Impact of Perovskite Solar Cell Degradation on Long-Term Performance of Perovskite/Silicon Tandem Modules
(Solar renewable electricity generation)

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Metal halide perovskite (PSK) solar cells are promising candidates for high-efficiency Si based tandem solar cells and the stability of PSK solar cells is currently rapidly improving. Crucial for the economic viability of PSK/Si tandem devices is the combined degradation rate, which depends on the device configuration, the individual degradation rates of PSK and Si solar cells, and degradation type.

We experimentally determine the electrical and optical PSK cell degradation characteristics and study the long-term performance and economic viability of two and four-terminal (2T and 4T) PSK/Si tandem modules [1].

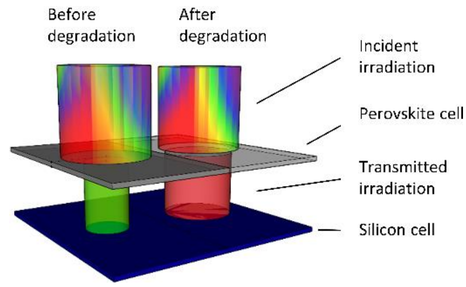

Figure 1: Schematic diagram of PSK cell optical degradation that leads to increased light transmitted to a Si bottom cell.

We investigate the impact of two critical issues involved in the combined degradation mechanism of PSK/Si tandem cells: (1) 2T tandem cells are commonly optimized by matching the maximum power current of both sub-cells to minimize current mismatch losses. However, different electrical degradation rates of the sub-cells can cause an increasing current mismatch and consequently a decrease in tandem efficiency. (2) Change in optical properties of the PSK top cell as illustrated in Fig. 1 due to degradation affecting the transmitted light to the bottom cell may cause increase of the current at the silicon cells. Such current gain could have different effects depending on the cell configuration.

Our PSK cell degradation experiments reveal that the degradation of our PSK cells is dominated by *FF* and I_{SC} degradation with negligible decrease in V_{OC}. We also observe an increase in the transmission of the PSK film after degradation. Based on the experimental results, we estimate the maximum permissible annual degradation rates of PSK top cells in 2T and 4T tandem modules to comply with an industry-typical performance warranty of 80% of the original value after 25 years.

Using the measured PSK cell degradation characteristics, we determine that 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 configurations as shown in Fig. 2. We project that 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 cell efficiency of 28% with a modest PSK cell degradation rate of 2%/year. Furthermore, we estimate the LCOE for 2T and 4T tandem modules. 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.

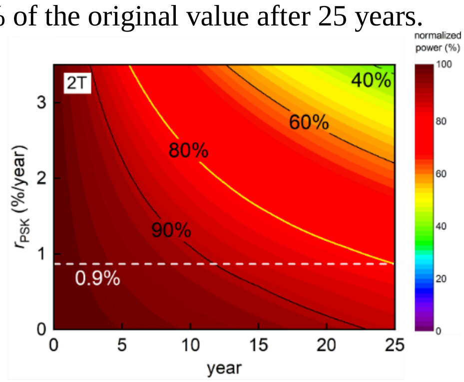

Figure 2. Normalized 2T tandem module power impacted by varying r_{PSK} over 25 years. The dashed lines represent the permissible degradation rate consistent with 80% relative end-of-life performance.

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 of perovskite/silicon tandem modules,” Sustainable Energy Fuels 6, 3583 (2019).

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