

Stability aspects of halide perovskite photovoltaic cells

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Halide perovskite (HaP) photovoltaic cells show great promise for practical application. It is generally agreed that the main question that needs to be answered before actualization of this promise is whether HaP-based cells can operate reliably over their required lifetime, generally taken as at least 20 years.

In this talk we consider various aspects of the stability of HaPs, both as isolated materials and incorporated in PV cells. There are many different types of stability measurements. In the first couple of years since the field began in earnest, stability most often referred to storage stability of the perovskite or of complete cells. More recently, stability now more commonly means cells operating under sunlight and often under maximum power conditions (in the end, the most important metric), sometimes under accelerated conditions of illumination intensity or temperature/moisture.

It is clear that moisture and sometimes air can degrade HaPs, but effective encapsulation, required for any long-lifetime PV cell, can prevent this. However, there are other factors, such as the effect of illumination (wavelength dependent), temperature, phase change and segregation, electrical bias (mainly maximum power voltage) and, in general, ion movement, that can impact cell lifetime and that might not be so amenable to engineering solutions. In this talk, we consider not only cell stability under normal operating conditions mentioned above, but also emphasize where some property of the HaP or HaP cells is to be measured, e.g. under electron beam or X-ray irradiation [1]. Since in any characterization of the perovskite material or cell, it is normally assumed that the measurement itself does not degrade the perovskite/cell (apart from stability measurement itself), such non-solar irradiation stability measurements are important.

Each element in the ABX_3 composition plays a role in stability. For the A cation, inorganic cations (usually Cs^+) result in much more thermally stable perovskites than the organic ones, and even the latter vary considerably between themselves. In fact even a relatively small percentage of Cs in an otherwise organic A cation improves stability and can also improve phase stability. For the B cation (usually Pb but sometimes Sn or other cations), Sn is in general much less stable, believed to be due to self-doping due to facile Sn(II) to Sn(IV) oxidation. Finally, while usually less critical, the nature of the halide is of some importance, bromides generally being more stable than iodides.

Another important factor is the effect of other cell components on cell stability. Of course this can be due to instability of one or more of these components. However, it may also be due to the effect of one of these components on the perovskite itself. Examples of this are the effect of UV radiation on the TiO_2 interface [2] or when the perovskite is deposited, under certain conditions, onto ZnO in inverted cells, when perovskite degradation occurs even before the cell is completed [3].

Finally, it is worth noting that almost all operational stability studies were carried out under constant illumination, in contrast to the day-night conditions that actual (terrestrial) cells will experience. Changes in cells that might occur under constant operation, in particular those that might involve ion migration, may be reversible (to a greater or lesser extent) when they are exposed to a day-night regime.

- In collaboration with David Cahen

References

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