



Surface Engineering of PTAA by adding Al₂O₃ interfacial layer for Inverted Perovskite Solar Cell

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Abstract

Perovskite solar cells (PSCs) have shown an enormous potential due to their excellent performance and simple architecture with low temperature and solution processing compatibility. PTAA, with good stability and well-matched energy levels, becomes a superior hole transport candidate for inverted PSC devices, however, its hydrophobic nature brings some processing problems. To address this dilemma, we adopt mesoporous Al₂O₃ nanocrystal as an interface control layer to modulate the wettability of perovskite solution. It has been demonstrated that the Al₂O₃ interfacial layer decreases the surface energies of PTAA and enables a better homogeneous perovskite film with improved coverage and increased crystallite size

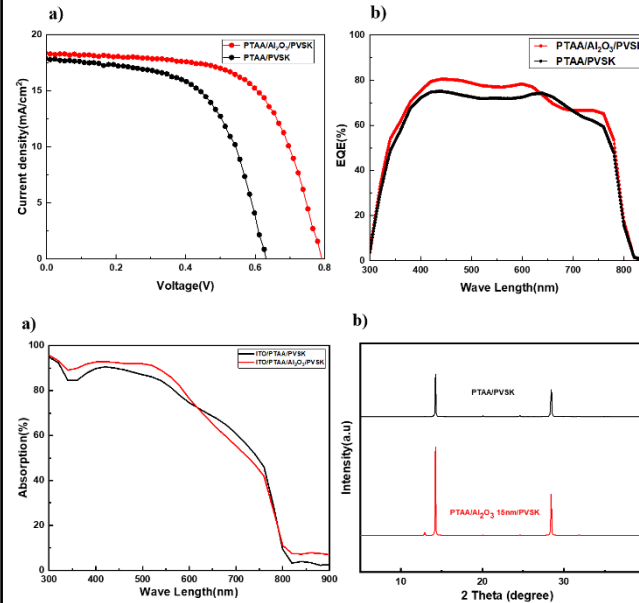
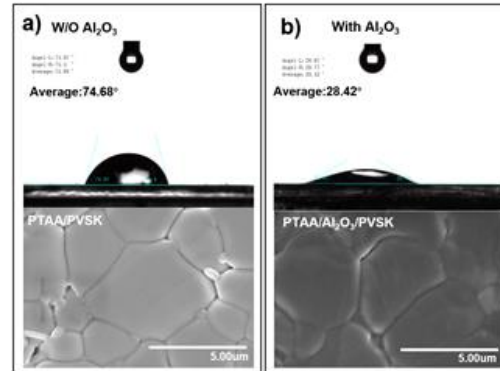
Introduction

Since methylammonium lead iodide (CH₃NH₃PbI₃) was first introduced, the organic-inorganic hybrid lead halide perovskite solar cells (PSCs) have attracted great attention due to a broad range of unique properties.^[1] The p-i-n device has smaller current hysteresis, higher stability and more simpler architecture allowing for low temperature processing,^[2] therefore, it has more development and commercial potential. But there are still many problems in the inverted perovskite layer. PTAA is a very efficient hole transport layer material. However, its strong hydrophobicity leads to poor coverage and morphology of perovskite film.^[3] While the power conversion efficiency (PCE) of the devices are highly dependent on the perovskite film morphology,^[4] crystal structure and quality etc.^[5] The wettability of PTAA underlayer is therefore imperative to be solved.

In this work, Al₂O₃ was used as the interface control layer to modulate the wettability of perovskite solutions.^[7-10] The result shows that the Al₂O₃ interfacial layer decreases the surface energies of PTAA and enables a better homogeneous perovskite film with improved coverage and larger crystallite size.

Conclusion

Our experiments have proved that the introduction of Al₂O₃ does improve the quality of perovskite film formation and further enhance the performance of the device.



	Jsc/mA/cm ²	Voc/V	FF(%)	PCE(%)
With Al ₂ O ₃	18.3	0.79	53%	7.68
W/O Al ₂ O ₃	17.8	0.62	57%	6.58

Results and Discussion

To illustrate the impact of Al₂O₃ on the wettability of PTAA, we evaluated the surface energies of the films by means of water contact angle measurements. As shown in Fig1, it is obvious that the contact angle of the as-deposited PTAA decreased from 74.68° to 28.42° with Al₂O₃ modification, indicating that the hydrophobic surface was translated to hydrophilic. The low surface energy enables the facile deposition of perovskite film, and the quality of perovskite films was further examined with a scanning electron microscope (SEM). An obvious conclusion can be drawn that the perovskite layer deposited on Al₂O₃ has a more uniform morphology with larger grain size and decreased pinholes. Larger grain size means better film formation and lower defect state density, which are beneficial to improve the performance of PCSs, especially in terms of reducing non-radiative recombination.

Absorption spectra of the perovskite film was measured to study the effect of Al₂O₃ layer on optical characteristics. As shown in Fig. 2a), the perovskite films deposited on Al₂O₃ has higher absorption in the wavelength of 350-600 nm. XRD was further applied to investigate the crystal structure of perovskite films, and the result is shown in Fig. 2b). It is found that the Al₂O₃ treated sample exhibits a stronger intensity diffraction peak, reflecting the improved film crystallinity. Both test results show that the introduction of the Al₂O₃ interface layer has indeed improved the crystallization and film-forming effects of the perovskite, and improved the absorption efficiency of the perovskite in the short-wave band. This also supports the test results of the J-V curve of the final battery device. To evaluate the modification effect of Al₂O₃ on the photovoltaic performance, a typical inverted planar heterojunction structure was employed as the solar cell device. The J-V, EQE curves and detailed photovoltaic parameters of the devices are shown in Fig. 3 and Table I. The device with Al₂O₃ interfacial layer exhibited an enhanced efficiency, which is ascribed to the improved crystallinity and morphology. It can be clearly seen from the test results of the J-V curve that the introduction of the Al₂O₃ interface layer significantly improves the Voc of the device, which can be explained by better interface transmission characteristics. In addition, it can be seen that the Jsc of the device has also been slightly improved, which can also be explained by the introduction of the Al₂O₃ interface layer, which improves the quality of the perovskite film.

According to the table, the fill factor of the device incorporating the Al₂O₃ interface layer is lower, which is due to the poor conductivity of Al₂O₃, which leads to an increase in series resistance. However, due to the improvement of Al₂O₃ on the quality of perovskite film formation, the parallel resistance of the device is significantly increased. The final device efficiency is higher than the comparison device.