High-Efficiency Perovskite Solar Cells Prepared by Low-Temperature Solution-Process

Yen-Tung Lin, Shih-Hsuan Chen, Ming-Chung Wu*

Department of Chemical and Materials Engineering, Chang Gung University, Taiwan
*E-mail address: mingchungwu@mail.cgu.edu.tw

1. Introduction

With the shortage of energy, developing the alternative energy sources becomes an important issue. Solar energy is considered as one of the most important alternative energy source because it is inexhaustible. Among many types of solar cells, the metal halide perovskite solar cells (PSCs) is the most promising solar cells due to its high solar-to-electric power conversion efficiency (PCE) [1]. The PCE of PSCs has rapidly increased from 3.8% to 22.7% since 2009 [2]. The high-efficiency PSCs typically required high-temperature-annealed (over 450 ℃) TiO_2 (HT-TiO_2) as hole blocking layer (HBL) [3]. However, the high-temperature process often limits the application in flexible solar cells and costs more energy. In this regard, we synthesized very fine TiO_2 nanoparticles under 150 ℃ (LT-TiO_2) as HBL material and the spray-coating method was employed for the deposition of LT-TiO_2. In this study, all the fabrication processes were under low temperature. We investigated the crystal structure, and surface morphology of our HBL, and the correlation between the interface of the HBL and perovskite active layer. Finally, we successfully developed PSCs without the need of high-temperature annealing process and obtained higher PCE than the typical PSCs which were under high-temperature process.

2. Result and Discussion

The LT-TiO_2 nanoparticles were synthesized by non-hydrolytic sol-gel method. Firstly, 2.0 mL $TiCl_4$ (99.9%) was added into a beaker containing 8.0 mL of anhydrous ethanol in the ice bath. After coolling the solution down to room temperature, 40.0 mL of anhydrous benzyl alcohol (99%) was added to the previous solution and then heated to 85℃ for 12 hours. The product, fine LT-TiO_2 nanoparticles, were then precipitated and dissolved into anhydrous ethanol (6.0 mg/mL), and the appropriate amount of titanium diisopropoxide bis(acetylacetonate) (15 μL/mL) was added directly. Finally, we obtaind the colloidal solution which contained the dispersion of LT-TiO_2 nanoparticles.

In Fig. 1(a), the X-ray diffraction pattern of LT-TiO_2 nanoparticle can be assigned to anatase TiO_2 (JCPDS Card No. 21-1272). The LT-TiO_2 layer was prepared by spray-coating the colloidal solution followed by thermal treatment at 150 ℃ for 30 minutes. In order to compare with typical planar PSCs which required high-temperature annealing process for the HT-TiO_2 HBL, we prepared the HT-TiO_2 by spin-coating a Ti precursor solution, titanium isopropoxide (TTIP, > 97%), in ethanol with the addition of 2.0 M HCl solution and then sintered at 550 ℃. The perovskite active layer was spin-coated on the LT-TiO_2 and HT-TiO_2 layer, respectively. Next, the spiro-OMeTAD solution was spin-coated on the perovskite active layer. Finally, silver electrode was vapor deposited on device surface with 0.09 cm^2 active area. Fig. 1(b) shows the configuration of overall PSCs. Fig. 1(c) shows the *J-V* curve characteristics of perovskite solar cells. The V_{oc} and J_{sc} of LT-TiO_2 are higher than HT-TiO_2. The PCE of the champion device with LT-TiO_2 is 15.08%.

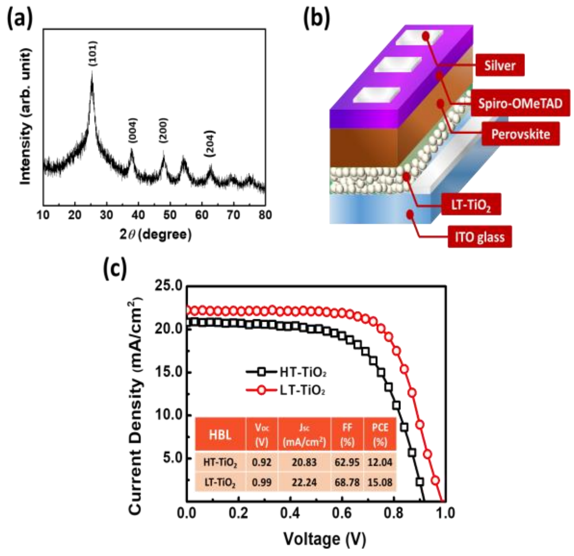

Fig. 1 **(a)** X-ray diffraction pattern of LT-TiO_2 nanoparticles. **(b)** The schematic diagram of PSC structure. **(c)** The *J-V* curves of the PSCs including LT-TiO_2 and HT-TiO_2 layers.

3. Conclusions

In summary, we successfully fabricated LT-TiO_2 layer as the HBL of PSCs by the spray-coating method. After optimizing the processing parameters of PSCs, the PCE of the champion device with LT-TiO_2 layer is 15.08%.

Acknowledgments

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