ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

Enhancing Silicon Solar Cells Using Singlet Fission

N.Ekins-Daukes[1,2], M.Nielsen[1], M.Tayebjee[1], M.Pollard[1], T.Ngyuen[2,3], B.Hoex[1], D.McCamey [2,3], T.W.Schmidt[2,4]

[1] School of Photovoltaic & Renewable Energy Engineering, UNSW Sydney, Australia
[2] Centre of Excellence for Exciton Science, UNSW Sydney, Australia
[3] School of Physics, UNSW Sydney, Australia
[4] School of Chemistry, UNSW Sydney, Australia

E-mail: nekins@unsw.edu.au

Among the pantheon of approaches to fundamentally improve the efficiency of silicon solar cells, the series connected tandem has garnered most of the interest and achieved efficiencies in excess of 35%.
An alternative approach under investigation at UNSW is to use a molecular layer that undergoes singlet fission to 'down-convert' short wavelength photons into two electron-hole pairs and resulting in an external quantum efficiency >100%, shown in figures 1 & 2. The thermodynamic limit for a singlet fission device interestingly results in an endothermic configuration and a limiting efficiency of 45.9% [1], but in a silicon solar cell singlet fission has the potential to increase the current by 20% under standard conditions and could ultimately result in a c-Si device exceeding 30% energy conversion efficiency.

The detailed photophysical mechanisms behind singlet fission are becoming well understood [2] and until recently had only been demonstrated in molecular [3] PV devices, or those using inorganic QDs to radiative the fission products (triplet-excitons) to provide an optical down-conversion scheme [4]. Recently a breakthrough has been achieved by Marc Baldo's group at MIT, reporting the first evidence of direct charge injection into silicon [5]. A tetracene layer was used to absorb short-wavelength light that upon excitation by a blue photon into a singlet state, readily generates two triplet excitons. The key step was the use of an ALD deposited hafnium oxynitride interfacial layer that serves as both a passivation and charge transport layer.

The study of this device, over a silicon tandem device is motivated by the parallel connection of the singlet fission layer to this silicon material, shown in figure 3. Ultimately the device could be as simple as an additional molecular layer deposited on the front of the cell with no metal contacts made to the molecular layer whatsoever.

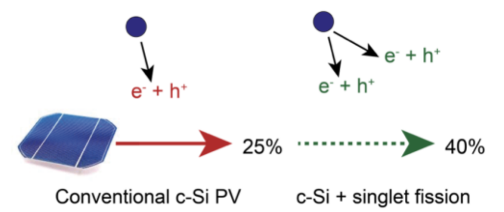

Figure 1, schematic oft he singlet fission process.

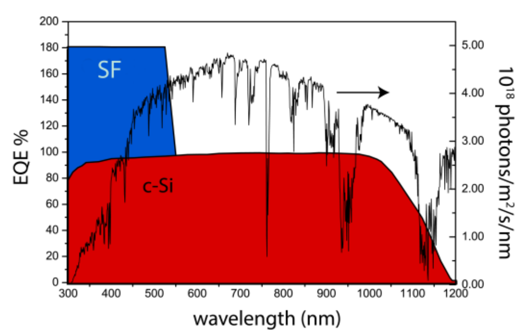

Figure 2. Schematic for the external quantum efficiency from a singlet fission layer plotted with the AM1.5G solar spectrum photon flux.

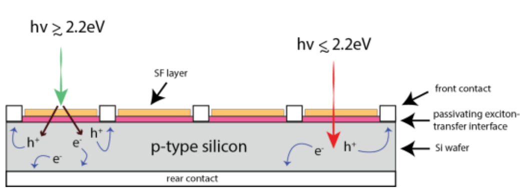

Figure 3. Schematic of a potential singlet fission enhanced front-contact c-Si solar cell.

Research is presently underway at UNSW to improve this proof of concept by obtaining a better understanding of the charge transfer mechanism at the tetracene/HfN interface, using alternative interfacial layers and alternative molecular singlet fission layers.

References

[1] M. J. Y. Tayebjee, A. A. Gray-Weale, and T. W. Schmidt, 2012, “Thermodynamic Limit of Exciton Fission Solar Cell Efficiency,” The Journal of Physical Chemistry Letters, vol. 3, no. 19, pp. 2749–2754.

[2] C. B. Dover, J. K. Gallaher, L. Frazer, P. C. Tapping, A. J. I. Petty, M. J. Crossley, J. E. Anthony, T. W. Kee, and T. W. Schmidt, 2018, “Endothermic singlet fission is hindered by excimer formation,” *Nature Chemistry*, vol. 10, no. 3, pp. 305–310

[3] D.N. Congreve, et al. ‘External quantum efficiency above 100% in a singlet- exciton-fission-based organic photovoltaic cell.’ 2013, Science 340, 334–337.

[4] N.Davies et al., ‘Singlet Fission and Triplet Transfer to PbS Quantum Dots in TIPS-Tetracene Carboxylic Acid Ligands’ 2018, *J. Phys. Chem. Lett.* 9,6, pp.1454-1460

[5] M. Einzinger, T. Wu, J. F. Kompalla, H. L. Smith, C. F. Perkinson, L. Nienhaus, S. Wieghold, D. N. Congreve, A. Kahn, M. G. Bawendi, and M. A. Baldo, 2019 “Sensitization of silicon by singlet exciton fission in tetracene,” *Nature*, vol. 571, no. 7763, pp. 90–94.