Design of Perovskite/Crystalline-Silicon Tandem Solar Cells

S. Altazin[1], L. Stepanova[1], K. Lapagna[2], J. Werner[3], B. Niesen[3,4], S. de Wolf[3], C. Ballif[3,4], B. Ruhstaller[1,2]

[1]Fluxim AG, Technoparkstrasse 2, 8406 Winterthur, SWITZERLAND,

[2]Zurich University of Applied Sciences, Institute of Computational Physics, Technikumstrasse 9, CH-8401 Winterthur, SWITZERLAND,

[3]Ecole Polytechnique Fédérale de Lausanne (EPFL), Institute of Microengineering (IMT), Photovoltaics and Thin Film Electronics Lab, Rue de la Maladière 71, 2002 Neuchatel, SWITZERLAND

[4]Centre Suisse d'Electronique et de Microtechnique (CSEM), Jaquet-Droz 1, 2002 Neuchâtel, Switzerland.

While the efficiency of silicon heterojunction solar cells has surpassed 25%, a novel route to high-efficiency wafer-based solar cells is being pursued with perovskite/silicon tandems. In the monolithic configuration, these tandem cellshave reached 21.2% [1], while 4- terminal measurements are approaching 25% [2] with potential to reach 30% efficiency. In this context we introduce a simulation tool [3] that combines a 3D ray-tracing algorithm with thin film optics to study light interaction with conformally coated layers on planar and textured silicon wafers. We validate the model with experimental data of silicon heterojunction cells. With knowledge of refractive index dispersion data of the involved materials and the measured interface texture as input to the model, the predicted photocurrent and absorption (i.e. EQE) spectra agree very well with the measured results. We then employ the model for designing and optimizing monolithic perovskite/crystalline-silicon tandem solar cells with optional rear-side random pyramid texture and an anti-reflection foil in the front. This concept for monolithic tandems would have the key advantage of allowing the perovskite absorber layer being deposited at high quality on the planar front face of the silicon wafer while still offering efficient light trapping. The simulations predict that the light scattering introduced by the anti-reflection foil mainly enhances the photocurrent of the silicon heterojunction cell by 2.2 mA/cm^2, in good agreement with measured results. Similarly, the random pyramid texture at the rear side of the silicon wafer enhances the photocurrent by 1.4 mA/cm^2. With additional adjustment of some layer thicknesses we conclude that the overall current enhancement with respect to the planar tandem cell can be as high as 3.9 mA/cm^2, corresponding to a relative boost of about 30% in current density and thus expected power conversion efficiency. As the production processes for perovskite/silicon tandems are becoming more reliable and reproducible, the tuning of both top-cell layer thicknesses and light-scattering structures is of major importance. Our light-scattering simulations provide guidelines on how to further improve the efficiency of perovskite/silicon tandem cells and break the efficiency record of single crystalline silicon cells.

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[3] SETFOS 4.3 software with Absorption and Light-scattering modules, Fluxim AG, Switzerland