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Ultra-Compact Titanium Oxide Prepared by Ultrasonic Spray Pyrolysis Method for Planar Heterojunction Perovskite Hybrid Solar Cells

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The electron transport layer of planar-heterojunction perovskite solar cells was produced by the ultrasonic spray pyrolysis (USP) of organotitanium precursors and the spin-coating of TiO_2 sol-gel. Although the TiO_2 products prepared from both methods have the same anatase crystal structure, the former route yields an ultra-compact, bulk-like film with reduced defects. Results from the electrochemical impedance spectroscopy measurements reveal the electron transfer resistance through the $TiO_2/CH_3NH_3PbI_xCl_{3-x}$ interface for the titanium oxide prepared by ultrasonic spray pyrolysis (TiO_2-USP) method is lower than that for the titanium oxide prepared by sol-gel (TiO_2-SG) method. Interesting, the TiO_2-USP device exhibits relative low interfacial resistance of charge carrier through the $CH_3NH_3PbI_xCl_{3-x}$/spiro-OMeTAD interface as well. As a result, replacing TiO_2-SG with TiO_2-USP substantially improves the power conversion efficiency from 12.98% to 16.13%, demonstrating the USP is a facile approach to fabricate high-quality TiO_2 for developing high-performance perovskite solar cells.

I. Introduction

In recent years, perovskite solar cells (PSCs) have become a high-potential candidate of hybrid solar cells in the third-generation photovoltaics because the power conversion efficiency (PCE) of such cell increased rapidly and achieved a remarkable record of 22.7% [1]. The organolead halide perovskite compounds were firstly used as photo-sensitizers in liquid-state dye-sensitized solar cells (DSSCs) by T. Miyasaka *et al.* and the solar cell based on $CH_3NH_3PbI_3$ had a moderate PCE of 3.81% [2]. Later on, N.-G. Park *et al.* applied [2,2′,7,7′-tetrakis(*N*,*N*-di-*p*-methoxyphenyl-amine)-9,9′-spirobifluorene] (spiro-

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