

Exploring Mixed Metal Oxides for Tandem Dye-sensitized Solar Cells

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DSCs offer a highly promising alternative to established commercial Si or thin-film solar cells due to their versatility, low cost, ease of manufacturing, integration into building materials and electronic devices and use of abundant materials. DSCs are more suitable for low-light conditions, giving greater sunlight to electrical energy conversion than Si over the course of a year, making them particularly attractive for applications in Northern Europe. Their efficiency (13%) and stability is competitive with amorphous Si and organic PV, but it lags behind crystalline Si (25%) and established thin film technology (20%). This is because the spectral response is much narrower so they do not convert as much sunlight. Extending the light absorption in n-DSCs to the red-NIR region leads to a drop in device voltage.

One way of improving the efficiency of dye-sensitized solar cells is to use two photoelectrodes in a tandem device (see Figure 1), 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. By adding catalysts to the device (Figure 2), we can drive chemical reactions such as carbon dioxide reduction or hydrogen production from water to make fuel, so the dual challenges of energy conversion and storage are addressed.² 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, until recently, the p-type concept had been largely unexplored since the first device was prepared in 1999.³ 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.⁴ In parallel we have investigated the charge-transfer processes to determine the mechanism and limitations to efficiency.⁵⁻⁷ This has increased our understanding of the redox processes at the dye/electrolyte and NiO/electrolyte interfaces.⁸

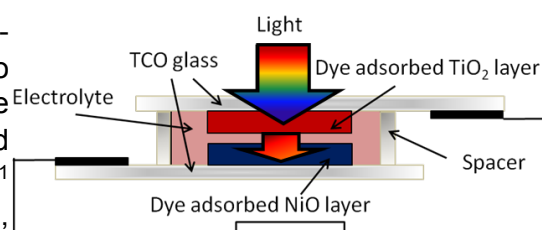


Figure 1. A Tandem dye-sensitized solar cell

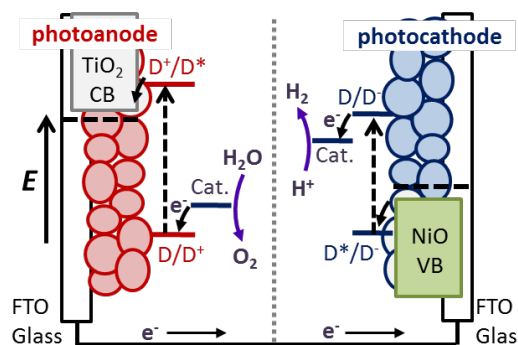


Figure 2. A photoelectrosynthesis cell for splitting H₂O.

Our research has led us to the conclusion that 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. n-Type transparent conducting oxides are present in many devices but their p-type counterparts are not largely commercialized as they exhibit much lower conductivities. The core part of our current project focuses on making

libraries of mixed metal oxides and selecting those which are promising p-type semiconductors.⁸ We are developing a high-throughput synthesis and screening system to enable us to accelerate the discovery and optimisation processes. Promising materials are assembled in tandem DSCs and tested. Our objectives are: A) Improve the efficiency of p-type dye sensitized solar cells and water-splitting cells by incorporating new p-type semiconductors which, for the first time, combine good transparency and high conductivity. B) Drive innovative engineering for the fabrication of high-efficiency low-cost tandem devices incorporating new photocathodes as a means of converting the majority of solar radiation striking the Earth. C) Underpin our research with state-of-the-art techniques for solar cell characterization to connect the fundamental research carried out at the molecular level and the events that take place in the device as a whole. Preliminary results with Ni Mg O and Ni Co O will be discussed together with the challenges faced in optimising the device as a whole.

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