Developing PbS colloidal quantum dot tandem solar cells

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Abstract: One of the most fundamental problems for colloidal quantum dot solar cells is the limited diffusion length, which limits the quantum dot absorbing layer's thickness hence power conversion efficiency (PCE). In the meantime, colloidal quantum dots are perfect candidate for tandem solar cells because of their widely tunable bandgaps. PbS quantum dots' bandgaps can be widely tuned from 0.6 eV to 1.7 eV,[1] which covers the optimal bandgap range for tandem solar cells. A tandem solar cell uses the strategy of increasing the number of energy levels to more efficiently convert the energy of a wider range of solar spectrum to electricity to overcome Shockley‐Queisser (S-Q) limit. The limiting efficiency depends on the number of sub-cells in the device. For 1, 2, 3, 4, and ∞ subcells with optimal bandgaps, the limiting efficiency η is 31.0%, 42.5%, 48.6%, 52.5%, and 68.2% for unconcentrated sunlight.[2]

However, the development of quantum dot tandem solar cell has lagged far behind that of its single-junction counterpart. One of the problems is that a weakened electrical field for extracting charge carriers can be created when narrow bandgap QDs are applied in the rear cell as absorbing layer, leading to lower cell performance due to the bad charge carriers' transport. For solving this problem, we applied graded band alignment strategy to improve tandem cells' performance.

In this research, guided by an optical modelling and utilising a graded band alignment strategy, taking advantage of the tunable bandgaps of quantum dots, a two-terminal monolithic solution-processed colloidal quantum dot tandem solar cell has been successfully fabricated and a power conversion efficiency of 6.8% has been achieved.

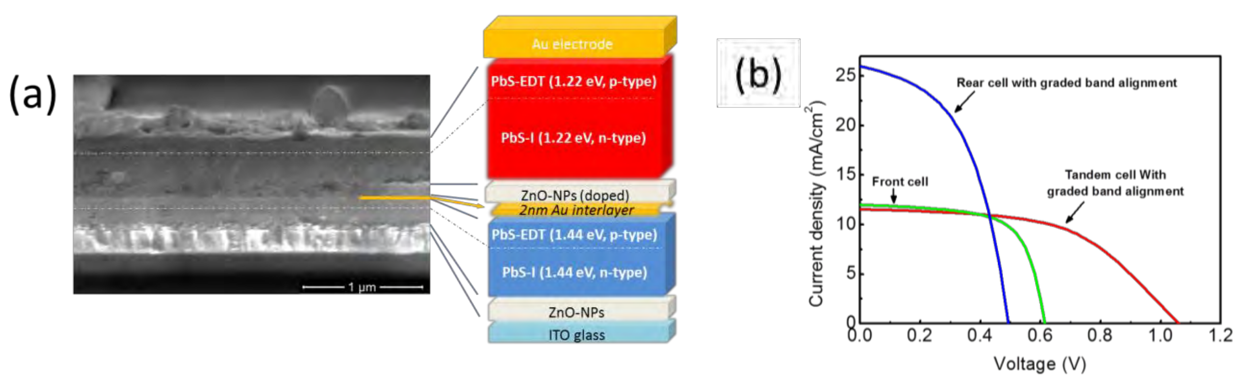

Figure 1 (a) Illustration of the structure of tandem PbS CQD solar cells. (b) J-V curves of fabricated tandem cell and single-junction cells with graded band alignment.

1 Moreels, I., Justo, Y., and Hens, Z.: 2011, ACS Nano, 5, (3), pp. 2004-2012

2 Jiang, C.-W., and Green, M.A.: 2006, Journal of Applied Physics, 99, (11), pp. 114902