Area: Perovskite Solar Cells

OPTIMUM PEROVSKITE CELL FOR HIGHLY EFFICIENT PEROVSKITE/SILICON TANDEM SOLAR CELL

Wayesh Qarony, Mohammad I. Hossain, Yuen Hong Tsang*

Department of Applied Physics, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
*Corresponding E-mail: yuen.tsang@polyu.edu.hk

The band-gap compatibility along with other impressive electrical and optical properties of perovskite (band-gap ~1.7 eV) and crystalline silicon (band-gap ~ 1.1 eV) materials make perovskite/silicon tandem solar cell distinctly promising to achieve a very high power conversion efficiencies. A high matched short-circuit current density provided by the top and bottom cells can ensure this efficiency. In this research, an integrated perovskite / silicon tandem solar cell was designed with a total current density close to the theoretical upper limit (46 mA/cm^2) to achieve a power conversion efficiency exceeding 30%. In the first step, a pyramidal textured $CH_3NH_3PbI_3$ perovskite (band-gap ~1.6 eV) top cell, serially connected on the textured and infinite silicon bottom cell, was simulated by three-dimensional (3D) finite-difference time-domain (FDTD) method. Such a tandem cell with relatively higher charge carrier mobility contact and transport layers of IOH and ZnO:Al leads to the enhanced decoupling of light and reduced front reflection losses. Then the tandem device was optimized for a matched short-circuit current density by varying the thickness (from 300 nm to 700 nm) of the perovskite active layer, where the texture period and height were kept constant at 3.0 µm and 2.07 µm, respectively. The solar cell was optimized for a matched short-circuit current density of 20.35 mA/cm^2 at the perovskite absorber layer thickness of 440 nm. This leads to achieve a total short-circuit current density of 40.7 mA/cm^2, where parasitic losses were ignored since they don't contribute to the short-circuit current density. Consequently, a power conversion efficiency of 30.86% can be estimated by considering standard open-circuit voltage and fill-factor for perovskite and crystalline silicon solar cells. Further enhancement is possible to reach by improving the band-gap and open-circuit voltage of perovskite top cell. (This work is supported by Hong Kong PhD Fellowship, The Hong Kong Polytechnic University (grant code: G-YBFR)).

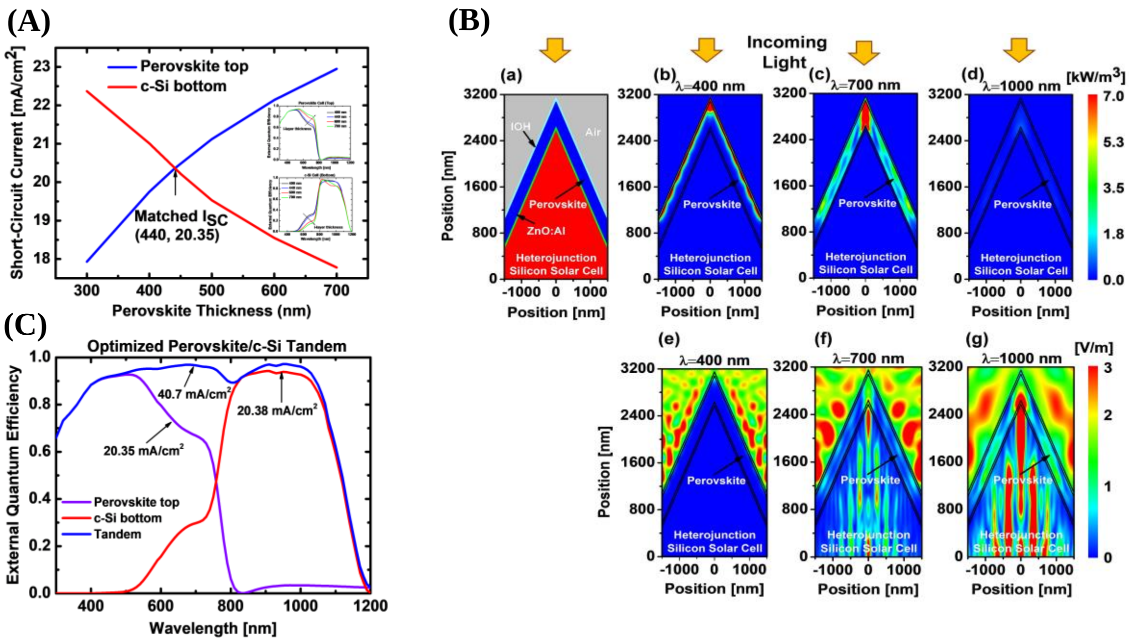

Figure 1: (A): Optimizing perovskite: Comparison of short-circuit current density and external quantum efficiency (insets) for top and bottom cells with the variation of perovskite active layer thickness.
(B): (a) Schematic of simulated perovskite/c-Si optimized tandem solar cell with (b, c, d) power losses and (e, f, g) electric field distributions for different incident wavelengths.
(C): External quantum efficiency plots for perovskite top cell, c-Si bottom cell, and tandem cell along with short-circuit current density achieved from each of them.