Development of a novel recombination junction for perovskite–silicon tandem solar cells

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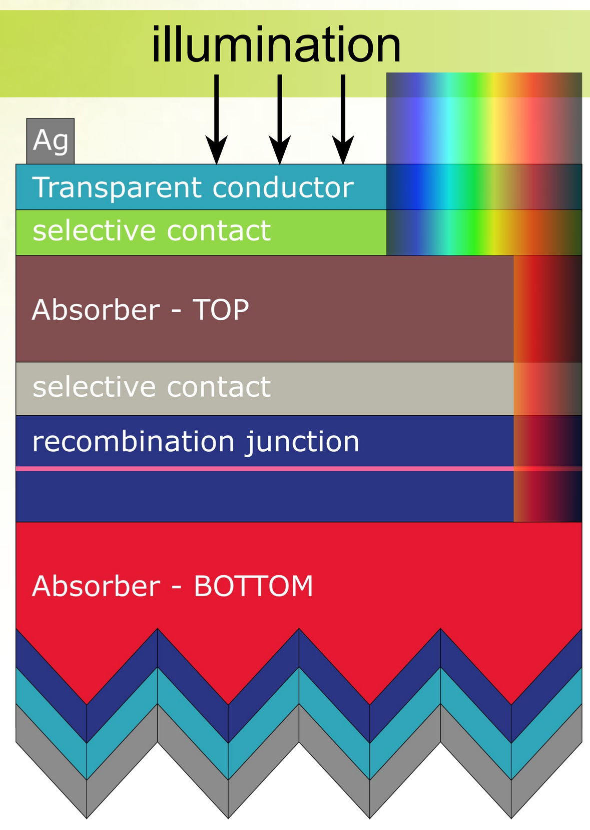
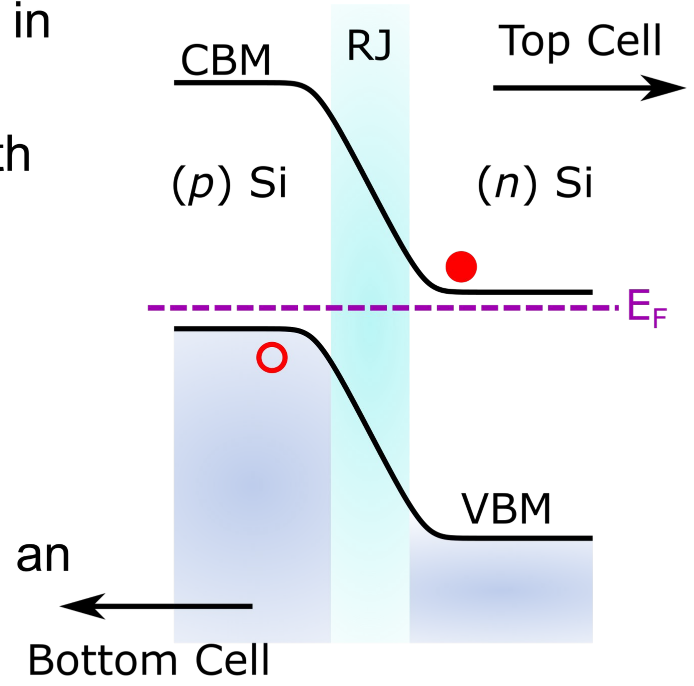
Tandem Solar Cells

- Forming tandem solar cells with silicon can further increase device performance.
- Lead-halide perovskites can match the silicon cell to form high-efficiency tandems.
- The facile deposition of perovskites makes them ideal for tandem devices with silicon.



What is the recombination junction (RJ)?

- Essential to collect charges generated in the top / bottom cells.
- Electrons (from top cell) recombine with holes (from bottom cell).
- Usually ITO used in perovskite-silicon tandems [1].
- Industrially favourable to reduce the complexity of the device structure.
- In this study we try to replace ITO with an in-situ deposited RJ using nc-Si:H.



Device Fabrication/Characterization

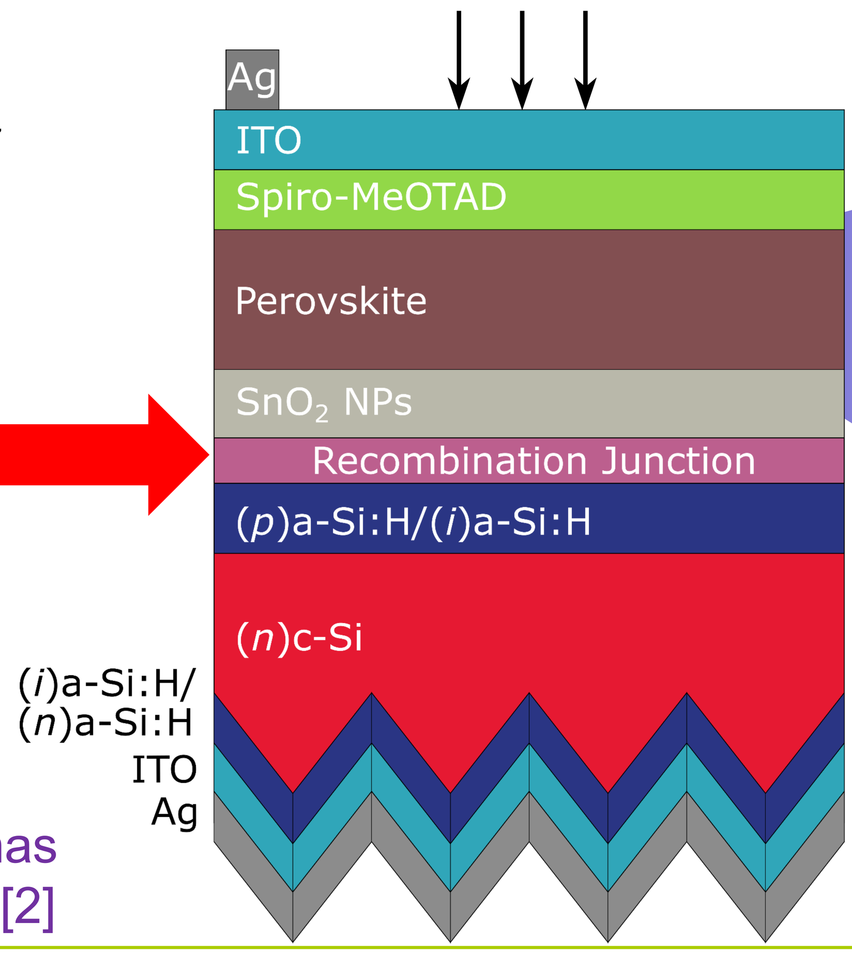
Top cell (n-i-p configuration)

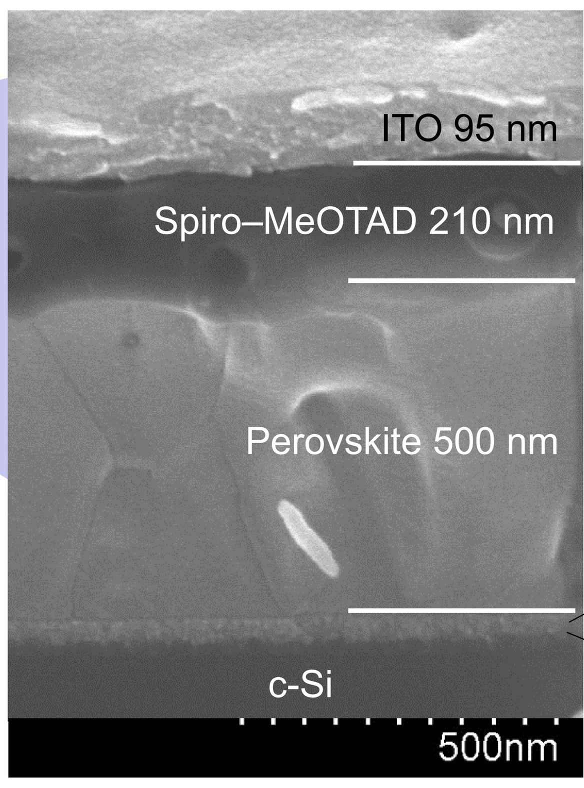
- ETL: SnO_2 nanoparticles.
- Perovskite: $Rb_{0.05}(FA_{0.83}MA_{0.17})_{0.95}PbI_{0.83}Br_{0.17}$
- HTL: doped spiro-MeOTAD.
- ITO/Ag (sputtered).

Bottom Cell (front emitter)

- Silicon heterojunction (SHJ): textured (rear), planar (front).
- Nanocrystalline Si (nc-Si:H) RJ deposited by plasma enhanced CVD.
- ITO RJ, deposited by sputtering.

Device optimization in this configuration has been demonstrated with efficiency >27% [2]

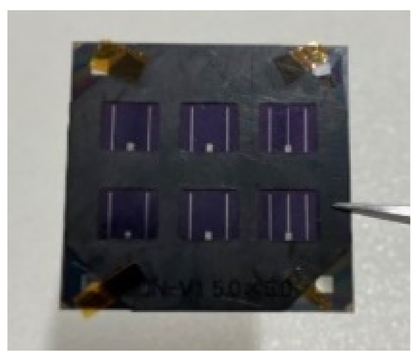




SnO$_2$ 40 nm

(n) nc-Si:H 20 nm

Device with mask

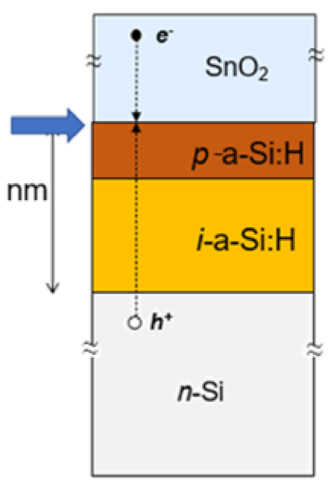


- Cells are shaded using a shadow mask.
- Cell area: 0.2275 cm²
- Without anti-reflection (AR).

Without RJ

S-shape curve, low V_{OC}.

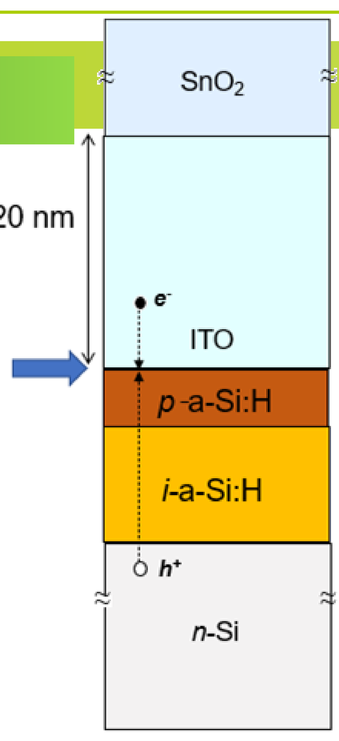
High contact resistivity at a-Si:H/SnO_2 interface.



ITO RJ

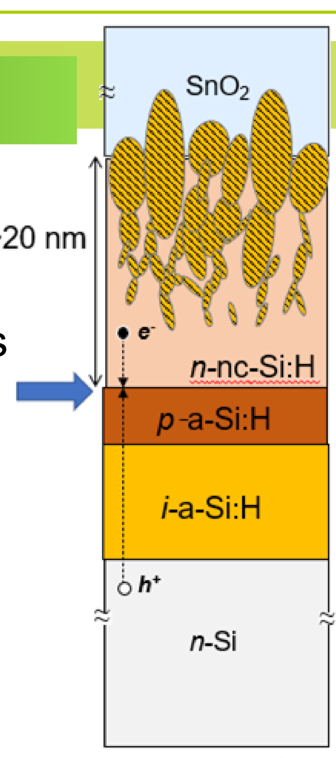
Improved V_{OC} and FF.

Lower J_{SC} caused by internal reflection.

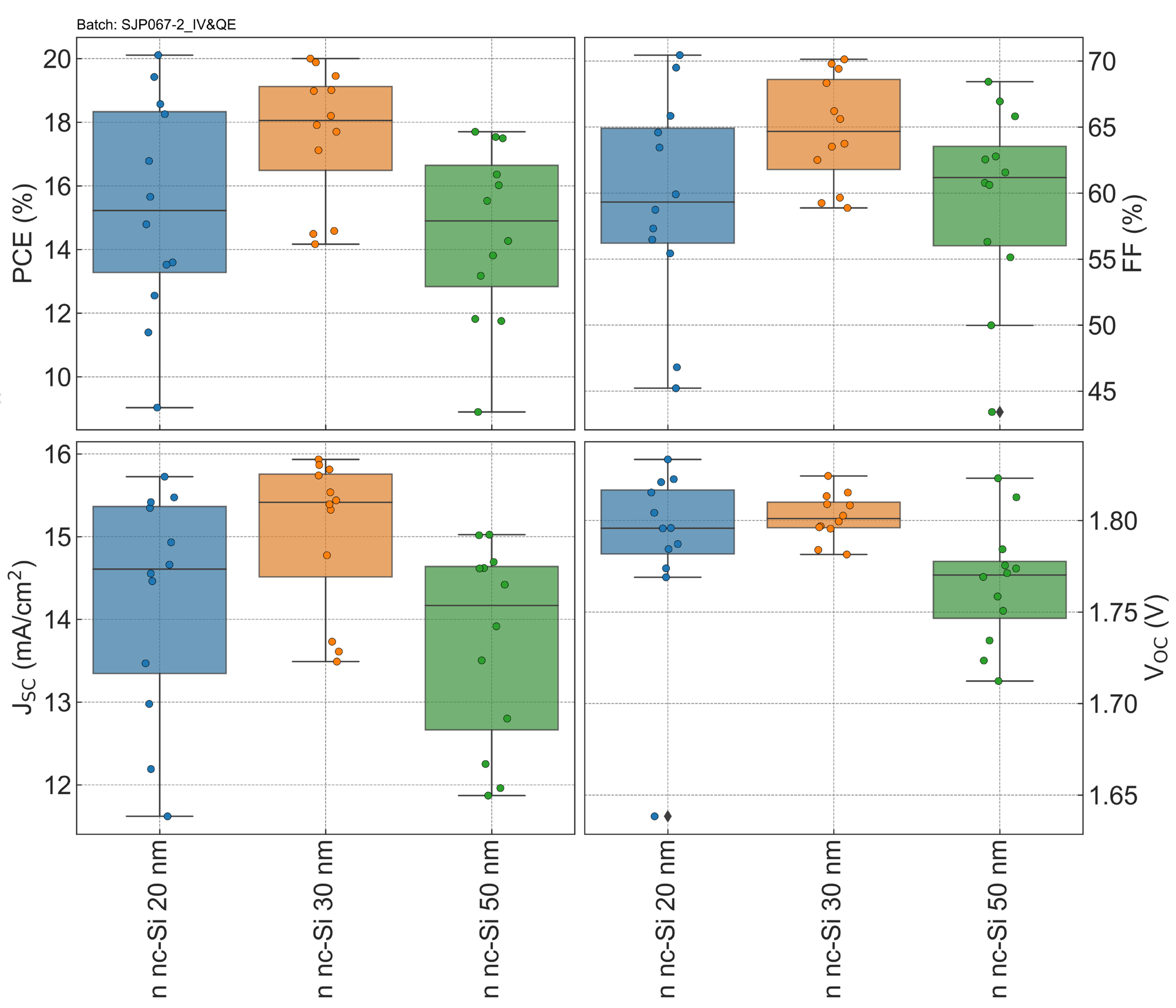


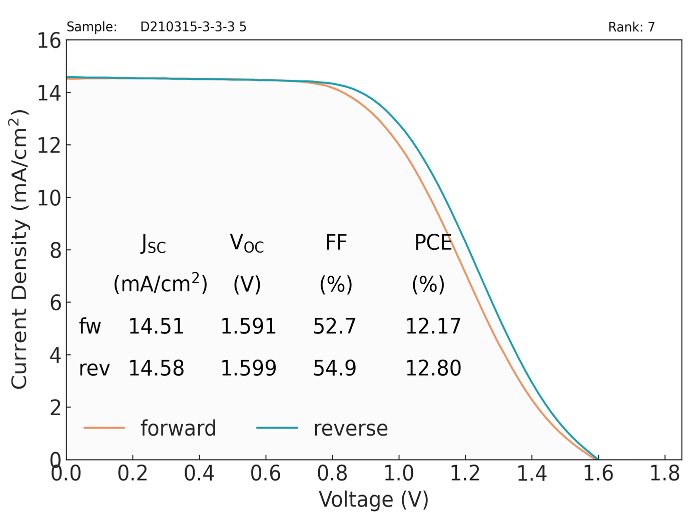
nc-Si RJ

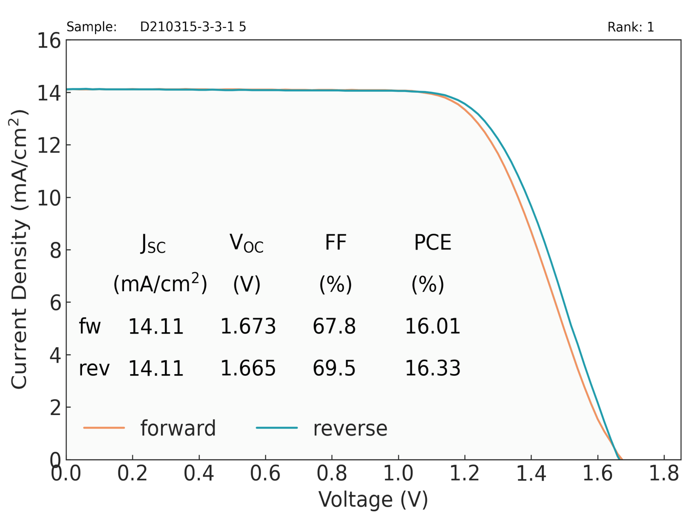
V_{OC} and FF further increases without sacrificing J_{SC}

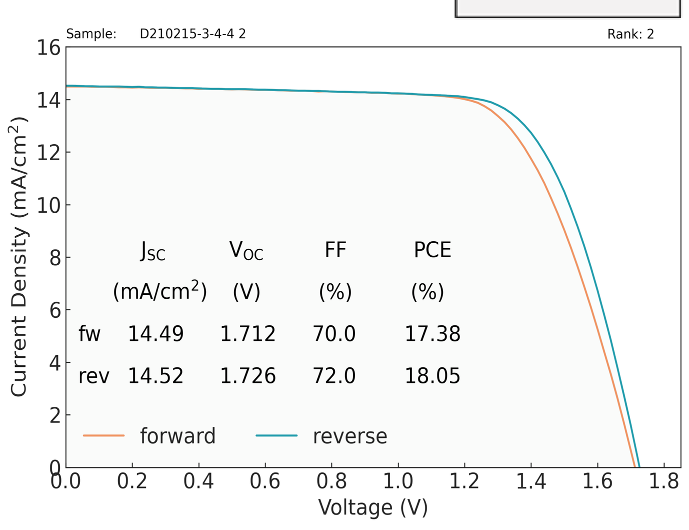


Varying the thickness of the nc-Si RJ









Conclusion

- We introduced nc-Si:H RJ into tandem devices.
- Unoptimized device for studying the nc-Si:H RJ.
- J_{SC} strongly limited by reflection and parasitic absorption in the thick spiro-MeOTAD layer (~200 nm).
- We observe superior performance when using nc-Si:H RJ over ITO RJ.
- 30 nm nc-Si RJ exhibited highest device performance.

References

[1] Al-Ashouri *et al.*, *Science* **370**, 1300–1309 (2020).
[2] Erkan Aydin *et al.*, *Energy Environ. Sci.*, **14**, 4377-4390 (2021).

Acknowledgements

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