Efficient Monolithic Perovskite/Perovskite/Si Triple-Junction Tandem Solar Cells

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As we are transitioning to a net-zero-CO_2-emission economy, demand for renewables continue to grow. In particular, solar photovoltaics has been the biggest contributor to this growth and will continue to so do motivating research and development on low cost high performance technology. Perovskite-based multijunction photovoltaic solar cell is a very promising approach to exceed the detailed balance limit of single junction solar cells for high performance low-cost photovoltaics [1].

According to the industry roadmap [2], Si-based tandems will become part of the technology mix starting in 2023. While there is no consensus on which photovoltaic technology will be used for the high bandgap cells, perovskites have the efficiency credentials to be a serious contender for both low-cost high-performance double-junction and triple-junction concepts. The efficiency of the best double-junction perovskite-silicon (Si) tandem solar cell has recently achieved a certified efficiency of 31.3% demonstrating rapid progress [3].Triple-junction perovskite-perovskite-Si tandems (having more headroom for PCE improvement) will likely follow a similar improvement rate when supported by research and development.

Here, we report a 2-terminal triple junction perovskite-perovskite-Si tandem solar cell (Figure 1) with a power conversion efficiency (PCE) of 20.1% and a fill factor (FF) of 86% (Figure 2). This is the second report for perovskite-perovskite-Si tandem since its last report in 2018 with an efficiency of 14.0% [4]. The efficiency reported here is the highest efficiency for this category to date and is comparable with that of the best perovskite-perovskite-perovskite triple-junction demonstrated to-date (Figure 3) noting that the perovskite-perovskite-Si device (1.03cm^2) demonstrated in this work is larger than perovskite-perovskite-perovskite devices reported to-date (<0.1cm^2). In addition, a fill factor of 86% demonstrated here is the highest for double or triple junction perovskite-based tandem reported to date. It is hoped that this work reporting a milestone will inspire further developments for low-cost high performance multi-junction solar cells.

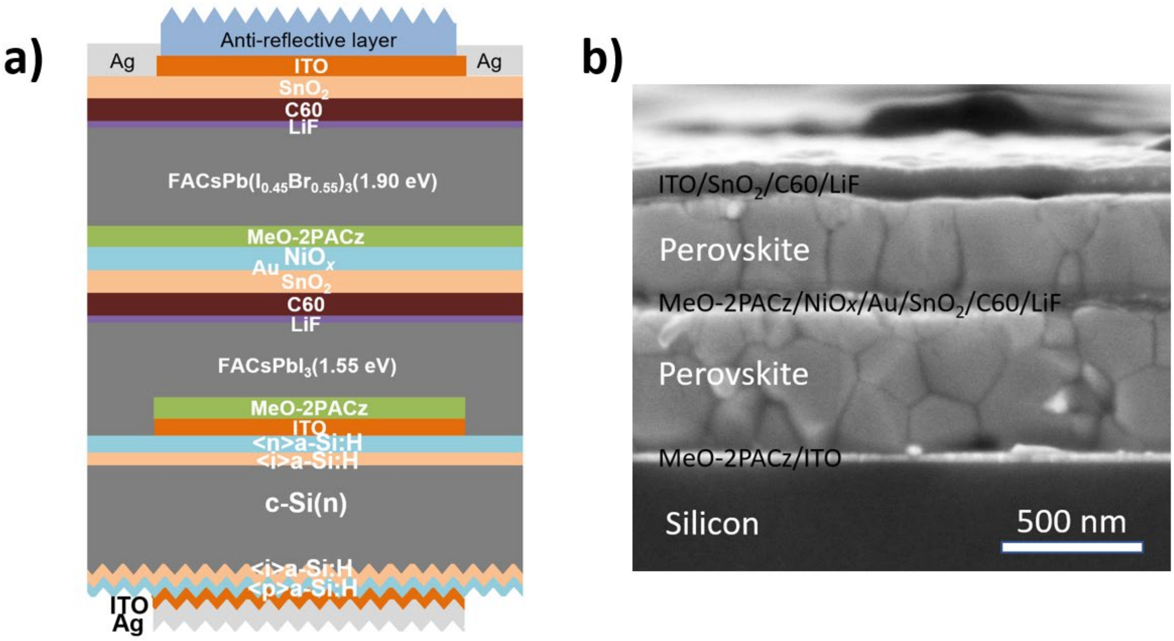

Figure 1 (a) Device structure schematic, (b) cross-sectional scanning electron microscopy (SEM) image of a triple-junction tandem.

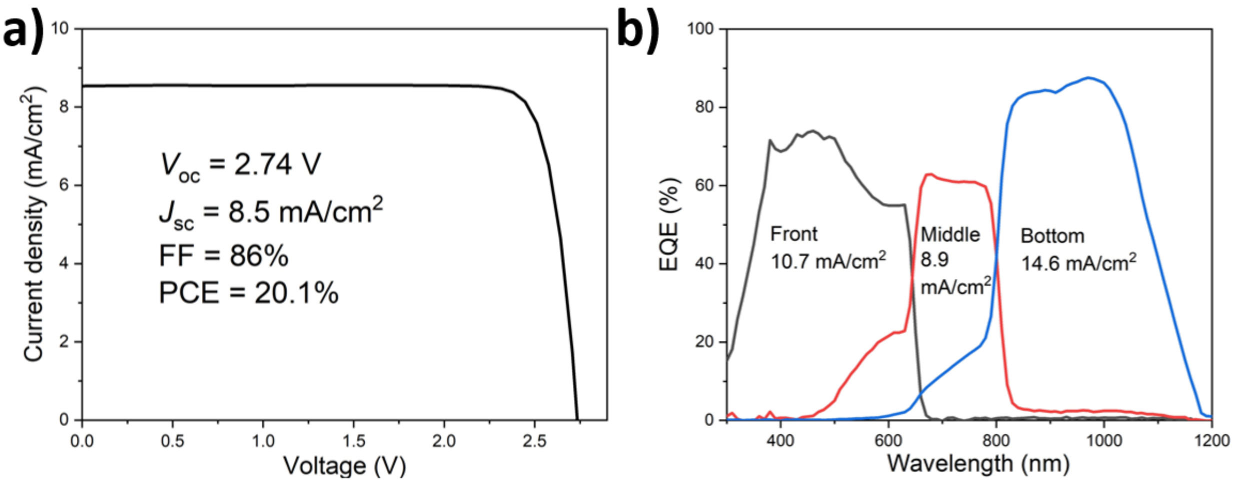

Figure 2 (a) current density-voltage (J-V) curve of the champion device on 1.03 cm2 and (b) external quantum efficiency (EQE) curves (black for high bandgap perovskite; red for mid bandgap perovskite; and blue for low bandgap silicon) of a triple-junction tandem.

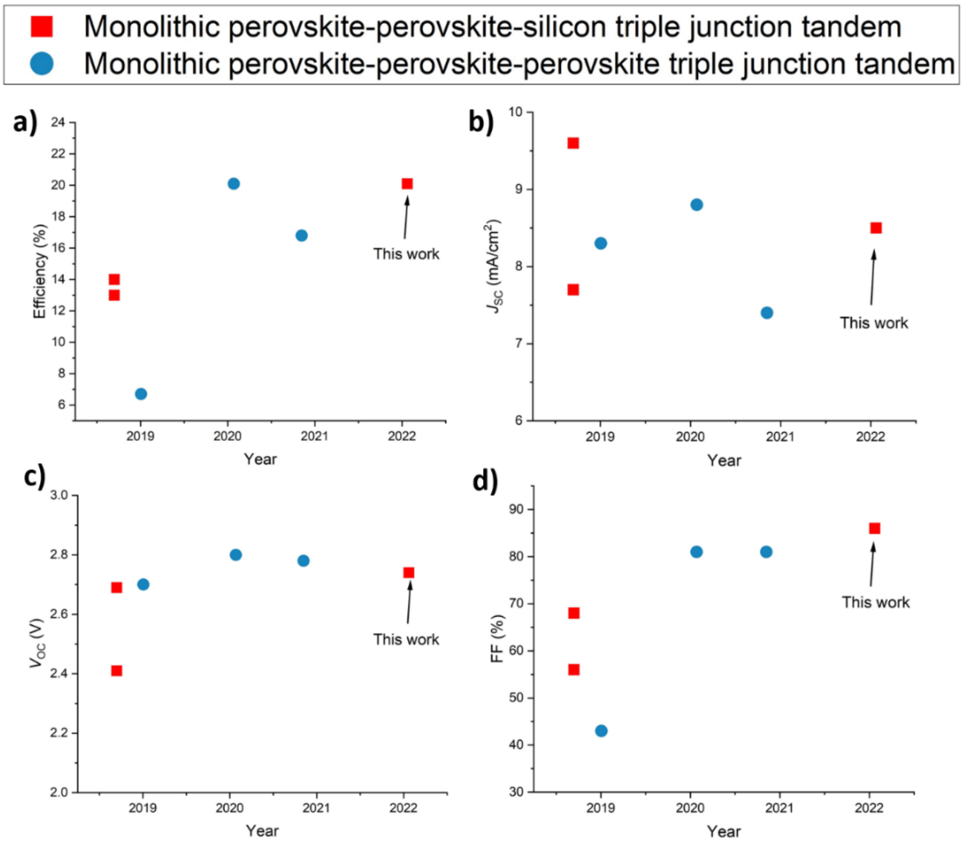

Figure 3. (a) Efficiency, (b) short circuit current density (J_{SC}), (c) open circuit voltage (V_{OC}), and (d) fill factor (FF) of perovskite-based triple-junction tandem solar cells reported in peer-reviewed journal articles to date. [5-8]

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