Study of Charge Recombination and Lattice Strain at the Interfaces of Tin-Based Perovskite Solar Cells

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The organic-inorganic hybrid lead halide perovskite (LHP) material has attracted a lot of attention in the photovoltaic field due to its excellent photoelectric characteristics. Among them, tin-based perovskites (Sn-PVK), with their narrow bandgap and non-toxic, are garnering much anticipation. Currently, the power conversion efficiency (PCE) of Sn-PVK solar cells has been increased over 15%, [1,2] but there is still a gap compared to that of the lead-based perovskite solar cells (over 26%). To further improve the efficiency of Sn-PVK solar cells, understanding the charge carrier recombination and extraction at the interface is crucial. In this study, we utilized time-resolved photoluminescence (TRPL) and transient photovoltage (TPV) techniques to analyze the charge carrier dynamics at the interfaces. Additionally, we estimated the lattice strain and defect concentration at the interface using techniques such as grazing-incidence X-ray diffraction (GIXRD) and capacitance-voltage (C-V) measurements. As shown in Fig.1(a), we measured the PL decays at the Sn-PVK/ETL and HTL/Sn-PVK interfaces by controlling the excitation light to be incident from the FTO side (bottom) and the PVK side (top), respectively. We observed that the PL decay lifetime where excitation light incident from the PVK side is significantly shorter than that from the FTO side, suggesting that the defects at the Sn-PVK/ETL interface is more significant than that at the HTL/Sn-PVK interface. We speculate that this phenomenon is caused by rapid crystallization on the upper surface of Sn-PVK thin film [3]. Next, to further evaluate the Sn-PVK/ETL interface, we passivated the ETL interface and used TPV to measure both the passivated and non-passivated samples. As a result, the carrier recombination lifetime of the passivated samples was significantly longer than that of the non-passivated samples. This is consistent with the open circuit voltage (Voc) increase after passivation. Additionally, through GIXRD (Fig.1(b)) and C-V techniques, we found that the strain and defect concentration at the Sn-PVK/ETL surface are higher than those in the bulk, and this phenomenon gradually alleviates with interface passivation.

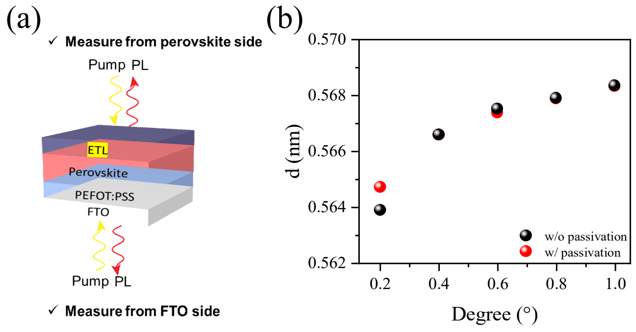

Figure 1. (a) Schematic diagram of TRPL measurement configuration, (b) The lattice constant varies with the grazing incidence angle.

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