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# Synthesis and Structural Characterization of $SnO_2$ Electron Transport Layer in Perovskite Solar Cells

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Energy crisis and environmental pollution become the problems that more and more researchers focus on, and perovskite solar cells have attracted most interesting due to their high-power conversion efficiency (PCE) of over 20% [1]. $TiO_2$ is usually utilized as electron transporting layer for perovskite solar cells, but its high synthesis temperature of 450 °C has limited its applications in flexible electronics. In comparison to $TiO_2$, $SnO_2$ can be synthesized through low temperature solution process and exhibit similar or even better electrical and optical properties. In this study, we synthesize $SnO_2$ by spin-coating followed by thermal treatment at 200 °C and study its structural and photoelectrical properties.

Figures 1a-b demonstrate schematic structure and energy band diagram of a perovskite solar cell, respectively. For the fabrication of a solar cell, fluorine doped tin oxide (FTO) glass substrate was firstly cleaned and treated with $O_2$ plasma to improve wettability. $SnO_2$ was then synthesized on the surface of the FTO substrate by spin-coating $SnCl_4{\cdot}5H_2O$ precursor at 4000 rpm for 20 s, followed by thermal treatment at 200 °C for 30 min. Then, perovskite $CH_3NH_3PbI_3$ and thiophene copolymer **P1** as hole transporting layer [2] were formed on top of $SnO_2$ layer by spin-coating successively. At the end, the sample was taken into a thermal evaporation chamber, where Ag electrode was deposited. Surface morphology of the films was characterized by scanning electron microscopy (SEM, Hitachi S-4800). Current-voltage (*J-V*) curves of solar cells were tested under 100 mW/cm$^2$ illumination of AM 1.5G with a Newport solar simulator through a Keithley 2420 source measurement unit [3].

As shown in Figure 2a, a compact $SnO_2$ nanocrystalline film is formed on the FTO substrate with a thickness of circa 30 nm (Figure 2c). Figure 2b shows high quality perovskite $CH_3NH_3PbI_3$ film with relatively large grains and excellent surface coverage is coated on the top of the $SnO_2$ layer. As given in Figure 2d, short-circuit current density ($J_{SC}$), open-circuit voltage ($V_{OC}$), fill factor (FF) and PCE of the perovskite solar cells are 9.22 mA/cm$^2$, 1.05 V, 65.01%, and 6.27%, respectively. This indicates that $SnO_2$ film can be successfully synthesized by low temperature solution process to replace $TiO_2$ or organic PEDOT/PSS as electron transporting layer for perovskite solar cells, and the PCE can be improved by optimizing parameters of solution process [4].

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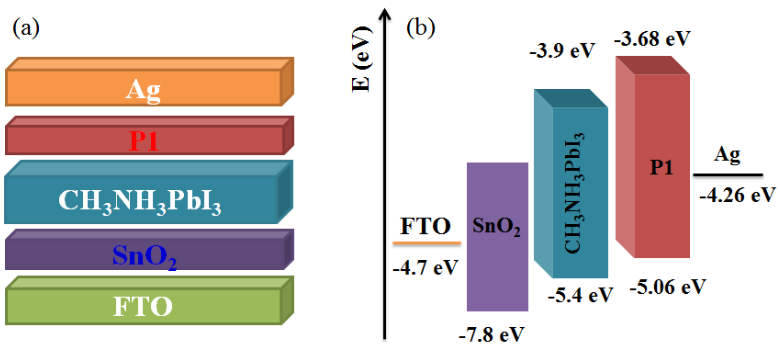


**Figure 1.** Schematic structure of a perovskite solar cell (a) and corresponding energy band diagram (b).

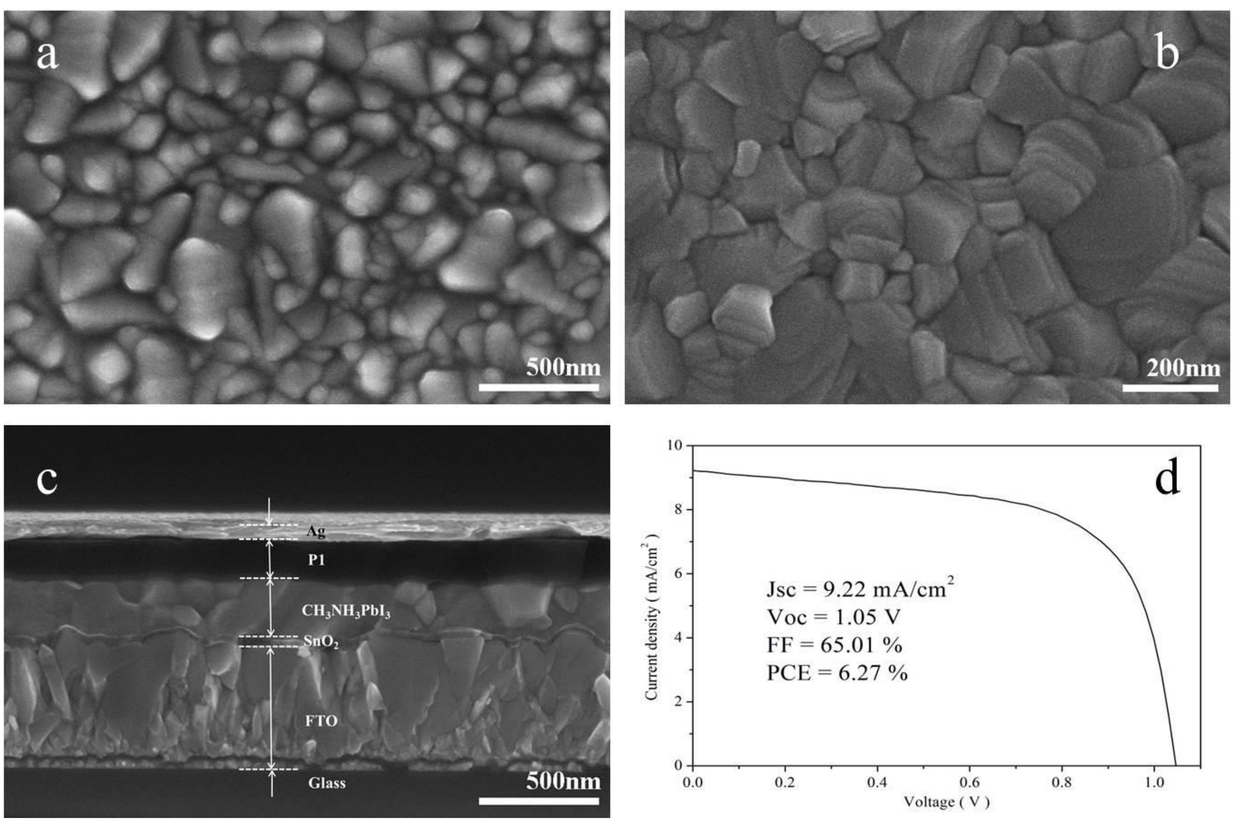


**Figure 2.** Top-view SEM images of $SnO_2$ film coated on FTO substrate (a) and perovskite $CH_3NH_3PbI_3$ film coated on the $SnO_2$ film (b). Cross sectional SEM image (c) and J-V curve (d) of the perovskite solar cell.