Reducing Reflective Losses by Texturing Perovskite-Silicon Tandem Solar Cells

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Introduction

- High efficiency solar cells are cost prohibitive to manufacture
- Traditional commercial silicon cells have low efficiencies (between 15% - 20%)
- Perovskite is an inexpensive [1] highly absorbent material [3]
- Stacking Perovskite on a Silicon cell allows absorbsion of a wider spectrum
- Perovskite-Silicon multi-junction cells require carful optical management
- Perovskite-Silicon multi-junction cells show significant reflective losses (above 13%)

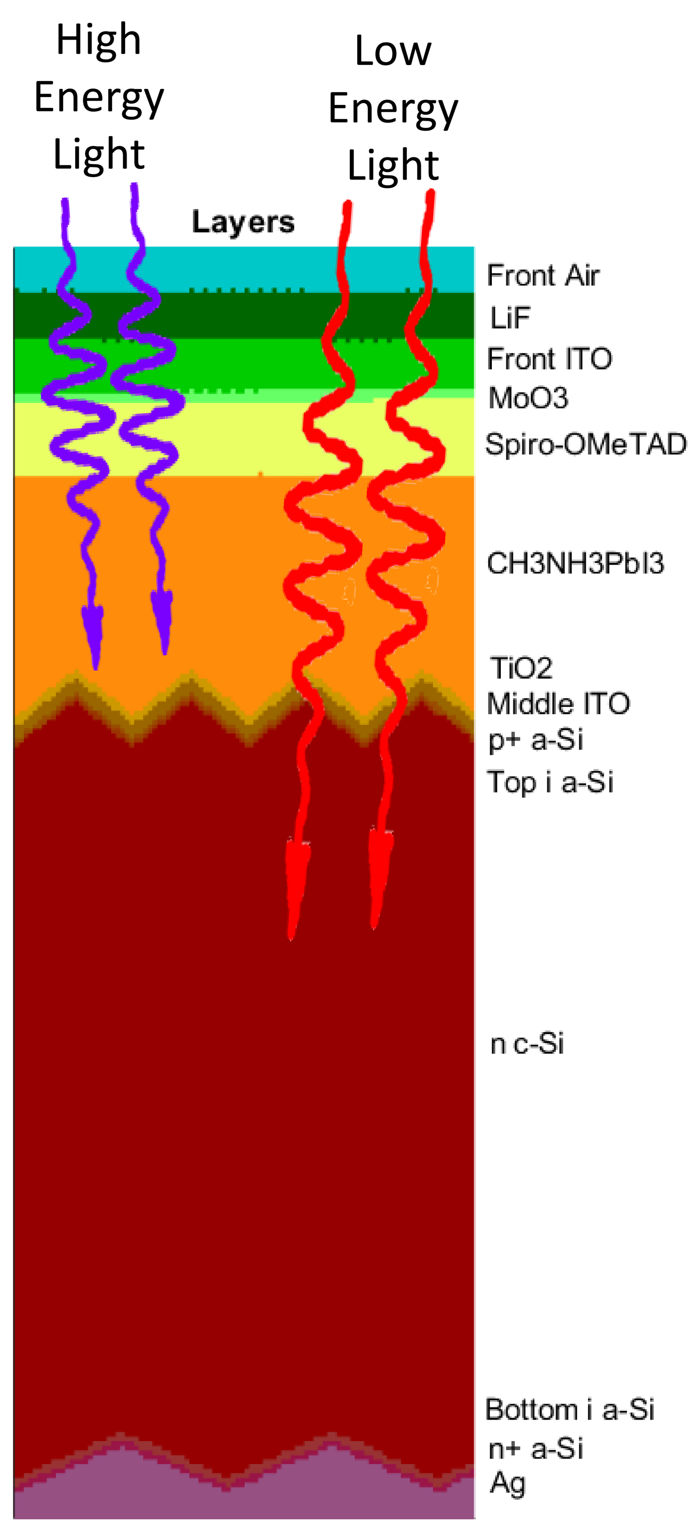


Figure 1: Structure of perovskite-silicon tandem cell

Results

- 17.5% reduction of reflection
- Increased power output by 3.4%
- Other losses showed only slight variation

Discussion

- Top texture -> no improvement
- Lower angle middle texture -> improvement
- Higher angle base texture -> improvement
- Losses: recombination (26.23%), thermalisation (20.04%), reflection (11.3%), and absorption of Spiro-OMeTAD (6.84%)

Conclusion

- Textured layers can increase efficiency
- Correct choice of angle is crucial
- Texture can decrease efficiency if not tuned

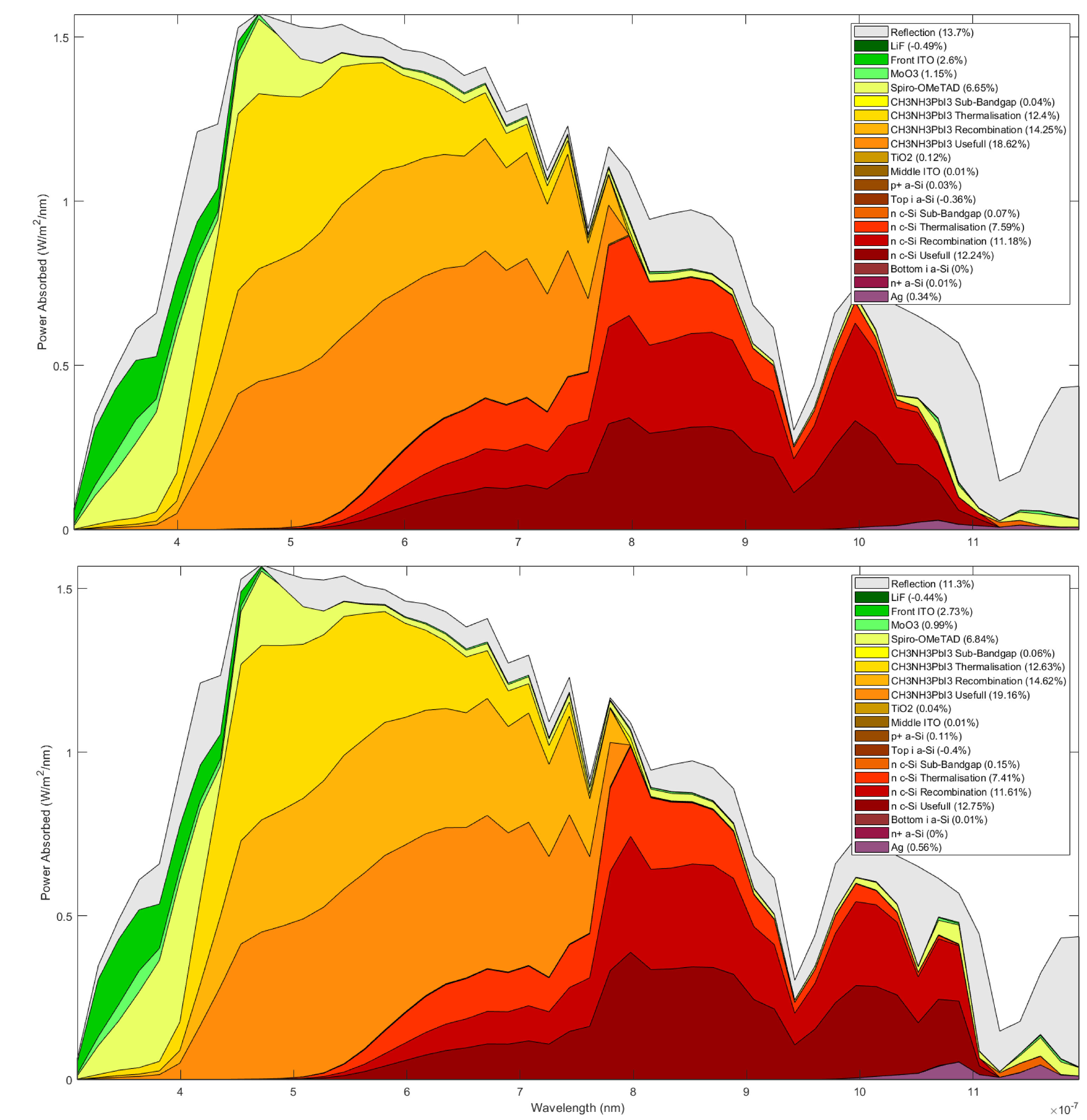


Figure 7: Spectral power map. Top figure w/o texture, bottom w/ texture

Methods

- Artificially texturing internal layer boundaries can increase efficiency
- Backward traveling waves can experience total internal reflection if incident above a specific angle

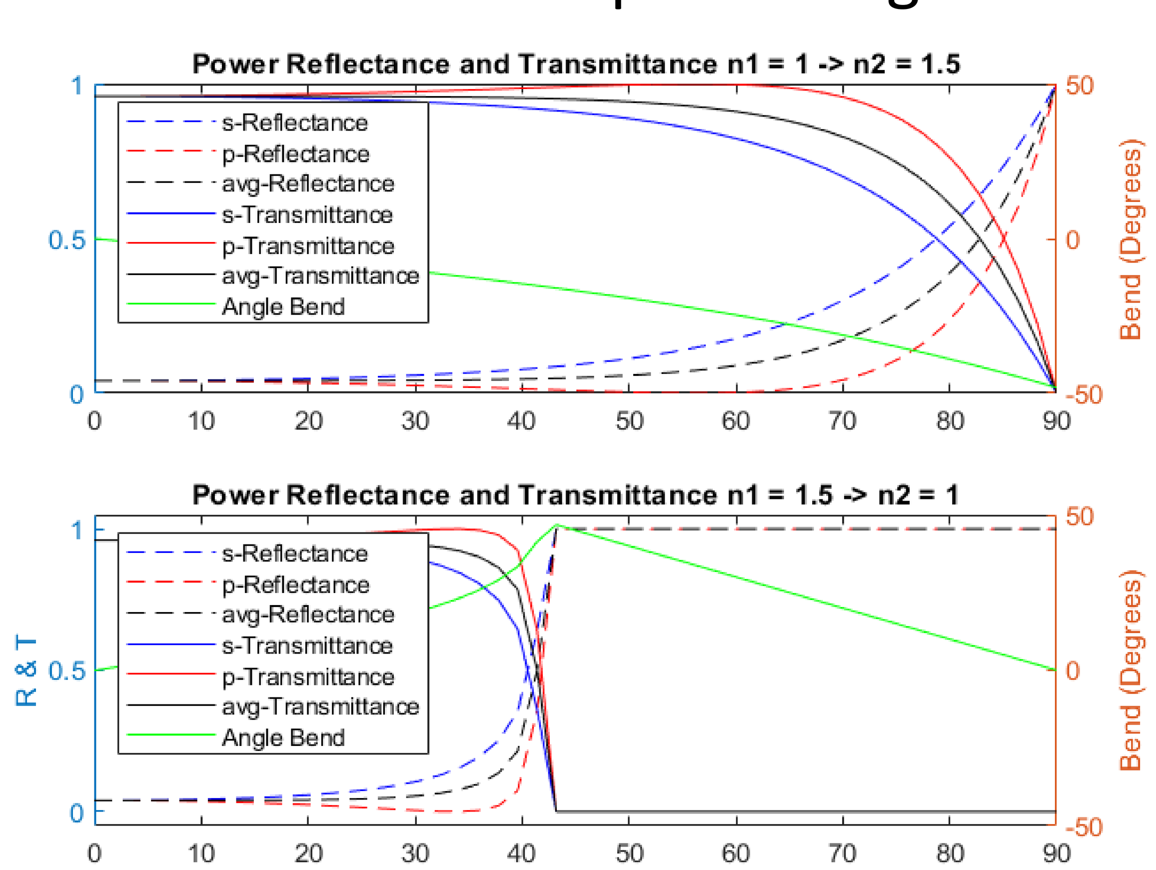


Figure 2: Fresnel coefficients

- Maxwell's equations predict the wave nature of light
- Helmholtz's wave equation describes the propagation of a wave

$$\triangle \vec{E} - k^2 \vec{E} = 0$$

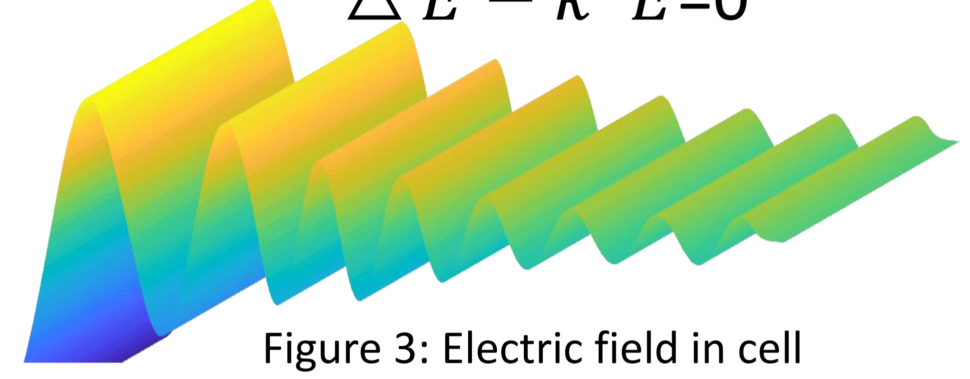
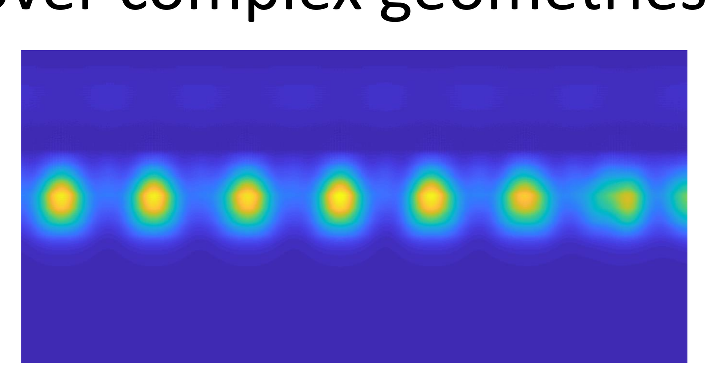


Figure 3: Electric field in cell

- Finite element analysis can estimate the solution of a partial differential equation over complex geometries

Figure 4: Absorption in cell (834 nm)



- Current matching is necessary to achieve max output power

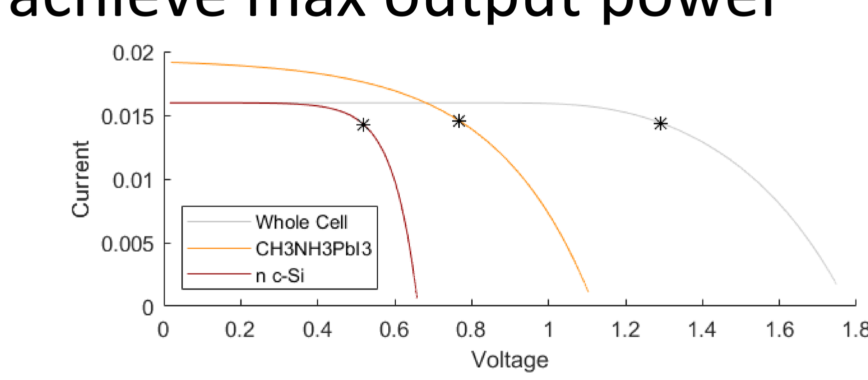


Figure 5: Matched maximum power point

- Evolutionary optimization is an excellent way to find optimum

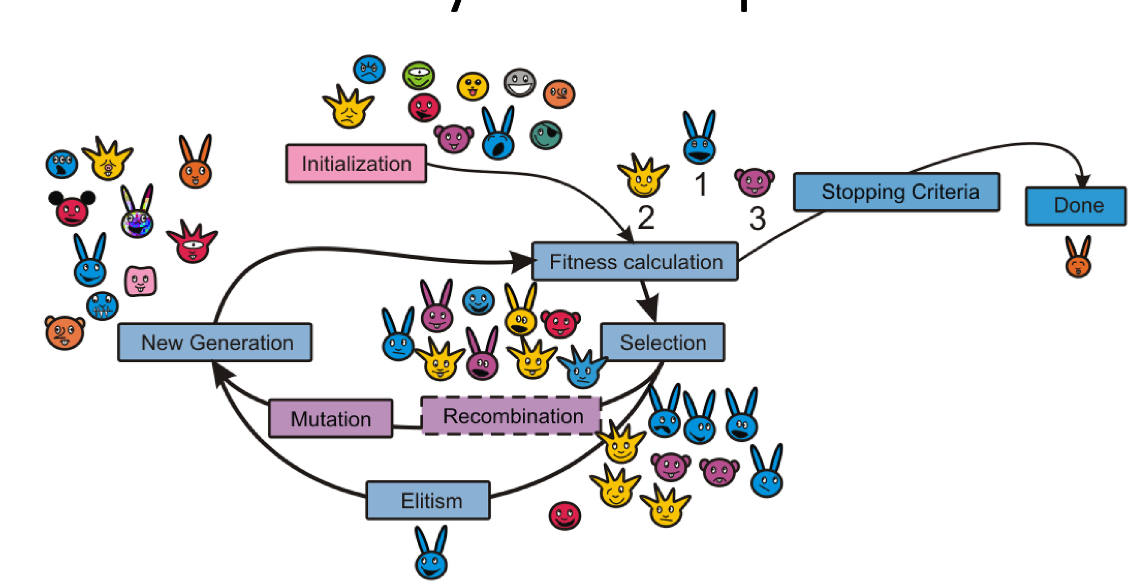


Figure 6: Evolutionary optimization flow [2]

References

[1] M. Cai, Y. Wu, H. Chen, X. Yang, Y. Qiang and L. Han, "Cost-Performance Analysis of Perovskite Solar Modules", Advanced Science, vol. 4, no. 1, p. 1600269, 2016.
[2] G. Oliveira, "Evolutionary Algorithms." [Online]. Available: https://cis.temple.edu/~pwang/3203-AI/Project/2014/Oliveira/Oliveira.pptx. [Accessed: 06-Apr-2018].
[3] S. De Wolf, J. Holovsky, S. Moon, P. Löper, B. Niesen, M. Ledinsky, F. Haug, J. Yum and C. Ballif, "Organometallic Halide Perovskites: Sharp Optical Absorption Edge and Its Relation to Photovoltaic Performance", The Journal of Physical Chemistry Letters, vol. 5, no. 6, pp. 1035-1039, 2014.

Acknowledgements

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