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Impact of Perovskite Solar Cell Degradation on Long-Term Performance of Perovskite/ Silicon Tandem Modules

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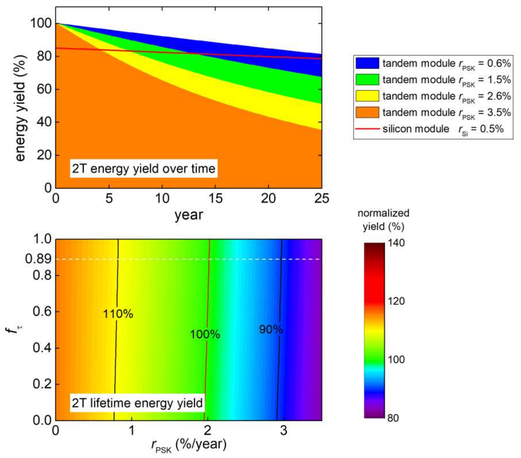
References
[1] J. Qian, M. Ernst, N. Wu, and A. Blakers, "Impact of Perovskite Solar Cell Degradation on the Lifetime Energy Yield and Economic Viability in Perovskite/Silicon Tandem Modules," Sustainable Energy Fuels 3, 1439–1447 (2019).

Tandem module power rating and degradation

Silicon based perovskite tandem cells have great potential to further improve solar module efficiency. However the uncertainty of perovskite solar cells' long term stability leads to uncertainty of economic competitiveness against conventional silicon modules.

Using unstable perovskite top cells, even featuring a high initial power rating, a tandem module could still have a lower lifetime energy yield than only using the same silicon bottom cells.



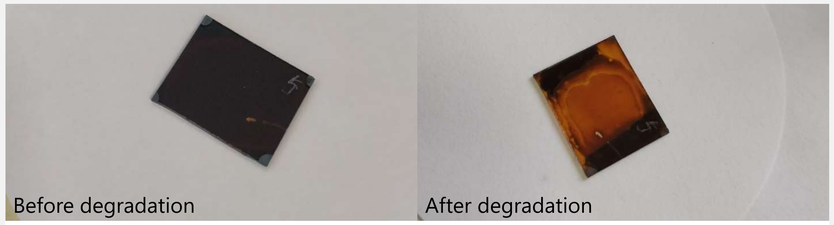
Lifetime tandem module degradation model

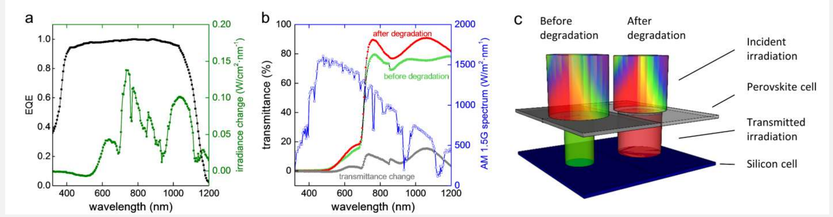
Input
- Electrical degradation of perovskite and silicon cell
- Optical degradation of perovskite cell
- Module configuration

- Solar cell IV model
- Parameter degradation model
- Module mismatch model

Output
- Tandem module power over lifetime
- Future discounted energy yield of tandem modules
- LCOE estimation in 2025

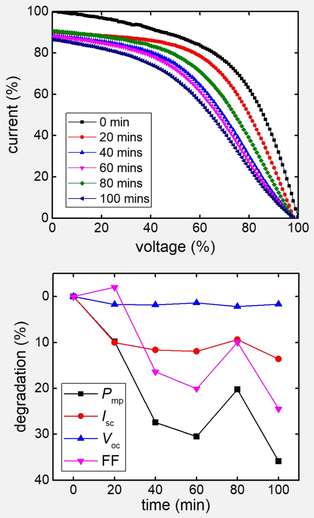
Perovskite cell bleaches as it degrades





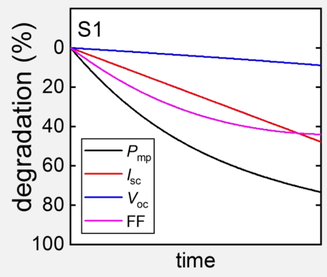
Optical degradation of the perovskite top cell may translate into *I*sc increase at the silicon bottom cell. Based on our in-house fabricated cell, we obtained a ratio of 0.89 between the *I*sc loss at the top cell and the *I*sc gain at the bottom cell.

Experimental and modelled degradation example



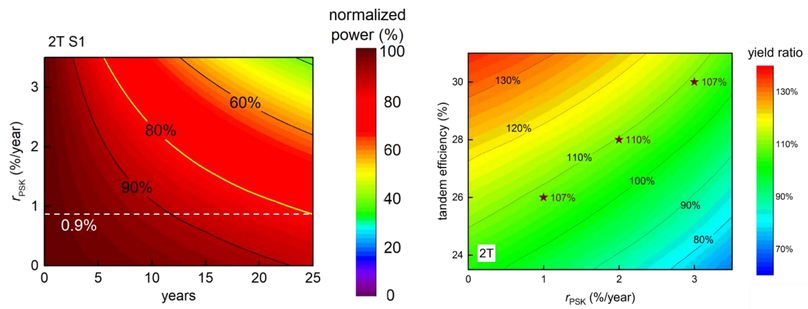
IV curves and cell parameters of an un-encapsulated PSK cell are measured after various degradation times at 65 °C in air and 35% humidity.

Based on these measurements we model a realistic degradation scenario of perovskite cells. We also model other scenarios not shown here.



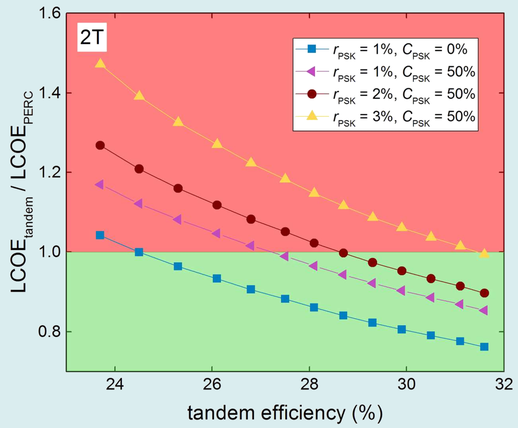
Tandem module power degrades at different rates with varied perovskite stability

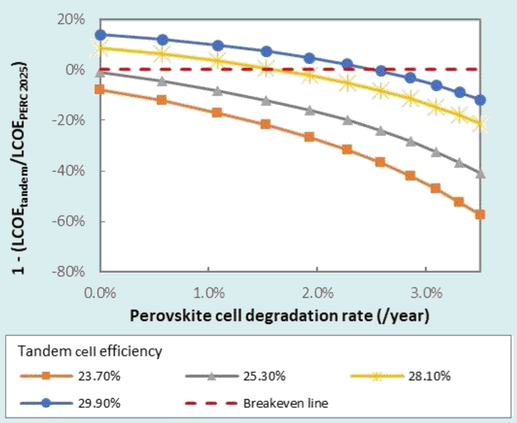
The module power is simulated for tandem modules considering electrical mismatch and optical compensation effect. While silicon cell degradation rate is based on field data, the perovskite cell degradation rate is varied between 0% and 3.5%.



Economical Viability of Tandem Module in 2025

By estimating the cost of the module, BOS and O&M, the projected LCOEs of perovskite/silicon tandem modules are compared to the projected LCOE of mono c-Si PERC modules in 2025. Simulations are conducted for different tandem cell efficiencies, perovskite cell degradation rates and additional cost for tandem technologies.





Conclusion

- To maintain 80% of the initial power in a tandem module after 25 years, the **maximum permissible perovskite** top cell degradation rates are **0.9%/year and 1.3%/year in 2T and 4T**.
- A future PSK/Si tandem module can produce over **10% more lifetime energy** than a 23.3% efficient single-junction Si module assuming a tandem efficiency of 28% with a PSK cell degradation rate of 2%/year.
- Assuming a PSK cell degradation rate of 2%/year and 50% additional cost for the tandem structure compared to single-junction modules, we find that tandem module **efficiencies of 28.7% and 27.6% enable the economic viability** of 2T and 4T **PSK/Si tandem modules**.