

Tandem Dye-sensitized Solar Cells for Energy Conversion and Storage

One way of improving the efficiency of dye-sensitized solar cells is to use two photoelectrodes in a tandem device, one harvesting the high energy photons, and the other harvesting the low energy photons.¹ This enables the photovoltage to be increased, whilst maximizing light harvesting across the solar spectrum. Despite their promise, a tandem cell with a higher efficiency than the state-of-the-art “Grätzel” cell has not yet been achieved. This is because the performances of photocathodes are significantly lower than TiO₂-based anodes, and the p-type concept has been largely unexplored since the first device was prepared in 1999.² The small potential difference between the valence band of the NiO, p-type semiconductor, and the redox potential of the electrolyte and the faster charge-recombination reactions compared to the TiO₂ system limits the efficiency. In recent years we have made progress by developing new photosensitizers.³ In parallel we have investigated the charge-transfer processes to determine the mechanism and limitations to efficiency.⁴ This has increased our understanding of the redox processes at the dye/electrolyte and NiO/electrolyte interfaces.⁵ The fundamental limitation of these devices arises from the NiO material itself and we have re-focussed our efforts on finding a replacement transparent p-type semiconductor. Our strategy and recent results will be presented. Recent work to expand the applications to photoelectrochemical water splitting for energy storage will be described, briefly.⁶

[1] E. A. Gibson, A. L. Smeigh, L. Le Pleux, L. Hammarström, F. Odobel, G. Boschloo, A. Hagfeldt., *Angew. Chem. Int. Ed.* **2009**, *48*, 4402–4405. [2] J. He, H. Lindström, A. Hagfeldt, S. Lindquist, *J. Phys. Chem. B*, **1999**, *103*, 8940–8943. [3] C. J. Wood, G. H. Summers, E. A. Gibson. *Chem. Commun.* **2015**, *51*, 3915 – 3918. [4] J.-F. Lefebvre, X.-Z. Sun, J. A. Calladine, M. W. George, E. A. Gibson. **2014**, *50*, 5258 – 5260. G. Boschloo, E. A. Gibson, A. Hagfeldt *J. Phys. Chem. Lett.*, **2011**, *2*, 3016–302. E. A. Gibson, L. Le Pleux, J. Fortage, Y. Pellegrin, E. Blart, F. Odobel, A. Hagfeldt, G. Boschloo, *Langmuir* **2012**, *28*, 6485–6493 [5] F. A. Black, C. J. Wood, S. Ngwerume, G. H. Summers, I. P. Clark, M. Towrie, Jason E. Camp, E. A. Gibson, *Faraday Discussions*, **2017**, *198*, 449 – 461. L. D’Amario, R. Jiang, U. Cappel, E. A. Gibson, G. Boschloo, H. Rensmo, L. Sun, L. Hammarström, H. Tian*, *ACS Appl. Mater. Interfaces*. **2017**, *9*, 33470–33477. [6] E. A. Gibson, *Chem. Soc. Rev.*, **2017**, *46*, 6194 – 6209. N. Pöldme, L. O’Reilly, I. Fletcher, I. Sazanovich, M. Towrie, C. Long, J. G. Vos, M. T. Pryce, E. A. Gibson *Chem. Sci. In press*.