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Techno-economic analysis of Silicon Perovskite Tandem cells

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Tandem cells, where two photovoltaic cells are stacked on top of each other, have the potential for higher efficiency compared to single junction cells. However, this efficiency benefit must be balanced against the additional cost of these cells. I intend to present some results that are currently under review for publication (Chang, 2020), where the projected cost of manufacturing 6 high efficiency lab silicon perovskite tandem (SPT) cells will be reported.

Cost and efficiency trade-off using LCOE analysis

As a first step, a Levelized Cost of Electricity analysis is conducted to identify what cost increase can be tolerated for a given efficiency increase. The base case is the Sunshot 2020 residential scenario reported by Jones-Albertus (2016), and the results are shown in Figure 1. This analysis assumes that cell degradation and lifetime and cost of cell encapsulation is equivalent to standard c-Si PERC cells.

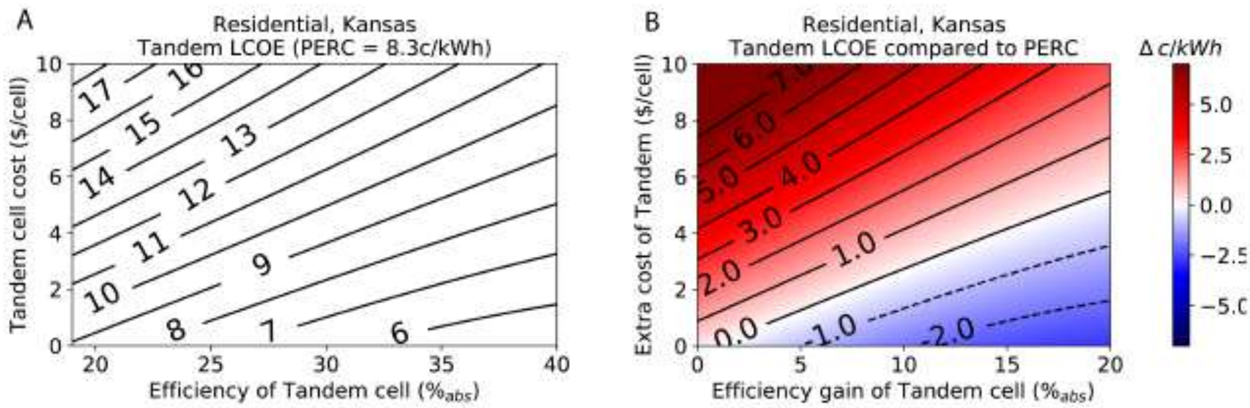

Figure 1. LCOE cost benefit comparison for varying tandem cell cost and tandem cell efficiency.

Sequences Analysed

In this work, the following sequences are analysed:

- Seq A (Fig 2A) - 17.1% cell on 16 cm2 area (Zheng, 2018).
- Seq B (Fig 2B) - 22.5% cell on 1 cm2 area (Wu, 2017).
- Seq C (Fig 2C) - 23.1% cell on 4 cm2 area (Zheng, 2019)
- Seq D (Fig 2D) - 22.9% cell on 1 cm2 area (Shen, 2018).
- Seq E (Fig 2E) - 27% cell on 1 cm2 area (Xu, 2020).

- Seq F (Fig 2F) - 22.6% cell on 57.4 cm2 area (Kamino, 2019).
- Seq G (Fig 2G) – Low-cost combination of previous sequences
- Seq H (Fig 2H) – Reference PERC cell

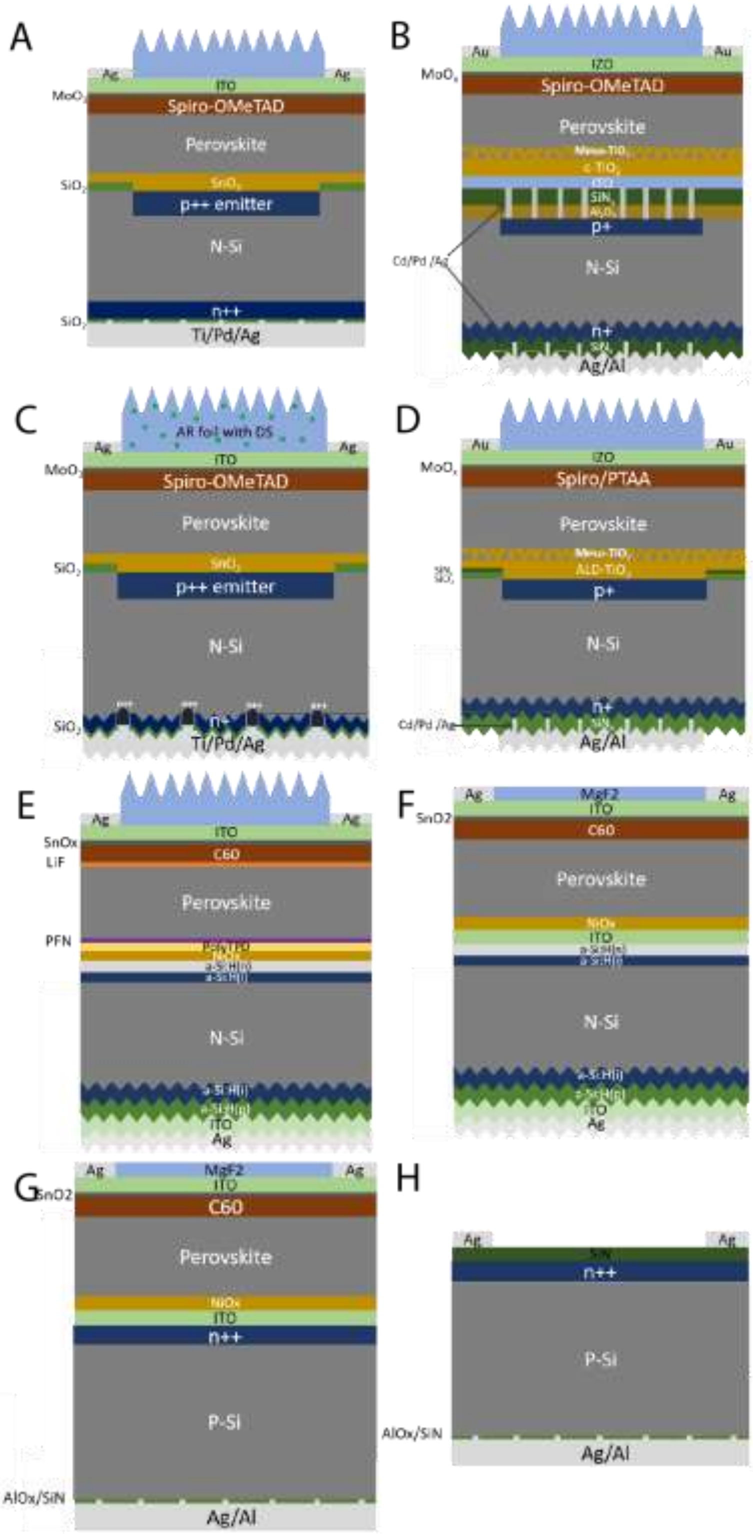

Figure 2. Sequences analysed in this work

Methods
The cost is analysed using a bottom-up cost of ownership analysis previously reported (Chang 2017).

Results

Detailed analysis of each sequence will be discussed. For example: i) Figure 3 compares modified Seq A1 and Seq A2, showing the key cost drivers, and ii) Figure 4 shows a progression of sequences with reduced costs.

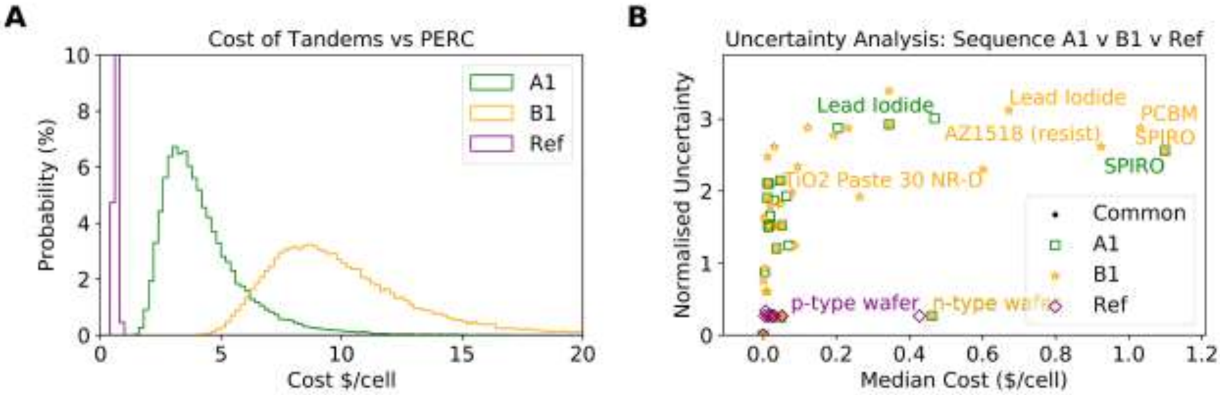

Figure 3. Seq A and Seq B cost results A) cost distribution and B) main cost drivers shown in a normalised uncertainty graph

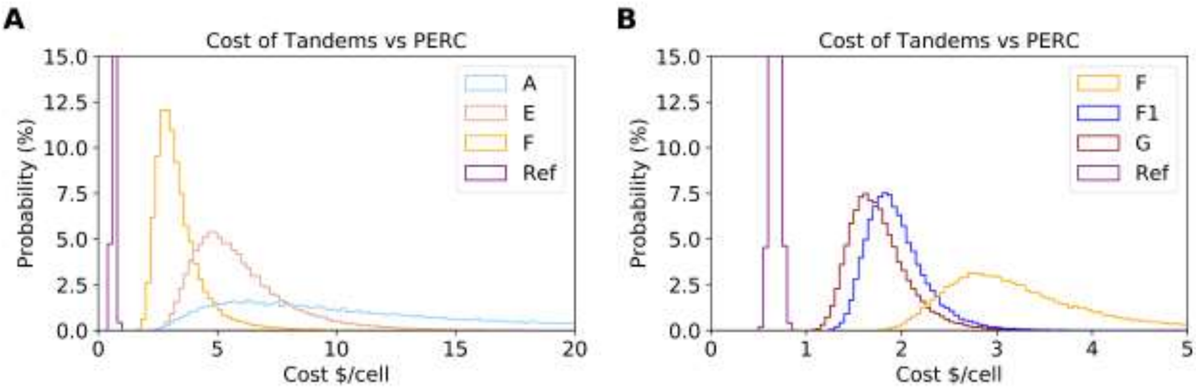

Figure 4. A) shows the reducing cost progression for Seq A, E and F, approaching the reference PERC cell. B) shows two further projected cost reductions F1 and G.

Conclusions

The results identify key cost barriers for each sequence. These include i) in the high cost HTM and ETL materials such as SPIRO and PCBM, ii) in the use of spin coating which has a high wastage rate and iii) the use of higher cost silicon cells.

A hypothetical medium term low-cost sequence that combines the lowest cost parts of the analysed sequences and an improved perovskite deposition process has a projected likely cost of $ 1.80 /cell, which if combined with 26% efficiency would give a favourable LCOE compared to industry standard c-Si cells (subject to the assumptions of the LCOE analysis, most importantly having equivalent degradation rates).

This analysis guides research directions to address cost issues in parallel with higher efficiencies in this technology area.

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