Optimization of Encapsulation Architecture for an efficient external barrier under Damp Heat aging tests

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The emerging solar cell technology based on metal halide perovskite materials has unlocked a new potential for PV field [1]. Currently, the certified conversion records are set at 33.7% for PK/Si solar cells [2]. Stability is a significant concern because perovskite-based solar cells display intrinsic and extrinsic stability challenges when subjected to varying environmental stress factors, notably temperature, light soaking, and ambient conditions, especially in the presence of oxygen and humidity. Moisture and oxygen exposure leads to rapid degradation of the Perovskite layer, compromising the module's performance and lifespan. To address this degradation caused by moisture and oxygen, it is crucial to protect the active layers from the external environment, while maintaining their functionality. Therefore, encapsulation of Perovskite Solar Devices plays a vital role in extending their lifetime and advancing towards commercialization, making it a key focus in research endeavors. While several research review on perovskite stability, fewer report are dedicated to the encapsulation of perovskite [3]. Accordingly, this study focuses on the impact of encapsulation on extrinsic stability. Several materials and processes are under benchmark and will be presented, in this abstract, we focus on a low cost and efficient process with PIB (PIB-PO - Polyisobutylene-polyolefin) encapsulation architecture (fig. 1).

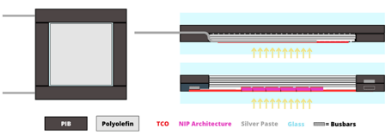

Fig.1 –PO-PIB encapsulation architecture and module constraints

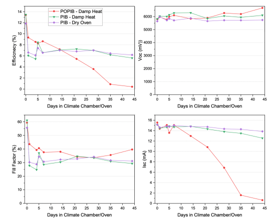

Fig 2. – Electrical performances of ST PK modules under aging tests

Validation of the encapsulation architecture with passive PK filter - Perovskite thin film absorber is very sensitive to the humidity condition. To validate the external environment barrier efficiency, IEC 61215-2 standard, also call Damp Heat tests (85°C – 85%RH) have been used for this study into a climatic chamber. If we initially observed rapid degradation on our first PO-PIB encapsulation architecture, we demonstrated the PIB as edge sealant alone is an efficient barrier in D.H. condition between glass substrate and glass cover (> 2000 h). The PIB is generally used in glass/glass configuration, however, the modularization of perovskite implies several barrier constraints: TCO as substrate, busbar charge collection and laser scribing pattern. We also observed a particularly good external barrier effect under DH using TCO substrate, busbar connections and laser scribing pattern. Thanks to that, it has been possible to observe the weakness of PO-PIB architecture was due to a leak of PO through the edge sealant material during the lamination. This leak is a preferential way for humidity ingress.

Influence of Damp Heat scenario on the stability of Perovskite modules - Thanks to our prior results with passive perovskite filters, we have studied the evolution of electrical performances of perovskite modules during D.H. aging. NIP (FTO/TiO_2/PK/PTAA/ITO) ST modules with an aperture area of 4 cm^2 have been used for this study (fig.2). To determine the influence of both humidity and/or thermal stress, PIB encapsulated modules have been placed in parallel in two different conditions: D.H. (85°C – 85 RH%) and dry oven at 85°C. In case of PO-PIB encapsulation we clearly saw a sharp degradation of the Perovskite layer and both Fill Factor and short circuit current that confirm our previous observation. In the case of PIB encapsulated modules, Perovskite show no visible degradation but a sharp decrease of the FF. Through iv analysis that fill factor degradation are correlated with the s-shape distortion of the curve. In contrast short-circuit current and V_{OC} remain relatively stable.

To conclude, D.H. aging tests demonstrate the weakness of our first PO-PIB architecture, thanks to that it would be possible to optimize lamination process with PO-PIB that is crucial for 4T tandem terminal integration. In complement, this study highlights the importance of both have internal and external stability of perovskite module to pass the damp heat qualification.

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