Nanocrystalline Silicon Recombination Junction: A Promising Alternative to ITO in Two-terminal Perovskite/Silicon Tandem Solar Cells

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Abstract

The growing demand for more efficient and sustainable renewable energy has accelerated interest in silicon/perovskite tandem solar cells. While crystalline silicon solar cells are widely used due to their cost-effectiveness and reliable performance, their power conversion efficiency (PCE) has saturated at 27.1%, approaching the theoretical efficiency limit. Organometallic halide perovskites, with their tunable bandgap and low-cost processing, have emerged as a complementary material to Si for tandem solar cells, enabling PCEs that surpass the single-junction limits. Since 2015, tandem solar cells combining silicon and perovskite materials have become promising avenue, with recent breakthroughs pushing PCE to a record 34.6%[1]. In the two-terminal (2T) silicon-perovskite tandem architecture, the interface between the top and bottom cells plays a critical role in device performance. A key component at this interface is the tunnel recombination junction (TRJ), which must enable efficient charge carrier recombination with minimal optical and electrical losses. Traditionally, indium tin oxide (ITO) has been used in TRJs[2,3], but it introduces parasitic optical losses and requires additional deposition steps such as sputtering. Moreover, the volatile cost of indium poses a significant challenge to scaling up the use of ITO. To circumvent these disadvantages, doped nanocrystalline silicon (nc-Si) thin films are considered a promising alternative to ITO for TRJs in perovskite/silicon tandem solar cells due to their lower optical losses, tunable electrical properties and more cost-effective compared to ITO[4]. In this study, doped nc-Si is prepared in a capacitively coupled plasma enhanced chemical vapour deposition (cc-PECVD) system after preparing the buffer and electron transport layers (*n*-a-Si) of a silicon heterojunction (SHJ) cell, as shown in Fig.1. The interface between various types of TRJs and the corresponding hole transport layer (HTL) of perovskite top cell was investigated. The current-voltage characteristics of a 2T-tandem cell featuring an nc-Si-based TRJ were found to be comparable to the ITO-based TRJ device, indicating that nc-Si as the TRJ has significant potential to improve tandem cell performance. Therefore, eliminating costly ITO as the tunnel recombination junction and optimizing the interface represent crucial steps towards achieving more cost-effective, high-efficiency tandem solar cells.

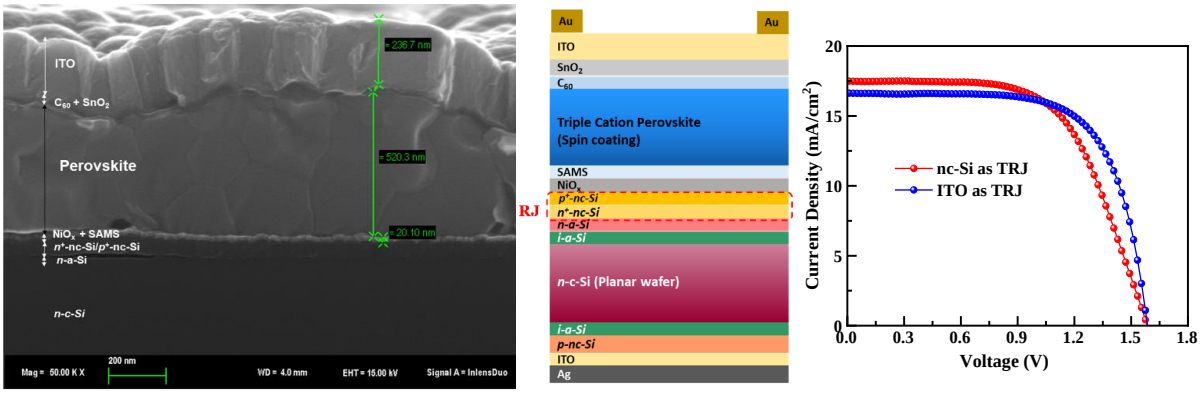

Fig. 1: Schematic diagram, corresponding cross-sectional SEM image and I-V characteristics of the Si/Perovskite tandem cells using nanocrystalline silicon (nc-Si) and ITO as tunnel recombination junctions (TRJ).

References

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