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PEROVSKITE AND ORGANIC PHOTOVOLTAICS AND OPTOELECTRONICS

PEAI - Indeed an Effective Synergistic Modification Material to Improve All Perovskite Tandem Solar Cell Efficiency to Nearly 27%

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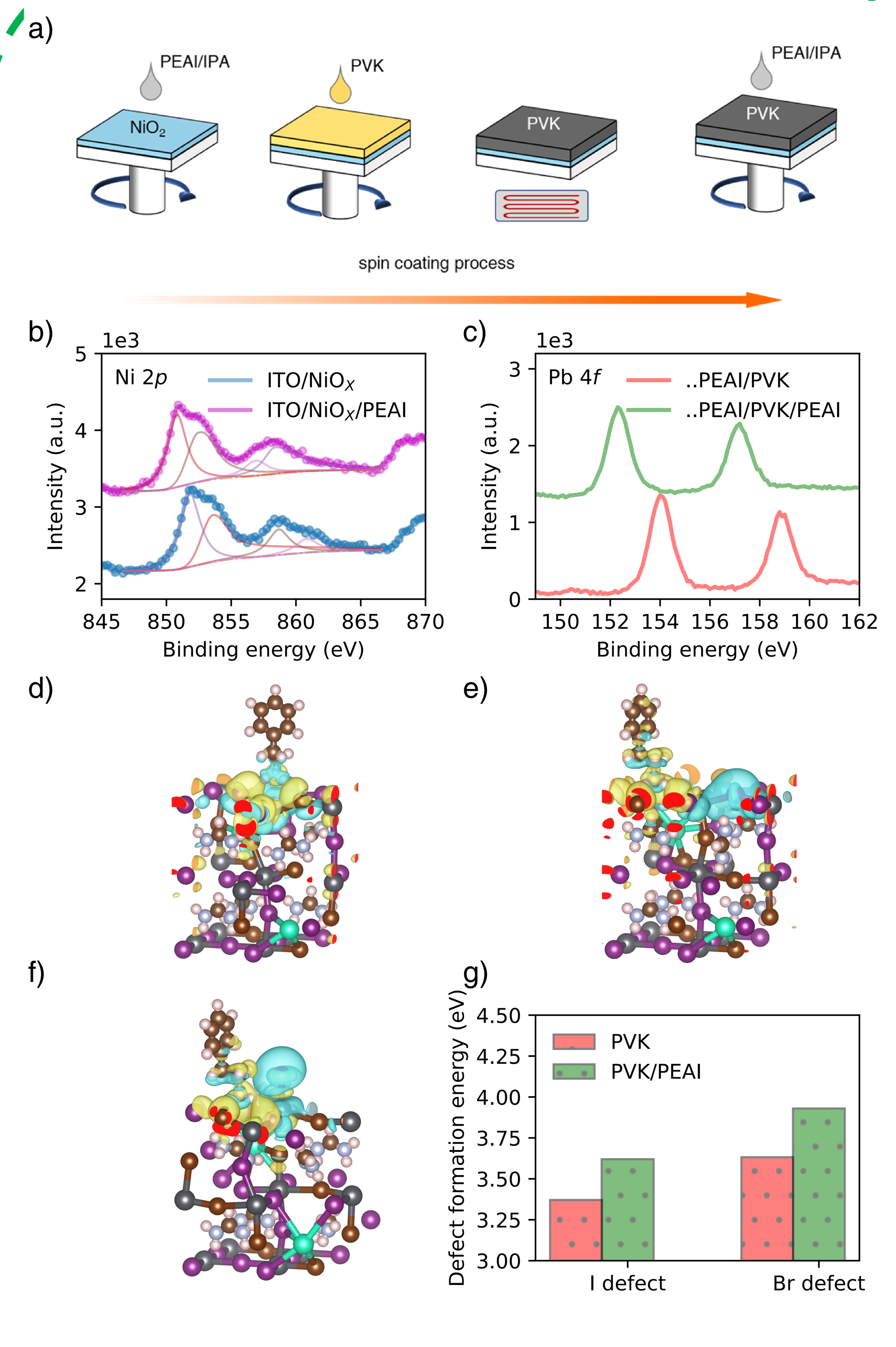
Introduction

All-perovskite tandem solar cells are considered next generation devices that can further improve the utilisation rate of solar energy. Compared to single-junction perovskite solar cells (PSCs), the performance of tandem cells depends on the performance of the top and bottom solar cells. Here, we use a co-modification strategy to introduce PEAI to the top and bottom interfaces of the perovskite film at the same time to improve the performance of the top solar cell. Experimental and theoretical results show that PEAI can not only improve the quality of the perovskite film through the chemical interaction but also reduce the nonradiative recombination in the device. Ultimately, the efficiency of the wide bandgap (1.77 eV) PSCs based on NiO_x reaches 16.5%. At the same time, the performance of the all-perovskite tandem solar cells also reached 26.81% and showed excellent stability.

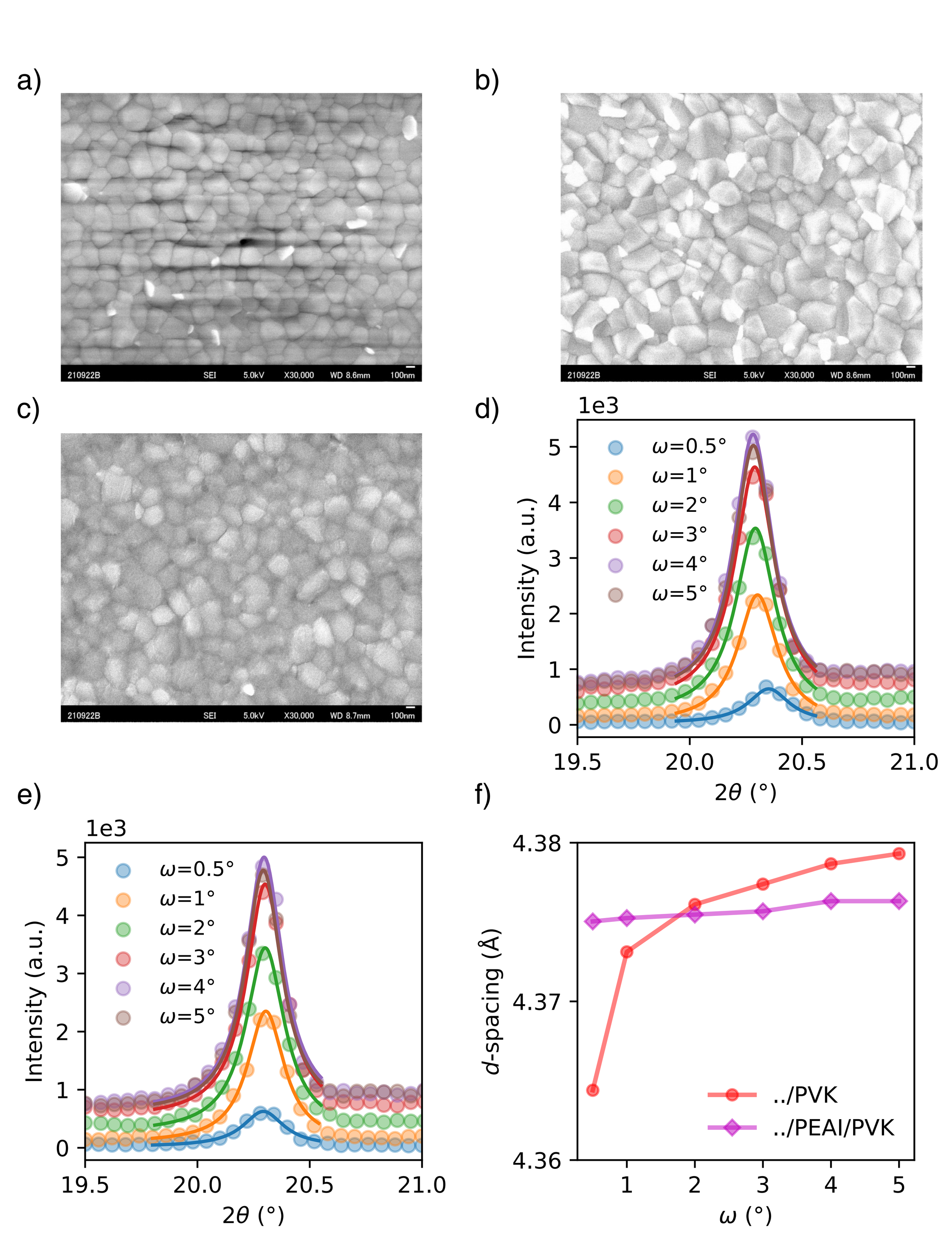
Conclusions

We propose a universal passivation strategy: co-interface collaborative passivation. By introducing PEAI, the quality of the perovskite film was improved, and the bulk nonradiative recombination of the film was reduced. At the same time, the interface connection of the film was strengthened through strong chemical interaction, and the surface defects of the film were passivated, thereby further reducing the interface nonradiative recombination of the device. The DFT results further prove the experimental conclusions. Finally, the efficiency of PSCs based on the co-modification strategy reached 16.5 %, while the efficiency of all-perovskite tandem solar cells reached 26.81 %.

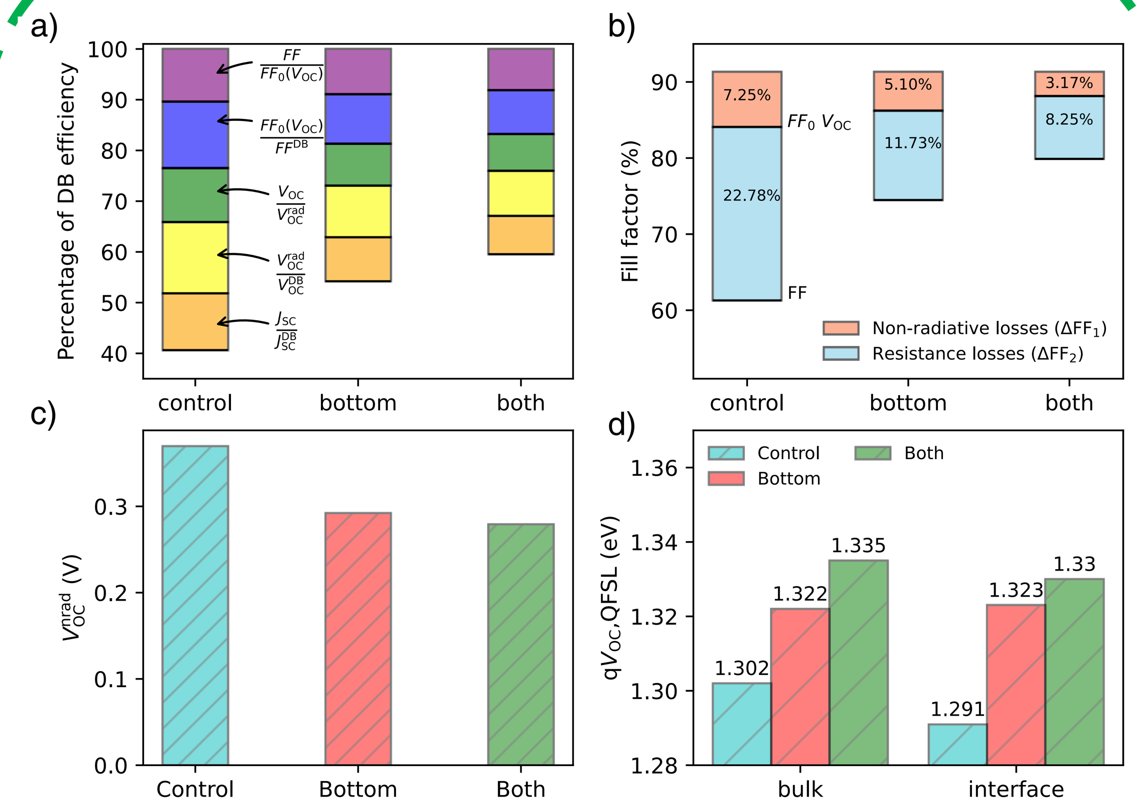
Results and Discussion



(a) Schematic diagram of PEAI co-modification strategy. XPS spectra of the PEAI with (b) NiOx Ni 2p and (c) perovskite Pb 4f. The surfaces for the perovskite with the (d) I-defect, (e) Br-defect, and (f) perfect surface contact with the PEAI. (g) Defect (I-defect and Br-defect) formation energy of the perovskite film with or without PEAI modification.



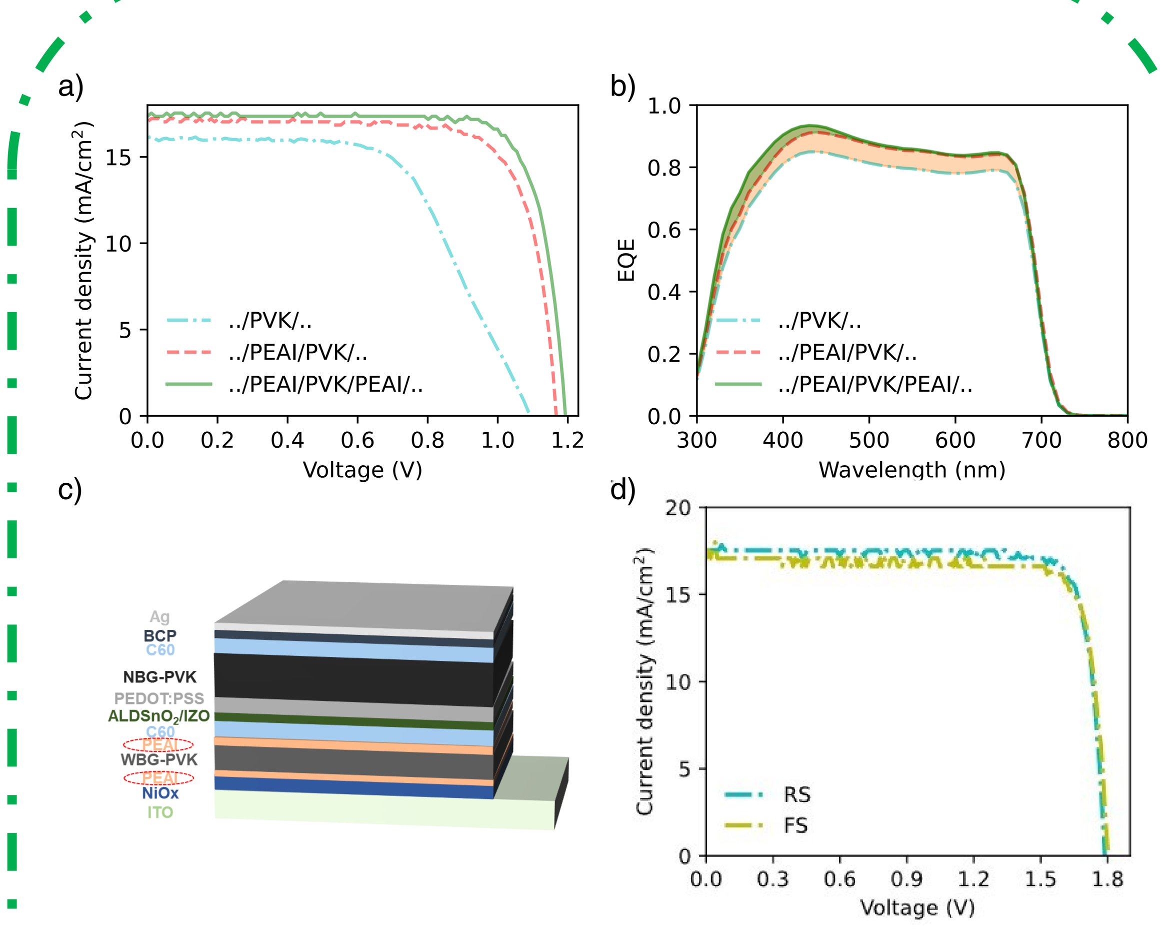
SEM image of the film with the structure of (a) ITO/NiOx/PVK, (b) ITO/ NiOx /PEAI/PVK, and (c) ITO/ NiOx /PEAI/PVK/PEAI. GIXRD patterns of the perovskite films based on c) ITO/ NiOx /PVK and d) ITO/ NiOx /PEAI/PVK. d) *d*-spacing values obtained from (c) and (d) as a function of incidence angle.



(a) Visualization of potential improvement for our devices relative to the ideal DB model, using partitioning of the different losses as introduced in a previous report. (b) The detailed fill factor losses of control and optimized devices. (c) V_{OC}^{nrad} of the device with or without PEAI modification. (d) QFLS test to uncover the nonradiative occurrences in bulk (glass/(PEAI)/PVK/(PEAI)) and interface (ITO/NiOx/(PEAI)/PVK/(PEAI)/C_{60}.

Device	PCE/PCE^{DB} (%)	J_{SC}/J_{SC}^{DB} (%)	V_{OC}^{rad}/V_{OC}^{DB} (%)	V_{OC}/V_{OC}^{rad} (%)	$FF_0(V_{OC})/FF^{DB}$ (%)	$FF/FF_0(V_{OC})$ (%)
Control	40.66	5186	65.90	76.54	89.63	100
Bottom	54.22	62.89	73.10	81.34	91.09	100
Both	59.55	67.14	76.01	83.26	91.89	100

The parameter values of the figures of merit for control device and optimized device



(a) *J-V* curves and (b) EQE spectra of the device with or without PEAI modification. (C) Schematic illustration of the tandem solar cell structure in this work. (D) *J-V* curves of the all-perovskite tandem solar cells with PEAI co-modification.

Device	J_{SC}	V_{OC}	FF	PCE
Control	16.12	1.085	61.3	10.72
Bottom	17.22	1.165	77.1	15.46
Both	17.35	1.192	79.2	16.37

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2. Bi, H., Liu, J., Shen, Q., Hayase, S., *ACS Energy Lett.* 2023, 8, 3852.
3. Bi, H., Liu, J., Shen, Q., Hayase, S., *Adv. Sci.* 2023, 2304790.