Quasi-two-dimensional perovskites for stable single junction and perovskite-silicon double junction solar cells

Chwen-Haw Liao,[a,b] Tik Lun Leung,[a,b] Guoliang Wang,[a,b] Jueming Bing,[a,b] Christopher G. Bailey,[a,b] Md Arafat Muhmud,[a,b] Jianghui Zheng, [a,b] and Anita W. Y. Ho-Baillie, [a,b,c*]
a School of Physics, The University of Sydney, Sydney, NSW, 2006, Australia
b Sydney Nano, The University of Sydney, Sydney, NSW, 2006, Australia
c Australian Centre for Advanced Photovoltaics, School of Photovoltaic and Renewable Energy Engineering, University of New South Wales, Sydney 2052, Australia

Three-dimensional (3D) metal halide perovskites have been the “material of choice” for the state-of-the-art perovskite solar cells as the best laboratory cell has recently reached a certified efficiency of 26.1% in 2023.[1]

Recently, low-dimensional perovskites, particularly the quasi-two-dimensional (2D) perovskites have emerged as alternatives due to their high stability and higher structural flexibility to their 3D counterparts for tuning opto-electronic properties.[2,3]

Perovskite cells demonstrated based on quasi-2D perovskites typically have an n-i-p structure[8-10], in which the n-type layers were fabricated first followed by the p-type layers which are unfortunately highly absorptive resulting in optical losses when implemented in a perovskite-silicon tandem solar cell as the p-type charge transport layer is on the sun-facing side. Therefore, quasi-2D perovskites compatible with p-i-n cell structure are highly attractive which this work reports.

Another challenge associated with quasi-2D perovskites is their slow crystalline formation resulting in surface defects thereby reducing associated cell performance. This work addresses this problem via surface treatment processes.

In the conference, we will report our demonstration of quasi-2D p-i-n perovskite solar cells (Figure 1a). The champion device produced a power conversion efficiency (PCE) of 19.0% and a fill factor of 75.6% (Figure 1b). The process of optimisation and passivation for such cell from the baseline and mechanism for performance improvement will be further discussed in the conference.

Initial stability test results are promising, the passivated and optimised quasi-2D device so far have maintained 79% of initial PCE after 300 hours at 85^{o}C in N_2 in the dark and 97% of initial PCE after 800 hours of light soaking in inert gas.

Lastly, we have successfully demonstrated the first quasi-2D perovskite-silicon tandem solar cell with a PCE exceeding 16.3%.

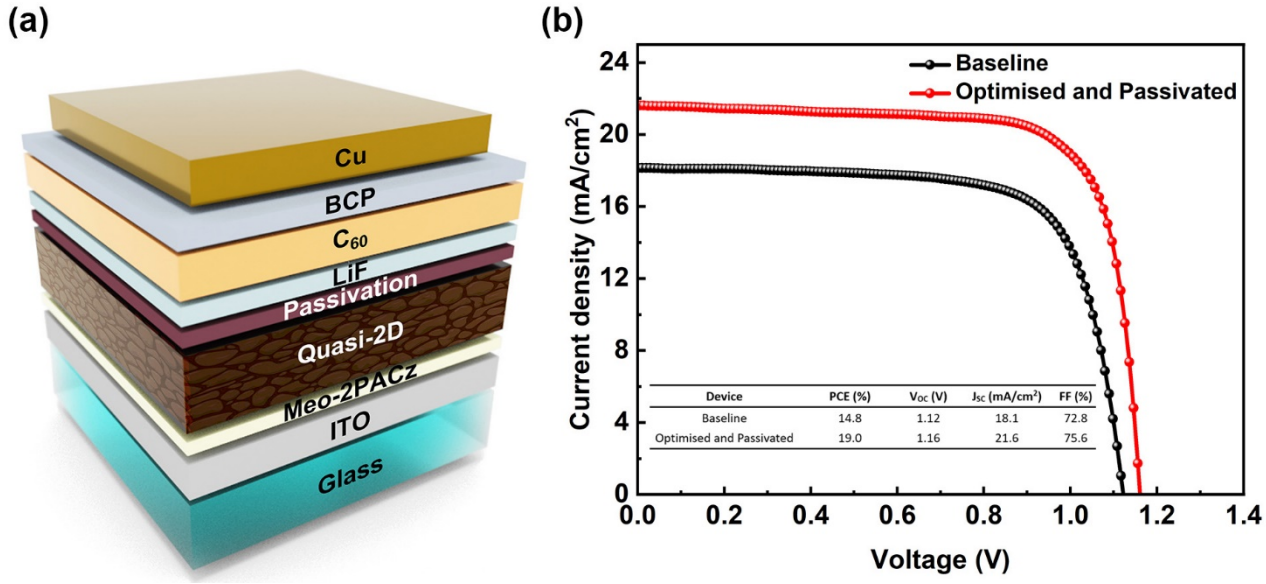

Figure 1. (a) Schematic and (b) Current density-voltage (*J-V*) curves of a baseline and a passivated and optimised quasi-2D solar cell.

References

(1) National Renewable Energy Laboratory, Best Research-Cell Efficiency Chart https://www.nrel.gov/pv/assets/pdfs/best-research-cell-efficiencies.pdf. **2023**.

(2) Liao, C.; Mahmud, M. A.; Ho-Baillie, A. W. Y. Recent progress in layered metal halide perovskite for solar cells, photodetectors, and field-effect transistors. *Nanoscale* **2023,** (15), 4219.

(3) Liao, C. H.; Chen, C. H.; Bing, J.; Bailey, C.; Lin, Y. T.; Pandit, T. M.; Granados, L.; Zheng, J.; Tang, S.; Lin, B. H.et al. Inorganic‐Cation Pseudohalide 2D Cs2Pb (SCN) 2Br2 Perovskite Single Crystal. *Advanced Materials* **2022,** *34* (7), 2104782.

(4) Xu, C.; Cheng, L.; Li, Z.; Zheng, X.; Shan, S.; Chen, T.; Fu, W.; Yang, Y.; Zuo, L.; Chen, H. Fast Solidification and Slow Growth Strategy for High‐Performance Quasi‐2D Perovskite Solar Cells. *Advanced Energy Materials* **2023,** *13* (17), 2300168.

(5) Lehner, L. E.; Demchyshyn, S.; Frank, K.; Minenkov, A.; Kubicki, D. J.; Sun, H.; Hailegnaw, B.; Putz, C.; Mayr, F.; Cobet, M. Elucidating the Origins of High Preferential Crystal Orientation in Quasi‐2D Perovskite Solar Cells. *Advanced Materials* **2023,** *35* (5), 2208061.

(6) Wang, B.; Cheng, Q.; Huang, G.; Yue, Y.; Zhang, W.; Li, X.; Li, Y.; Du, W.; Liu, X.; Zhang, H. Sulfonium‐Cations‐Assisted Intermediate Engineering for Quasi‐2D Perovskite Solar Cells. *Advanced Materials* **2023,** *35* (5), 2207345.

(7) Zhang, Y.; Chen, M.; He, T.; Chen, H.; Zhang, Z.; Wang, H.; Lu, H.; Ling, Q.; Hu, Z.; Liu, Y. Highly Efficient and Stable FA‐Based Quasi‐2D Ruddlesden‐Popper Perovskite Solar Cells by the Incorporation of β‐Fluorophenylethanamine Cations. *Advanced Materials* **2023**, 2210836.

(8) Zhang, Y.; Park, N.-G. Quasi-Two-Dimensional Perovskite Solar Cells with Efficiency Exceeding 22%. *ACS Energy Letters* **2022,** *7* (2), 757.

(9) Jin, L.; Ren, N.; Wang, P.; Li, R.; Xue, Q.; Huang, F.; Zhang, X.; Zhao, Y.; Zhang, X. Secondary Anti‐Solvent Treatment for Efficient 2D Dion‐Jacobson Perovskite Solar Cells. *Small* **2023,** *19* (3), 2205088.

(10) Liang, J.; Zhang, Z.; Xue, Q.; Zheng, Y.; Wu, X.; Huang, Y.; Wang, X.; Qin, C.; Chen, Z.; Chen, C.-C. A finely regulated quantum well structure in quasi-2D Ruddlesden–Popper perovskite solar cells with efficiency exceeding 20%. *Energy Environmental Science* **2022,** *15* (1), 296.