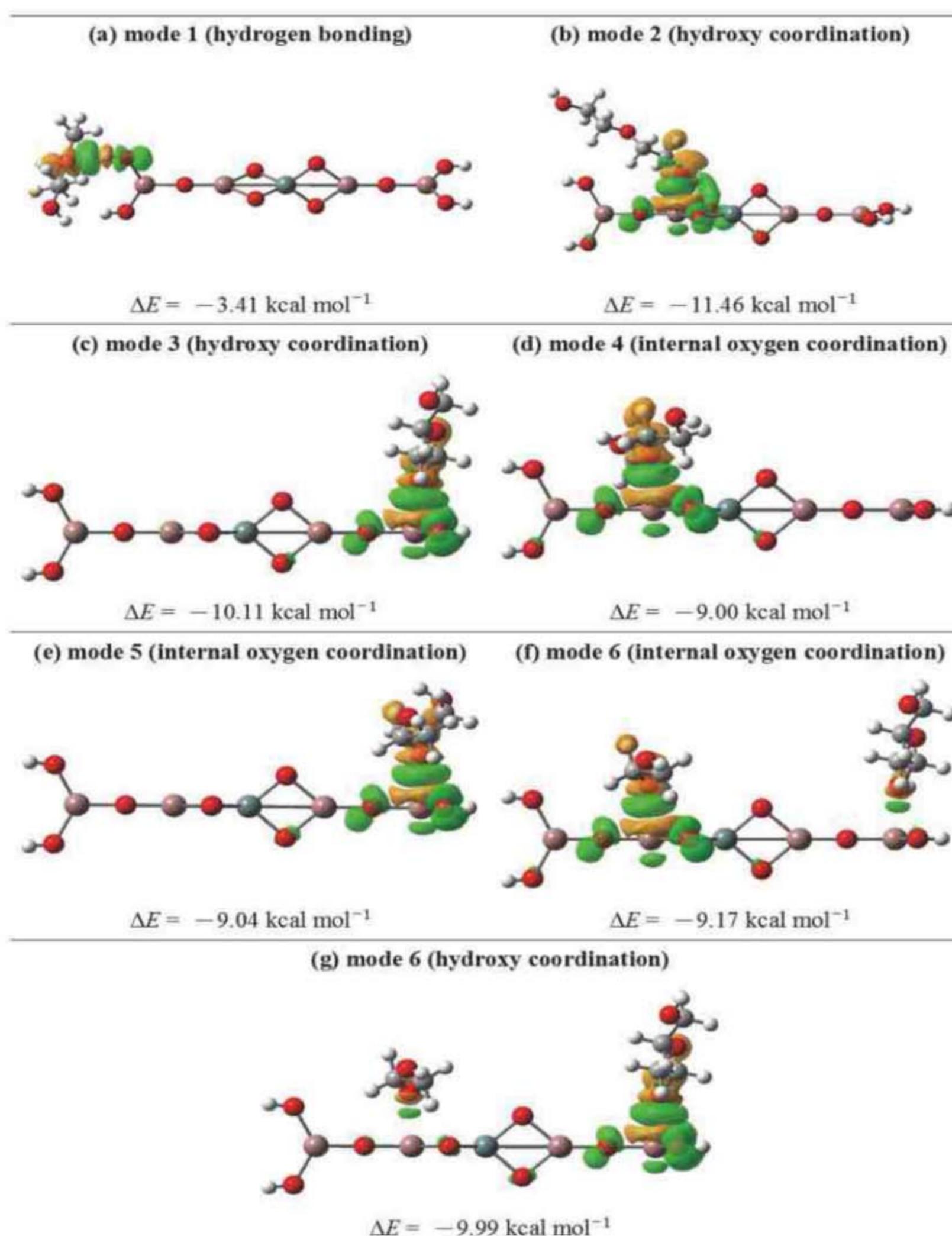
◆ The energy level diagram of the (a) ITO/P3HT/MoO₃/Ag and (b) ITO/SA-EG/P3HT/MoO₃/Ag devices and the change of V_{oc} .



◆ The energy level diagrams of the device (a) ITO/PC₆₀BM:polymer/MoO₃/Ag and (b) ITO/SA-EG/PC₆₀BM:polymer/MoO₃/Ag, and the change of the ITO WF.



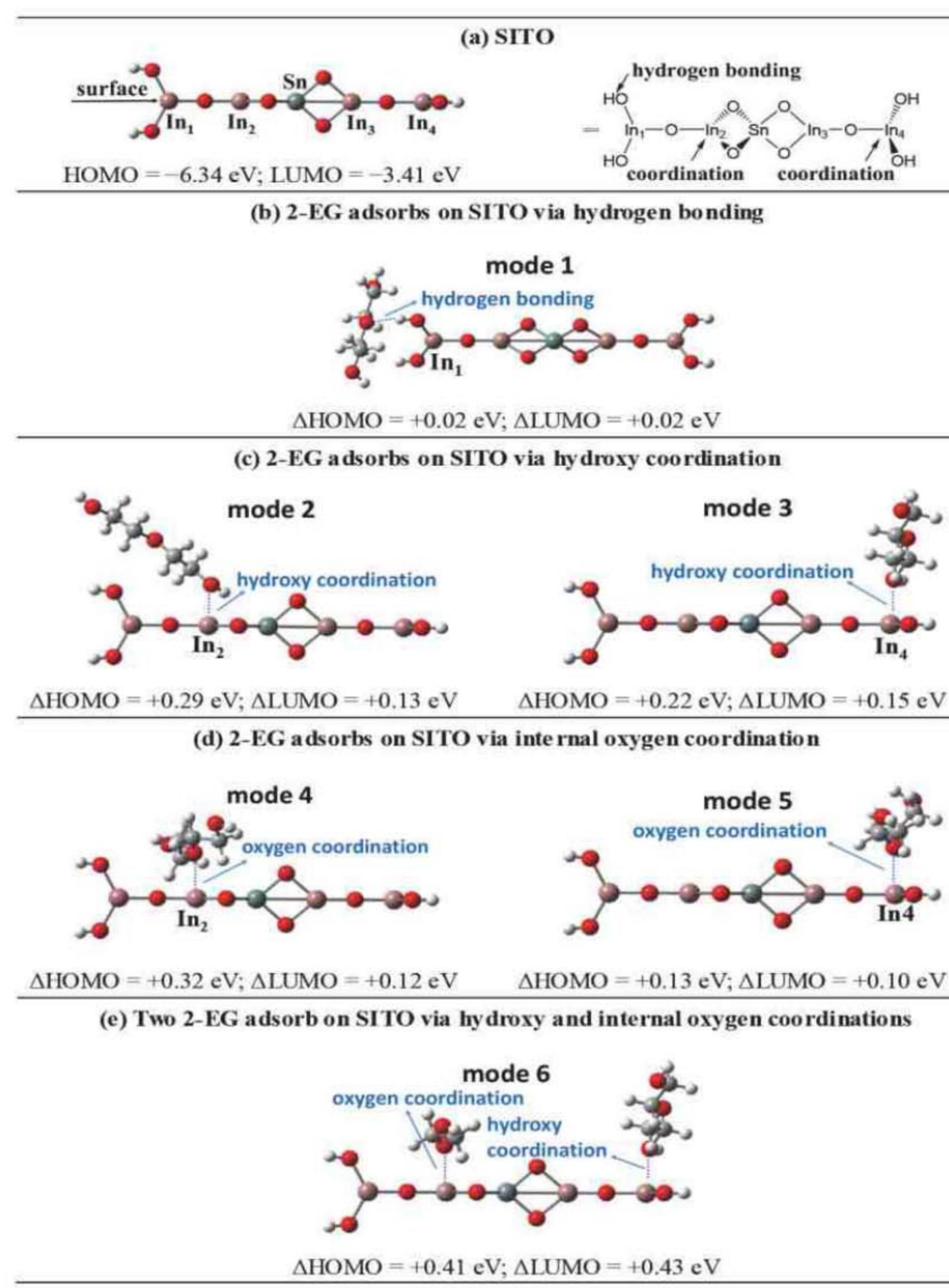
◆ Possible interaction modes for diethylene glycol (2-EG) adsorbing on the simplified ITO surface (SITO) deduced from DFT calculations.



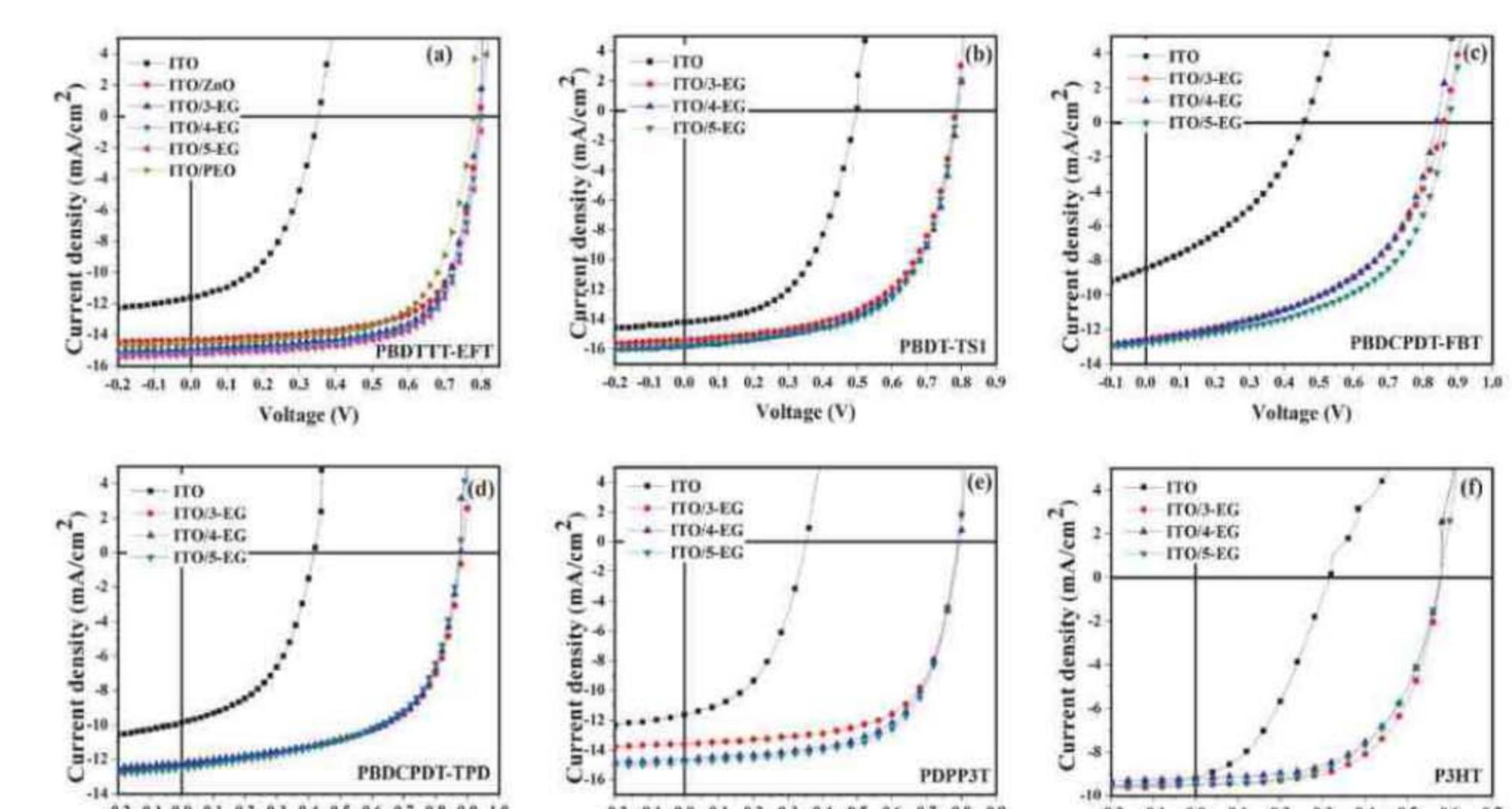
◆ Characteristics of devices with PBTTT-EFT, PBDT-TS1, PBDCPDT-FBT, PBDCPDT-TPD, PDPP3T and P3HT as the polymer donor, respectively.

Polymer donor	Device	V_{oc} [V]	J_{sc} [mA/cm ²]	FF [%]	PCE [%]	R_s [Ωcm^2]	R_{sh} [Ωcm^2]
PBTTT-EFT	1a	0.36	11.63	46.23	1.94	8.4	176.6
	1b	0.80	14.34	68.16	7.82	4.3	629.8
	1c	0.80	14.92	68.20	8.14	4.7	997.4
	1d	0.80	15.09	68.48	8.27	5.1	833.4
	1e	0.80	15.27	69.29	8.46	3.0	951.1
	1f	0.78	14.55	65.46	7.43	4.8	676.3
PBDT-TS1	2a	0.50	14.19	52.61	3.73	6.6	405
	2c	0.78	15.41	59.47	7.15	5.7	890
	2d	0.78	15.80	60.00	7.39	4.0	732
PBDCPDT-FBT	3a	0.46	8.47	38.02	1.48	20.6	129
	3c	0.86	12.58	49.73	5.38	13.0	285
	3d	0.84	12.62	50.91	5.40	11.1	421
PBDCPDT-TPD	4a	0.42	9.89	48.18	2.00	11.2	196
	4c	0.88	12.33	60.49	6.56	6.5	535
	4d	0.88	12.21	60.67	6.52	6.8	406
	4e	0.88	12.48	58.32	6.41	9.7	581
PDPP3T	5a	0.26	14.90	42.45	1.65	5.1	88
	5c	0.66	16.17	62.01	6.62	4.3	416
	5d	0.66	16.02	62.45	6.60	4.3	688
P3HT	6a	0.32	9.19	39.10	1.15	14.8	213
	6c	0.58	9.49	59.23	3.26	7.5	2251
	6d	0.58	9.18	56.91	3.03	7.2	1411
	6e	0.58	9.47	56.01	3.08	10.8	1867

◆ Contours of deformation density contributions (isovalue = 0.0004 au) describing the largest orbital interactions.



◆ J-V curves of the devices using (a) PBTTT-EFT (b) PBDT-TS1 (c) PBDCPDT-FBT (d) PBDCPDT-TPD (e) PDPP3T (f) P3HT as the donor material under AM 1.5G illumination at 100 mW/cm².



◆ Characteristics of the PBDCPDT-TPD-based devices with the 3-EG layer made by spin-coating, drop and immersion methods.

EG processing condition	V_{oc} [V]	J_{sc} [mA/cm ²]	FF [%]	PCE [%]
spin-coating	0.88	12.33	60.49	6.56
drop	0.88	11.68	60.24	6.19
immersion	0.88	11.60	58.96	6.02

研究生活及心得

此次很開心也很感謝中技社能給我這個機會獲得此科技研究獎項，也感謝實驗室老師的指導與支持讓我可以盡情地進行我的研究。在這博士班的期間遇到了很多挫折和瓶頸，總是在堅持和努力下撐過去，我想要得到一個好的成果並非偶然，堅持自己的信念，如果累了就先稍微停下來想一下再繼續前進，也許會為你開出另一條路。