Rough surface texture of high haze FTO improves the short circuit current density of Perovskite solar cells

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Perovskite solar cells (PSCs) have attracted much attention because of the fast progress of their power conversion efficiency (PCE), from 3.8% to 25.7% in the past decade.[1] To fabricate high-efficiency PSCs, high short circuit current density (J_{sc}), high open circuit voltage (V_{oc}) and high fill factor (FF) should be achieved at the same time. However, it is found that the development of the J_{sc} is much more difficult than the V_{oc} and FF in high-performance PSCs. The J_{sc} of the optimized PSCs usually keeps very similar values compared to the control devices, even though V_{oc} shows great improvement.[2]

We believe that the defect density is low enough in high-efficiency PSCs, which has a minor influence on the J_{sc} because of the built-in electric field under the short circuit condition. Therefore, it is necessary to improve the J_{sc} through the consideration of the optical process. The anti-reflection coating is one of the most useful techniques to improve the J_{sc} of solar cells which can reduce the reflection loss of the Air/glass surface. However, the reflection loss from the fluorine doped tin oxide (FTO)/perovskite interface is also serious in the PSCs, which can not be solved through the anti-reflection coating. Therefore, the selection of suitable FTO glass substrates is very important for the fabrication of high-efficiency PSCs. In this work, we fabricated PSCs using different FTO glass substrates, including low-haze FTO (L-FTO) and high-haze FTO (H-FTO).

The H-FTO substrate has a larger grain size and rougher surface texture than that of the L-FTO substrate. Figure 1 (a) and (b) presents the transmittance of the FTO substrates and current density-voltage (J-V) curves of the PSCs fabricated based on the L-FTO and H-FTO. H-FTO shows lower transmittance in the region of 350 nm to 700 nm, but higher transmittance in the region of over 700nm than that of L-FTO. Interestingly, PSCs fabricated on the H-FTO substrates have much higher PCE than that of the L-FTO-based PSCs. The PCE of H-FTO based device is 21.0 % (Jsc is 31.10 mA/cm^2, V_{oc} is 0.848 V, FF is 0.796). On the other hand, the PCE of L-FTO base device is 17.6 % (Jsc is 27.16 mA/cm^2, V_{oc} is 0.834 V, FF is 0.777). There is a noticeable improvement in J_{sc} when PSCs are fabricated using H-FTO. The mechanism of the J_{sc} improvement is due to the reduction of the optical loss through the anti-reflection effect of the rough surface texture of H-FTO, which will be detailed discussed in the presentation.

In conclusion, H-FTO substrates with rough surface texture should be considered as the substrates for PSCs with high PCE.

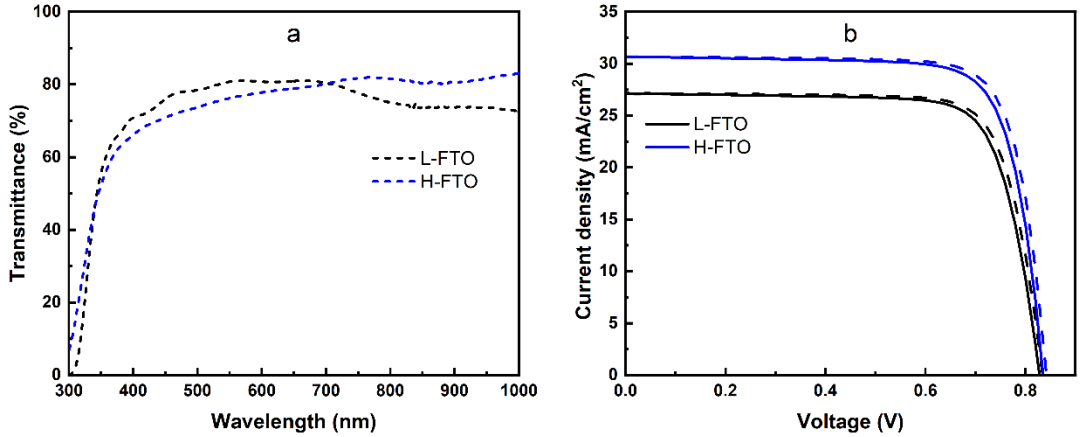

Figure 1 (a) Transmittance of the L-FTO and H-FTO substrates, (b) Comparison of the J-V curves of the PSCs fabricated on different FTO substrates.

References:

[1] NREL Best Research-Cell Efficiency Chart. [https://www.nrel.gov/pv/cellefficiency.html]
[2] F. Li, X. Deng, F. Qi et al. J. Am. Chem. Soc. 2020, 142, 47, 20134–20142.