

## Introduction

In conventional silicon solar cells, photons with high energy loses its energy via thermalization and so developing new materials, such as dye-sensitised solar cells (DSCs), that capture the high energy photons have shown promising efficiencies. Combining negative (n)-type and positive (p)-type DSCs onto a single p/n device (figure 1) should give rise to a substantial increase in photocurrent and therefore be of use in more efficient DSCs. By selectively choosing semiconductors that absorb the high energy photons on one semiconductor and low energy photons on the other, there is a possibility to utilize a wider range of the solar spectrum.

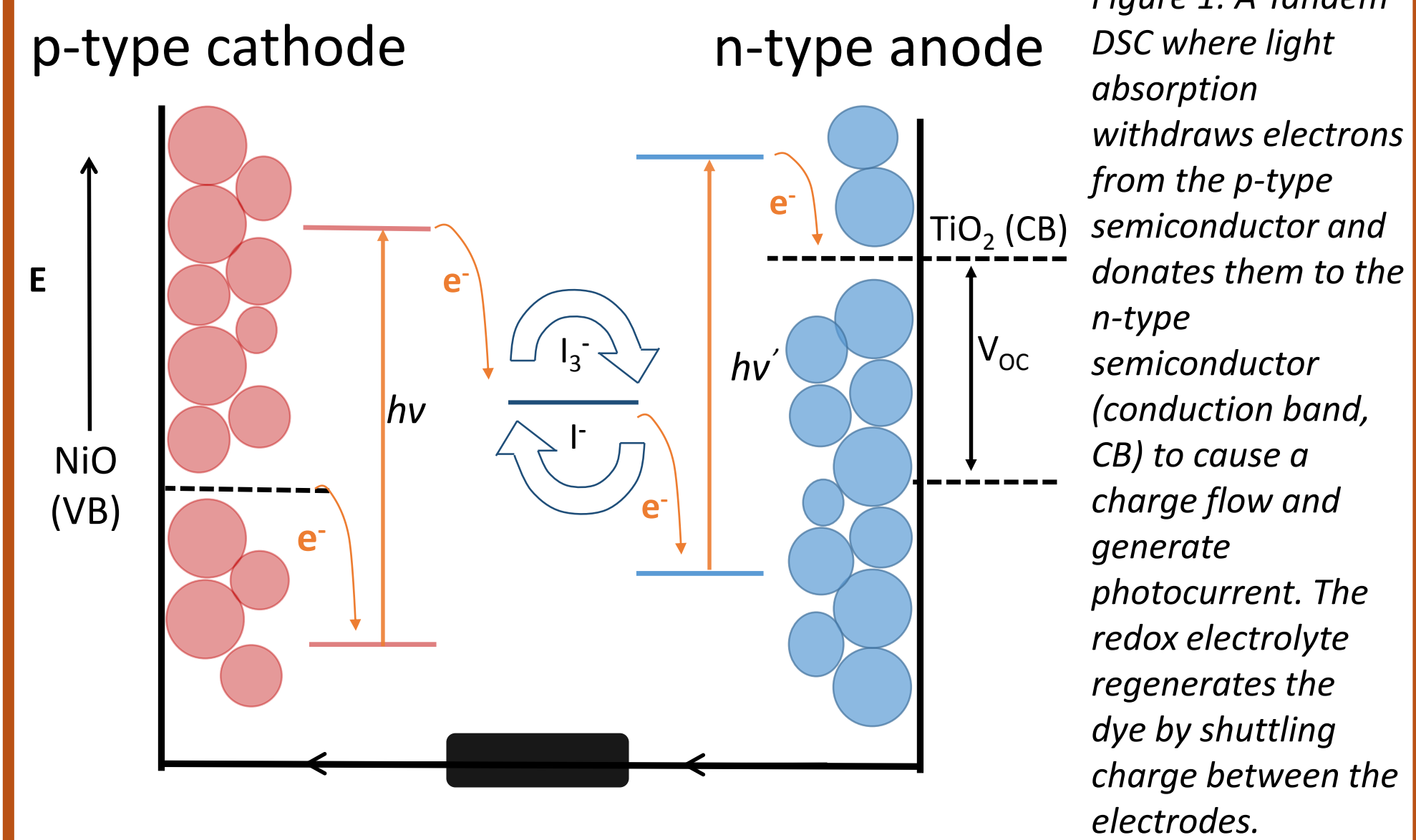


Figure 1: A Tandem DSC where light absorption withdraws electrons from the p-type semiconductor and donates them to the n-type semiconductor (conduction band, CB) to cause a charge flow and generate photocurrent. The redox electrolyte regenerates the dye by shuttling charge between the electrodes.

## Aims

- Synthesis of NiO nanoparticles and preparation of NiO films using the sol-gel method.
- Characterization of the NiO films by powder X-ray diffraction (XRD).
- Investigation of new p-type semiconductors based on copper-doped NiO.

## Method and Results

NiO electrodes were prepared using the sol-gel following the method by Gibson et al. Solutions were prepared by dissolving NiCl<sub>2</sub> (1 g) and the triblock copolymer F-108 (1 g) in a mixture of distilled water (3 g) and EtOH (6 g), resulting in a green sol-gel. Films were prepared by applying a thin layer of the sol-gel onto conducting FTO glass by doctor-blade in 3 cycles, annealing in a furnace in air at a ramping rate of 16°C/min, 8°C/min and 4°C/min between layers. XRD was used to identify the material composition (figure 2).

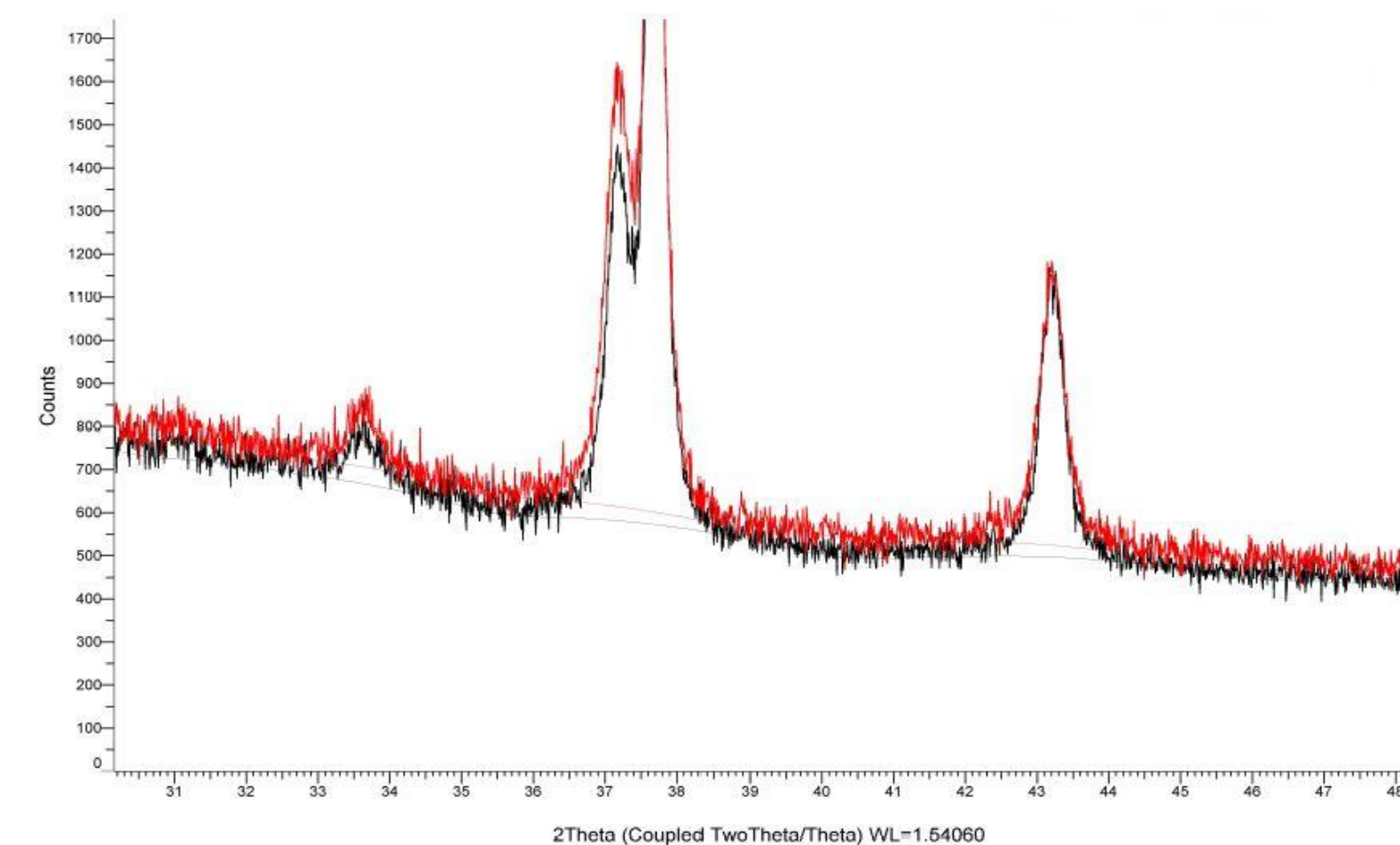


Figure 2: p-XRD pattern for nanocrystalline NiO selective peaks at the ramping rate of 16°C/min (black) and 4°C/min (red).

The NiO electrodes were soaked in an acetonitrile solution of two different dyes (Coumarin 343 and BODIPY, 0.3 mM) for 48 hours. The dyed NiO electrodes were assembled face-to-face with platinumized counter electrodes. The electrolyte, containing LiI (1.0 M) and I<sub>2</sub> (0.1 M) in acetonitrile, was introduced in the counter electrode, which was then sealed resulting in a working solar cell (figure 3) which produced a photocurrent of 70 μA cm<sup>-2</sup>.

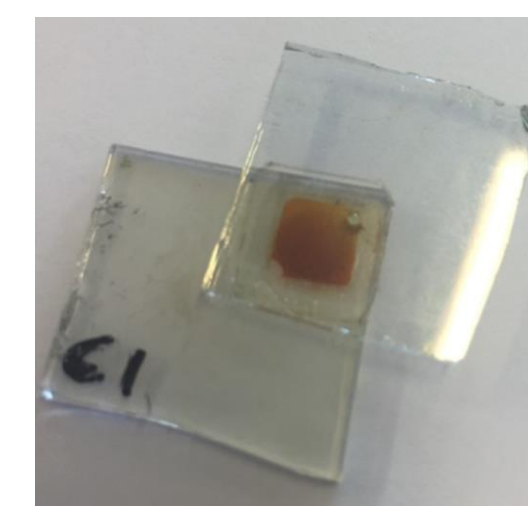


Figure 3: DSC using Coumarin 343 dye.

Copper-doped NiO films were prepared using the sol-gel method described in method, with a variation of copper atomic mol %, 0.1 mol %, 1 mol %, 5 mol % and 10 mol % of copper. Upon heating observation the 10 mol % Cu-doped NiO film had formed significant grey flaking which was then abandoned. The remaining films were assembled into a solar cell with P1 dye (0.3 mM) and tested to obtain a J/V graph, summarized in table 1. The J/V graph for 5 mol % is shown in figure 4.

| % mol. Cu | Photo-current (mA cm <sup>-2</sup> ) | Voltage (mV) |
|-----------|--------------------------------------|--------------|
| 0         | 2.5                                  | 46           |
| 0.1       | 1.55                                 | 18           |
| 1         | 1.13                                 | 31           |
| 5         | 2.43                                 | 15           |

Table 1: Photocurrent obtained from DSCs with a variation of copper mol %.

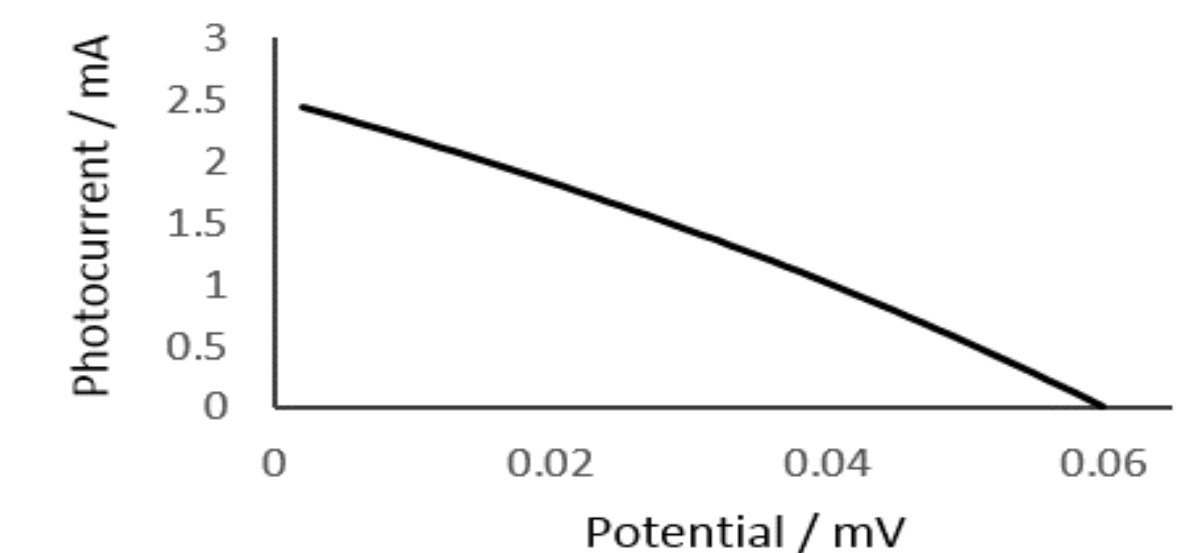


Figure 4: JV graph for 5 mol% to obtain a photocurrent of 2.43 mA cm<sup>-2</sup>.

## Conclusion

On analysis of the NiO films it was conducted that the optimum aging for the films was 7-8 days and this can be explained by the copolymer expanding as it takes up water to form a gel like solution. The p-XRD showed a clear difference is the intensity of the film at 4°C/min which can be concluded that at slower ramping rate there is higher crystallinity and therefore, if required selective crystalline size can be achieved. Initial results from Cu-doping shows 0.1 mol % and 1 mol % lowers the photocurrent whereas, 5 mol % does produce photocurrent and is the limit for atomic mol % of copper. These findings indicates potential to enhance the efficiency and provides future development of DSCs.

## References:

- M. Zannotti, C. J. Wood, G. H. Summers, L. A. Stevens, M. R. Hall, C. E. Snape, R. Giovanetti and E. A. Gibson, *ACS Appl. Mater. Interfaces*, 2015, **7** (44), 24556–24565.

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