Graphene and Graphene-oxide composites as back contact for dip-coated perovskite solar cells

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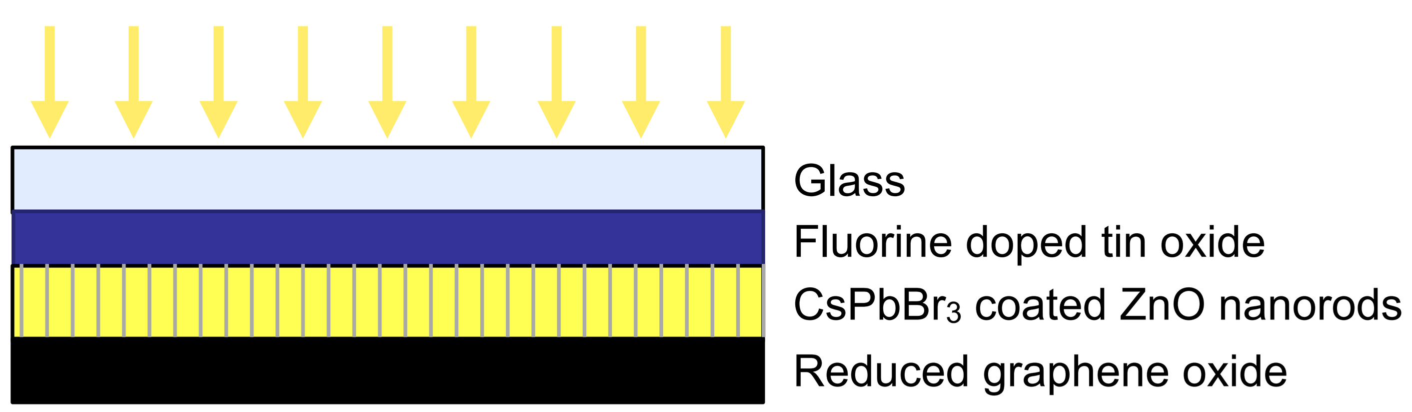
Introduction

Perovskite solar cells (PSC) are an emerging photovoltaic technology that promise high photo-conversion efficiency while remaining cost-effective. PCE's rose from 3.8% in 2009 to 22.1% in early 2016, making it the fastest growing solar cell type till now. Given the low expense and ease of scaling up production perovskite solar cells are very commercially attractive, and since the technology is fairly new there is a lot of potential that remains to be realised.

The cell functions on a principle similar to dye-sensitised solar cells. A photactive layer is nestled between a p-n junction. When light strikes the perovskite layer a potential difference is induced by the passage of an electron to the n-type semiconductor and a hole to the p-type semiconductor, the charge carriers are then transported by the electrodes at both ends to either store or power a circuit.

For this project I chose to work on testing the feasibility of reduced graphene oxide working as hole-extraction layer and back contact. Therefore, as both HEL and hole-transport layer.

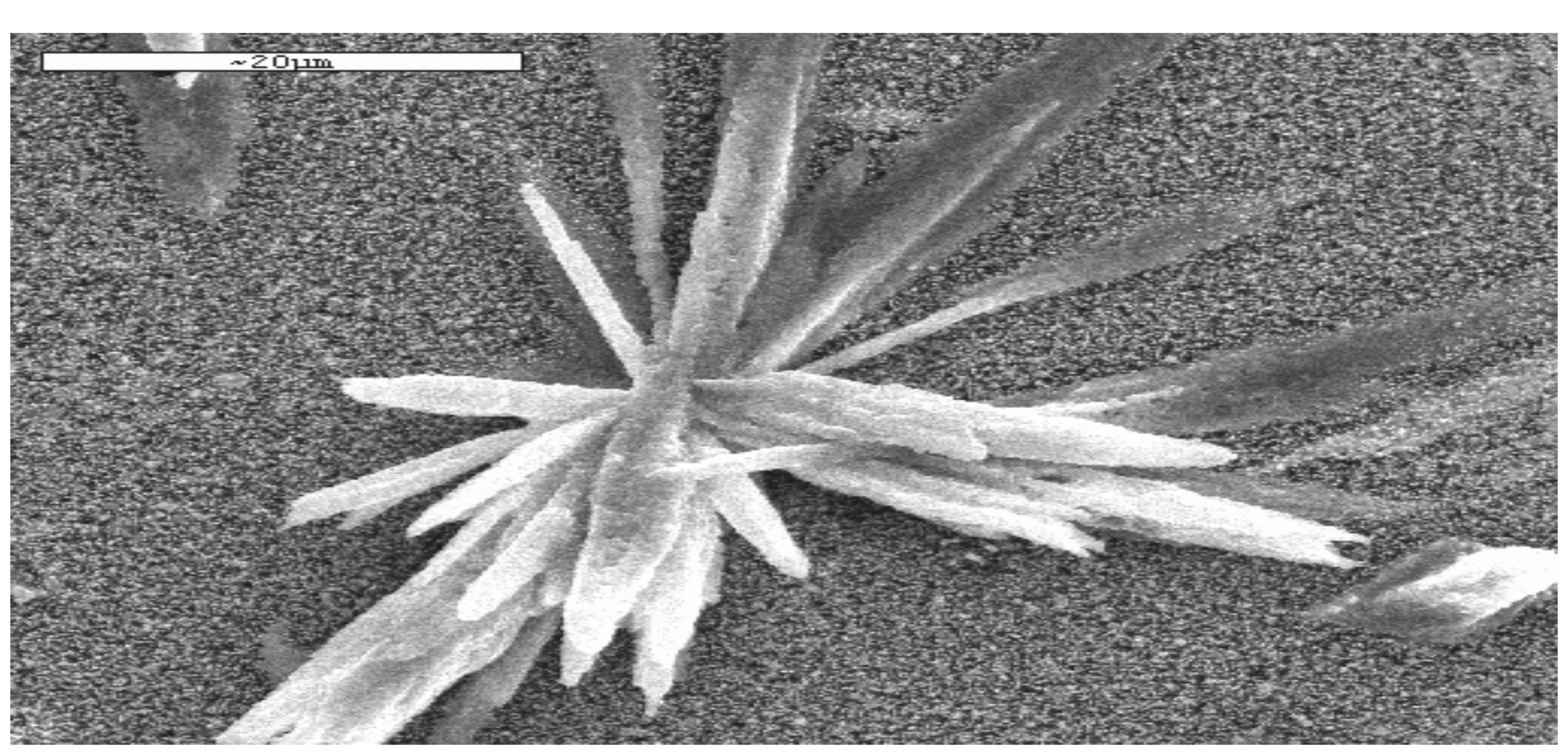


Methods

Yttrium-doped Zinc oxide nanorods work as both perovskite scaffold and electron transport to the FTO. These were synthesised by seeding the FTO with Yttrium and letting it sit in a chemical bath overnight. The resulting nanorods are shown in Fig1. Once annealed the sample was spincoated with a $PbBr_2$ solution, and then heated to 80°C. Once dry, the solution was dipped into a methanol solution of CsBr which resulted in an immediate change in hue due to the alignment of the perovskite crystals.

Graphene oxide was obtained through the modified Hummer's method, which through chemical exfoliation of graphite flakes yielded 2-dimensional graphene oxide layers. The powder was then photoreduced by placing in front of a UV lamp as shown in Fig4. The success of photoreduction was measured by X-ray diffraction.

Once photoreduction was determined to be an affective way to reduce graphene oxide a cell was constructed with graphene oxide spray coated atop the perovskite layer, and then photo-reduced resulting in the architecture shown above.



Data and images

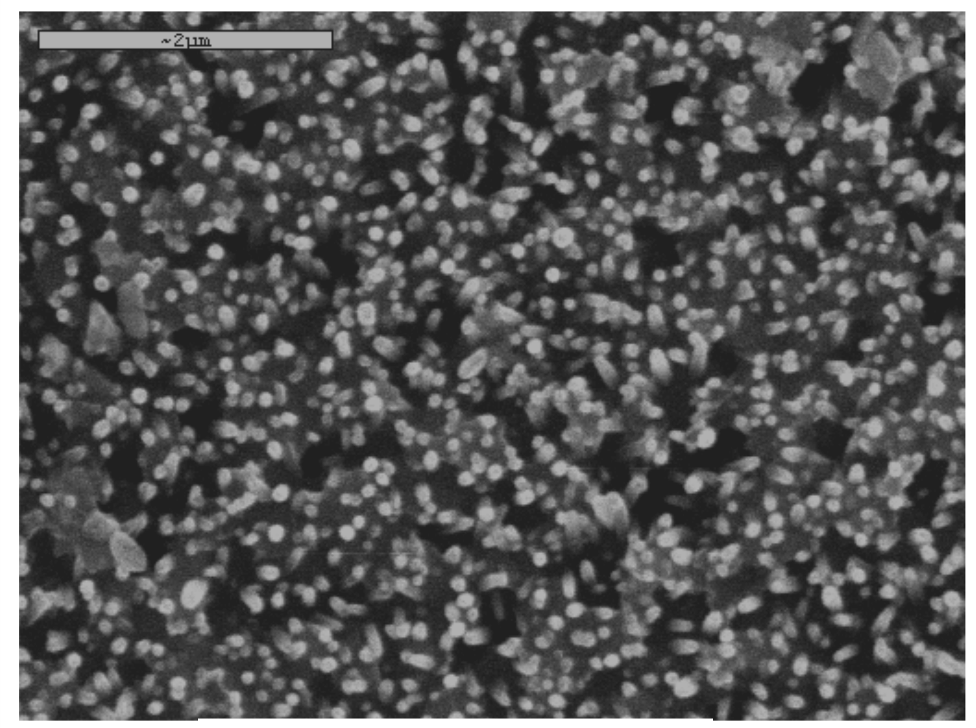


Fig1. Yttrium-doped ZnO rod morphology

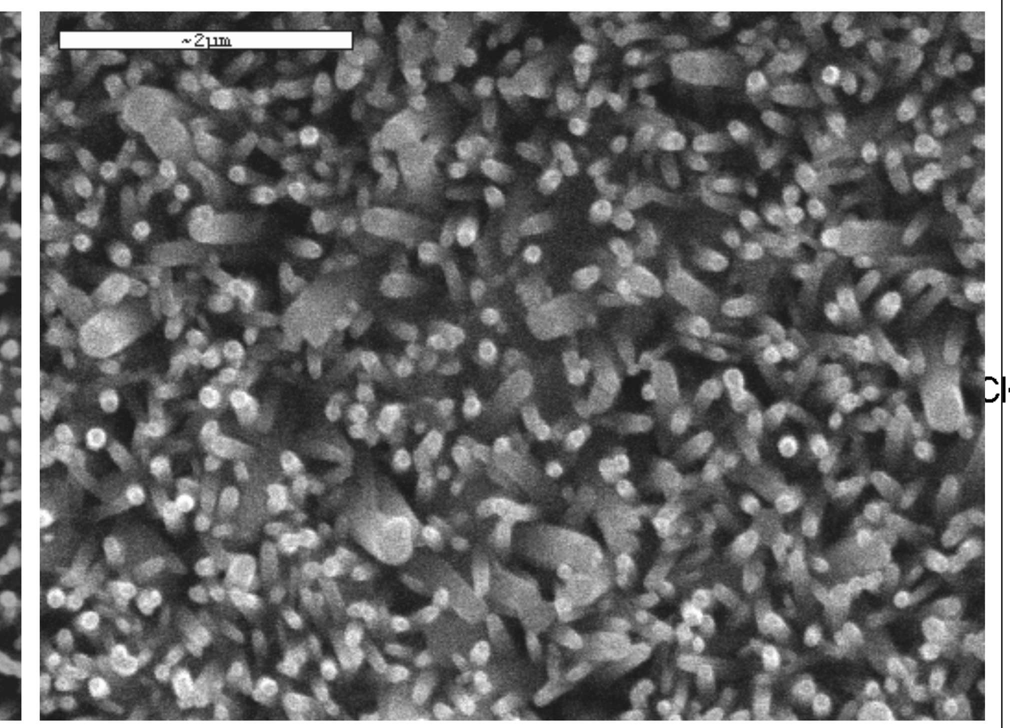


Fig2. Perovskite coated ZnO rods

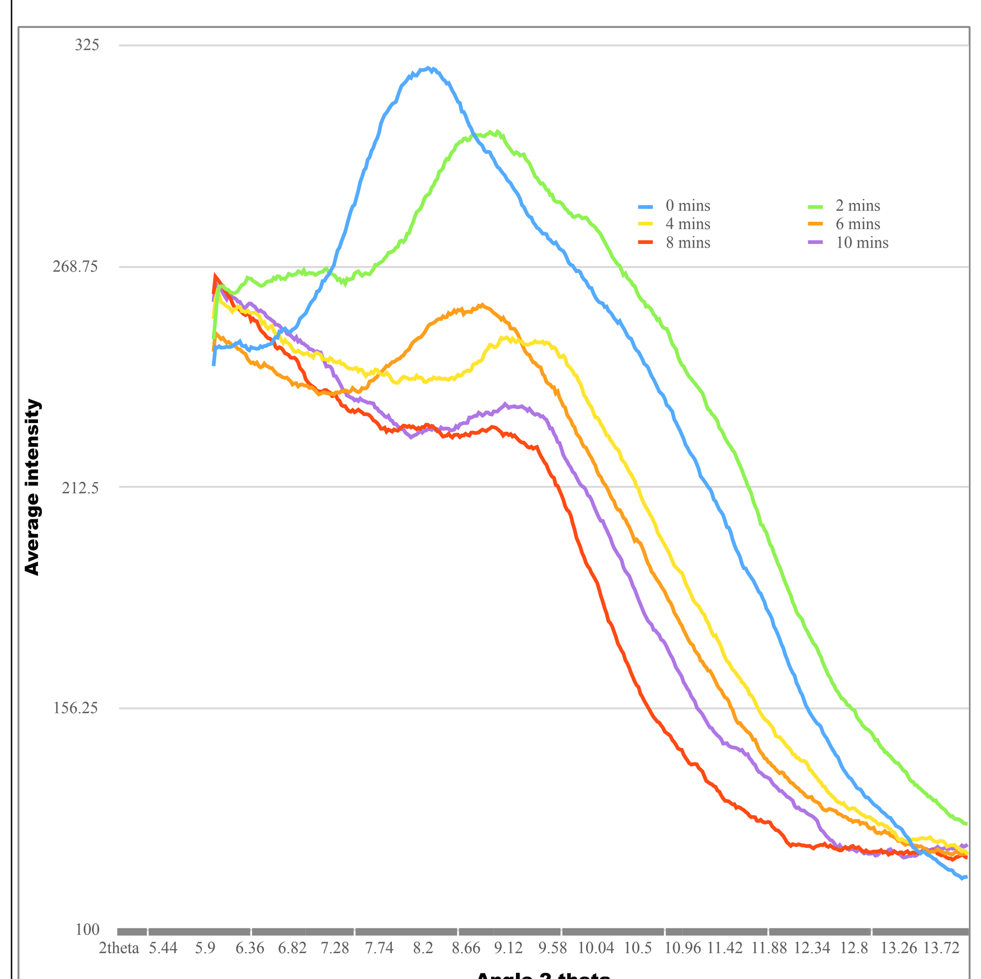


Fig3. Graphene oxide peak range

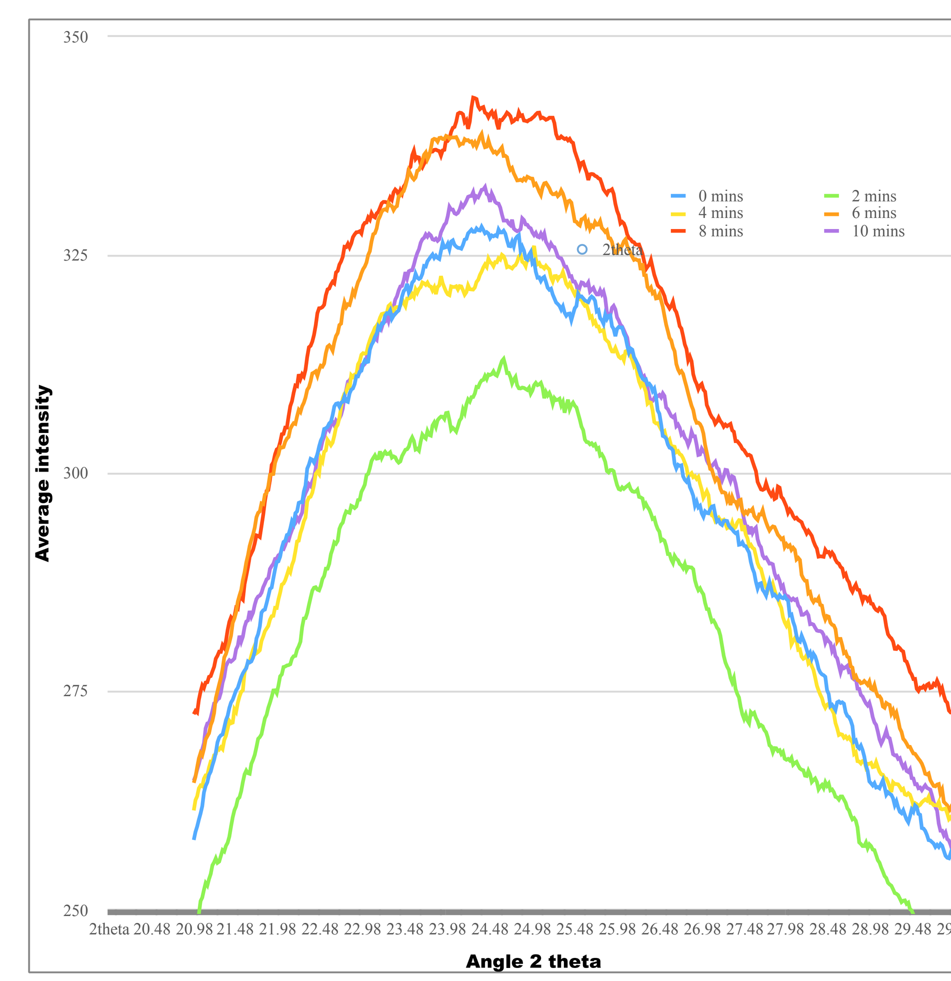


Fig4. Graphene peak range

Results

The proposed architecture, when tested, yielded a photo-conversion efficiency. The data of which is below:

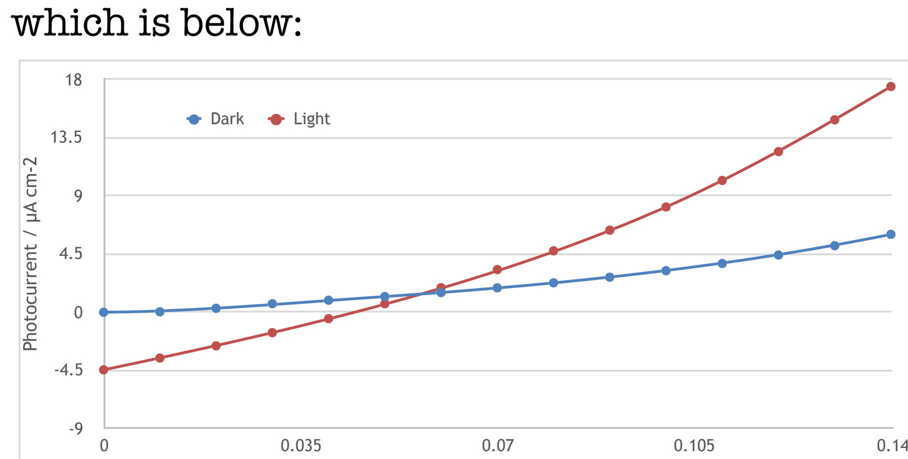


Fig5. Applied voltage against measured current

The calculations for the PCE are as follows:

$$PCE = Jsc * Voc * FF / Iin$$

Which yields a PCE of $5.2\,e^{-5}$.

Conclusion

The proposed architecture was successful, however it yielded a photoconversion efficiency below 1%. The reduced graphene oxide therefore can function as both hole-extraction layer and hole-transport layer, and the CsPbBr3-ZnO nanorod complex transports holes and electrons to their respective electrode, the efficiency of which is yet to be determined, as recombination could be another factor in low PCE value.

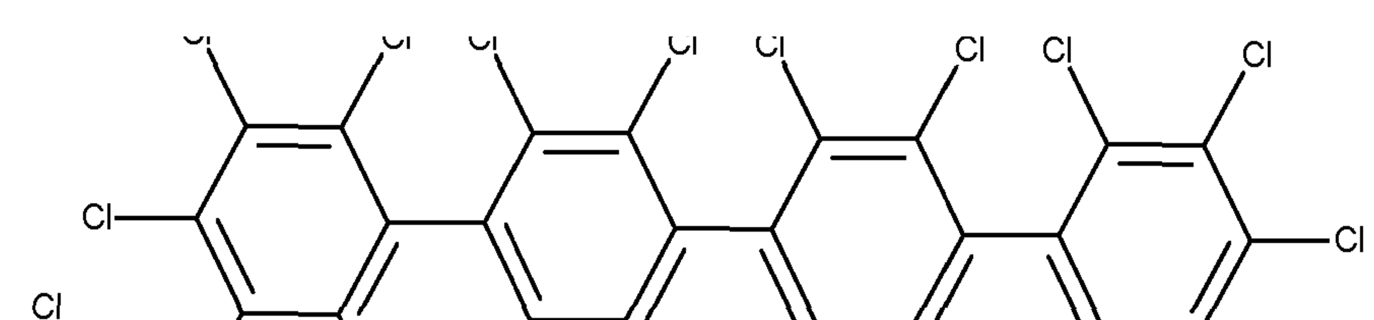
The perovskite deposition method will require more thought to ensure complete infiltration of the gaps between the nano-rods to ensure that the rods are coated completely.

Further improvements could be made on the reduced graphene oxide film, such as varying the method of coating and improving the degree of reduction by reducing in an inert environment.

Future Work

Future considerations are working with finer graphite for the improved Hummer's method to ensure a purer graphene oxide slution, with minimal graphite residue. This may enable the fabrication of a cohesive monolayer of graphene, which will allow the complete inversion of the cell and thus improve PCE.

Working with different types of perovskites such as $FA_{2/3}MA_{1/3}Pb(Br_{1/6}I_{5/6})_3$ and methyl ammonium lead iodide will help determine what perovskite compound is best compatible with this cell architecture.



References

Chen, C. Y., Lin, H. Y., Chiang, K. M., Tsai, W. L., Huang, Y. C., Tsao, C. S., & Lin, H. W. (2017). All-Vacuum-Deposited Stoichiometrically Balanced Inorganic Cesium Lead Halide Perovskite Solar Cells with Stabilized Efficiency Exceeding 11%. *Advanced Materials*, *29*(12), 1–7. https://doi.org/10.1002/adma.201605290

Dhingra, P., Singh, P., Rana, P. J. S., Garg, A., & Kar, P. (2016). Hole-Transporting Materials for Perovskite-Sensitized Solar Cells. *Energy Technology*, *4*(8), 891–938. https://doi.org/10.1002/ente.201500534

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Park, N. G. (2015). Perovskite solar cells: An emerging photovoltaic technology. *Materials Today*, *18*(2), 65–72. https://doi.org/10.1016/j.mattod.2014.07.007

Pei, S., & Cheng, H. M. (2012). The reduction of graphene oxide. *Carbon*, *50*(9), 3210–3228. https://doi.org/10.1016/j.carbon.2011.11.010

Zhou, H., Chen, Q., Li, G., Luo, S., Song, T. -b., Duan, H.-S., … Yang, Y. (2014). Interface engineering of highly efficient perovskite solar cells. *Science*, *345*(6196), 542–546. https://doi.org/10.1126/science.1254050