Hole-selective contact engineering for efficient high-bandgap perovskite single-junction and perovskite-silicon double-junction tandem solar cells

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Hybrid organic-inorganic metal halide perovskite solar cells (PSCs) have drawn immense research interest in the past ten years and the certified power conversion efficiency (PCE) has increased to 25.7%,[1] approaching the theoretical limit for single-junction solar cells[2] leaving small headroom for improvements. To overcome the theoretical limit for single junction solar cell, multi-junction perovskite-based solar cells, such as perovskite-silicon[3] tandems have been recognized as a promising strategy as the latest perovskite-silicon tandem cell efficiency record has reached 31.3%.[1]

Despite the huge progress in two junction perovskite silicon tandem solar cells, their efficiencies still lag behind the theoretical limit (~45%).[2] A limiting factor is the performance on the wide-bandgap PSC, with large open-circuit voltage (Voc) loss in the current form.[4] Factors contributing to huge V_{OC} deficits include non-radiative recombination and mismatched energy level between the perovskite and the carrier transport layers.[5]

To reduce the V_{OC} deficit in 1.67 eV (suitable for perovskite-silicon tandem) PSCs in our work, we systematically engineered the properties of hole-selective layers for inverted PSCs. While the best control device demonstrates a V_{OC} of 1.15V. the champion cell with engineered hole-selective contact produced an improved V_{OC} of 1.24V resulting in PCE improvement from 19.7% to 21.0%. A low V_{OC} deficit of 0.43V was obtained. When the 1.67 eV cell was integrated into a perovskite-silicon monolithic tandem solar cell, the best tandem device produced a V_{OC} over 1.90 V and a PCE over 28% on a 1 cm^2. This work demonstrates an effective strategy to reduce the V_{OC} loss in high-bandgap PSCs contributing to high performance tandem device development.

Table 1 Photovoltaic parameters of single-junction PSCs and perovskite-silicon tandem soar cell.

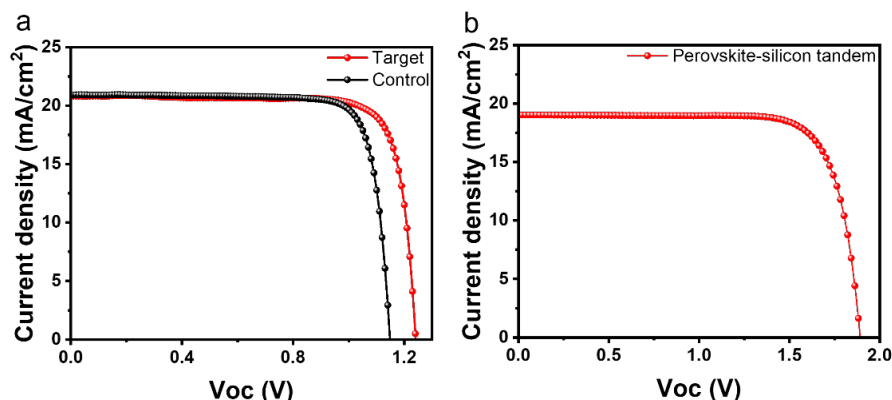|	V_{OC} (V)	J_{SC} (mA/cm^2)	FF (%)	PCE (%)
Single junction control device	1.15	20.9	82.0	19.7
Single junction Target device	1.24	20.8	81.0	21.0
Tandem device	1.90	19.0	78.1	28.1

Figure 1. J-V curve of a) single-junction inverted perovskite, b) double-junction perovskite-silicon tandem solar cells.

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