Structuring of Perovskite-Silicon Tandem Solar Cells for Reduced Reflectance and Thermalization Losses

Adrian Callies[1], Mario Hanser[1], Jan Christoph Goldschmidt[2], Benedikt Bläsi[1], Oliver Höhn[1]

[1]Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstraße 2, 79110 Freiburg, Germany

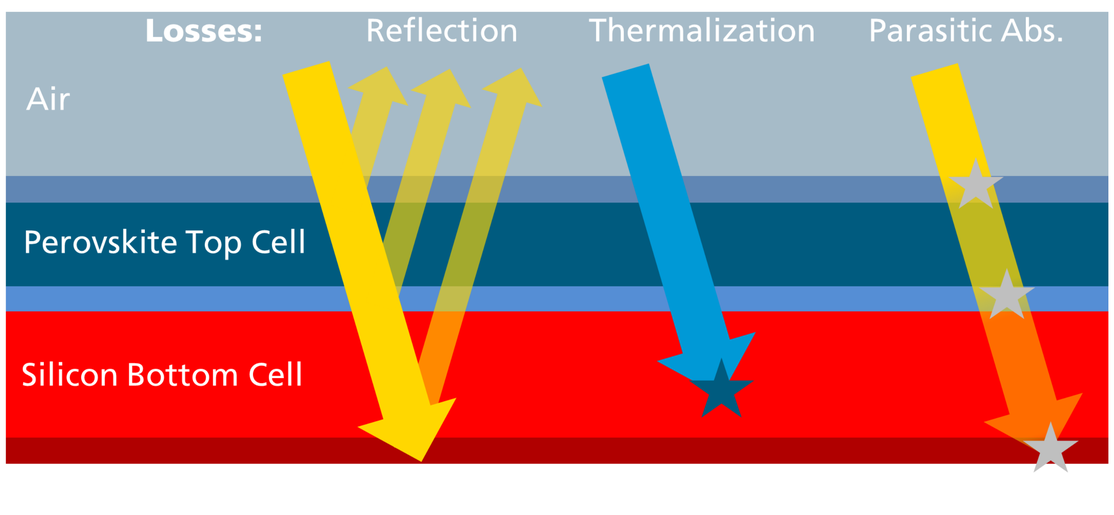
[2]Philipps-University Marburg, Renthof 7, 35032 Marburg, Germany

Corresponding paper

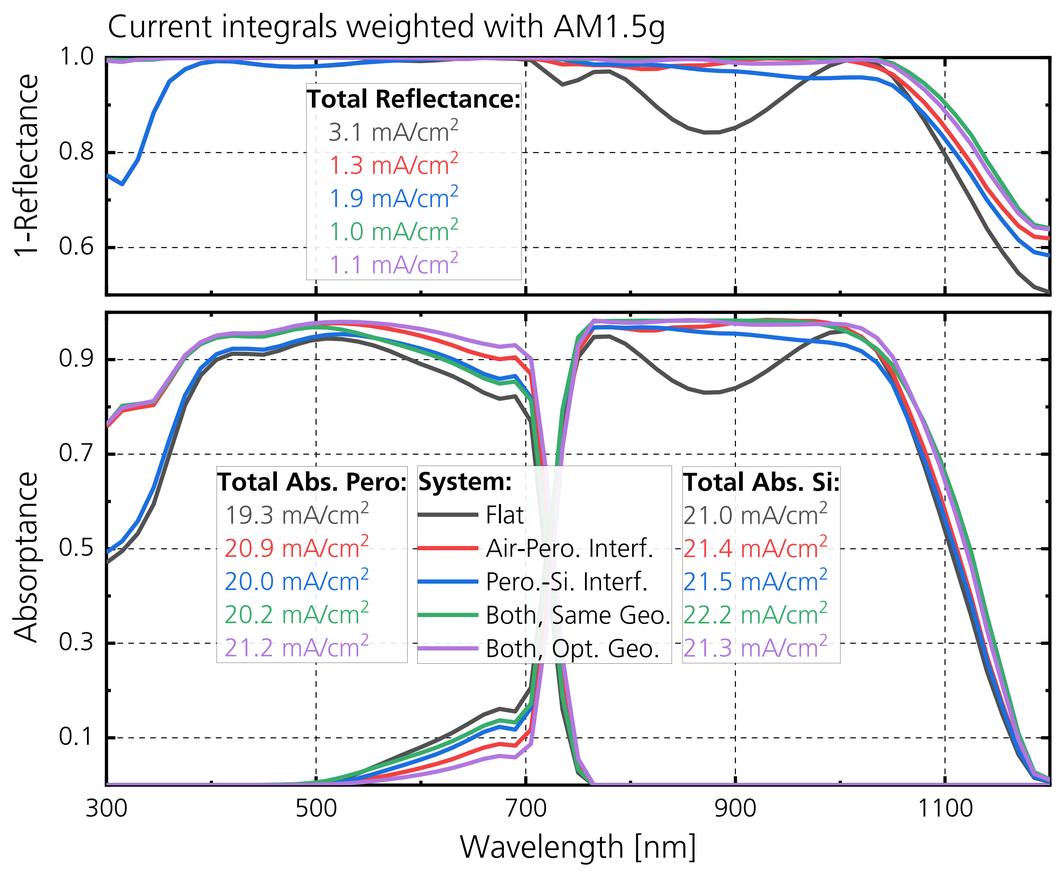
Identification of Loss Channels

Location in the Tandem Solar Cell Stack

- Reflection losses caused by interfaces with a refractive index contrast, mainly
  - air – perovskite
  - perovskite – silicon
- Top cell transmission of high-energy photons increase thermalization losses
- Parasitic absorption in all contact layers to be addressed by material engineering and a layer thickness reduction



Reflection and Thermalization Loss Reduction Potential



Nanostructured Tandem Solar Cell Stacks

Different nanostructures have been numerically evaluated using a combination of RCWA[3], Raytracing and a Lambertian rear side model[4]:

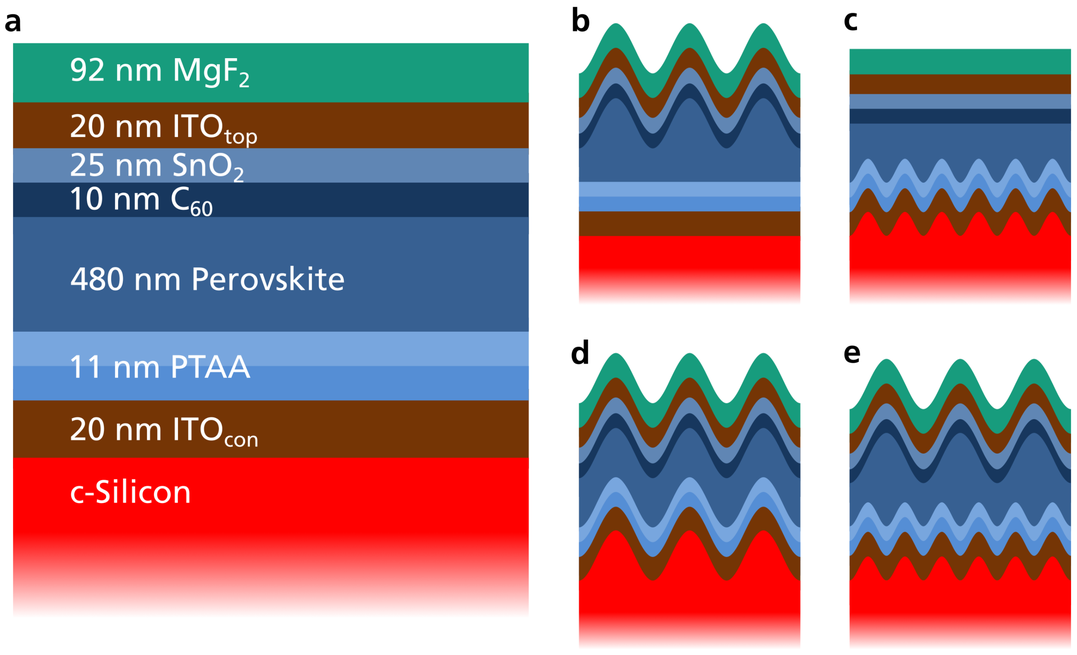
a) Reference tandem solar cell stack

b) Nanostructure at the air-perovskite interface
➔ reduces reflection and increases perovskite absorption close to bandgap

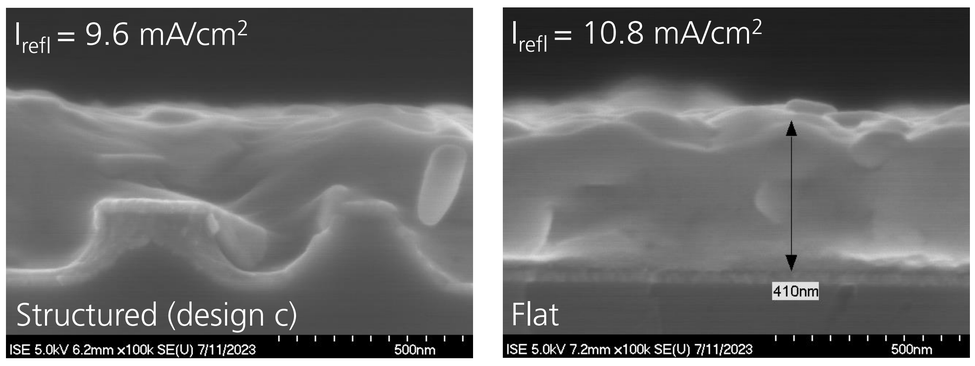
c) At the perovskite-silicon interface
➔ reduces reflection between 650-1200 nm

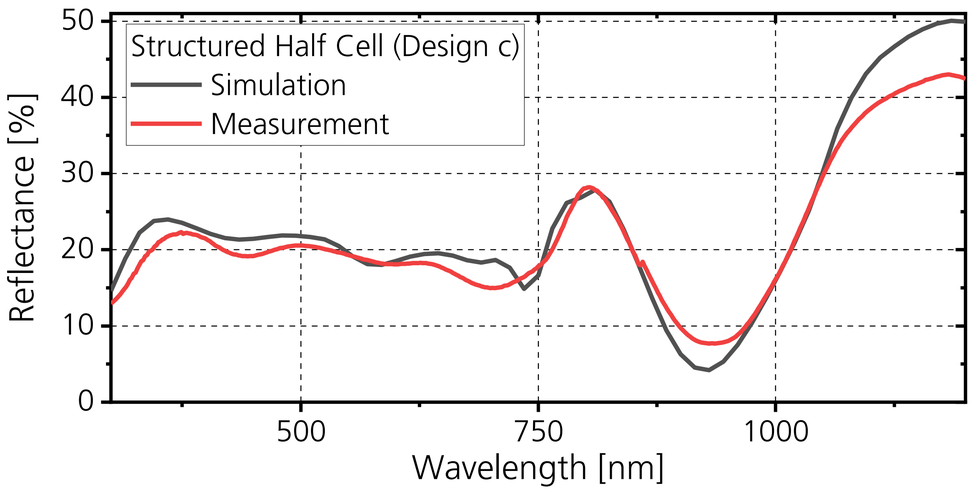
d) Same structure at both interfaces
➔ optimal antireflective behavior

e) Optimized structures at both interfaces
➔ minimum reflection and increased top cell current share at the same time



Model Validation: Current Reduction in Half-Cells





Summary

- Reflection caused by interfaces with large refractive index contrast
- Reflection can be reduced by up to 2.1 mA/cm² by nanostructures
- Nanostructures can also positively impact perovskite absorption close to the bandgap, allowing for current matching at a higher bandgap

1 Messmer et al., Prog. Photovoltaics (2020)
2 Messmer et al., Prog. Photovoltaics (2022)
3 Moharam et al., J. Opt. Soc. Am. (1995)
4 Green, Prog. Photovoltaics (2002)

Find all Fraunhofer ISE contributions here

sponsored by DBU Deutsche Bundesstiftung Umwelt
www.dbu.de

Contact: Adrian Callies, Fraunhofer Institute for Solar Energy Systems.
adrian.callies@ise.fraunhofer.de / +49 761 4588-5967

Detailed results: Callies et al., Opt. Express 31, 19428-19442 (2023); See QR-Code at the top.

Funding: Fraunhofer (ICON MEEt); Deutsche Bundesstiftung Umwelt (Scholarship Adrian Callies)