Perovskite-silicon tandem cells utilizing a semi-transparent silver nanowire composite electrode

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Over the last 4 years the rate of improvement in the efficiency of perovskite solar cells has surpassed that of any other solar cell technology. Device efficiency records stand at over 20%, with similar performance achieved in a range of architectures processed by a variety of different routes. Perhaps the most impressive characteristic of perovskite solar cells are their high open-circuit photovoltages, with the highest reported V_{oc} approaching 1.2 V for a material with a bandgap of around 1.55 eV[1]. The impressive ratio of V_{oc}/E_g is approaching that achieved by GaAs solar cells.

The bandgap of the traditional perovskite material, $CH_3NH_3PbI_3$, is close to being at the optimal energy for a top cell in a silicon tandem. With tuning of the perovskite chemical structure, for example by halide substitution or by using a different organic cation, the bandgap can be adjusted towards the optimum value of 1.73 eV[2]. The combination of the two cells allows the short wavelength part of the solar spectrum to be absorbed by the perovskite, which generates a higher voltage than the silicon would. The two sub-cells can be connected either in a monolithic 2-terminal arrangement or mechanically stacked as a 4-terminal tandem. These approaches have the potential to push device efficiencies beyond 30%[2].

We have utilised a semi-transparent composite silver nanowire electrode which can be deposited using a spray or spin coating technique. The layer has a sheet resistance below 10 Ω/□ with broad spectral transmission exceeding 80%. This was employed as the top contact in a TiO_2/Perovskite/Spiro-OMeTAD architecture cell. The bandgap of the perovskite layer was tuned using Br^- substitution to give a slightly wider, more optimal bandgap for Si tandem application. This has allowed us to produce semi-transparent perovskite cells with a PCE of 12% for a 1 cm^2 active area. A series connected 4-terminal tandem has a V_{oc} of over 1.6 V.

Stability of the device has been studied and improved using encapsulation techniques to reduce the effect of the reaction between silver and the perovskite. Advanced electrical characterisation techniques including TPV and impedance spectroscopy have been used to study the transparent perovskite device, with particular emphasis on investigating the origins and passivation of the relevant degradation mechanisms.

References

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2. M. H. Futscher and B. Ehrler, *ACS Energy Letters*, 2016, **1**, 863-868.