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Durability Testing and Post-fabrication Processing of Organic/inorganic Perovskite Solar Cells

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Metal halide organic/inorganic perovskite solar cells (PSC's) have undergone remarkably rapid progress in the power conversion efficiency (PCE) increasing from 3.8 % to 22.7 % in merely 8 years. Coupled with their potential for low fabrication cost, perovskite solar cells are the most promising photovoltaic (PV) technology to challenge the dominance of silicon PV, either as a standalone perovskite cell or as a tandem device. PSC technology has a few potentially show-stopping obstacles remaining, however, before it can be fully commercial viable. One of them is the instability against environmental elements such as moisture, heat and light. In this work, innovative encapsulation using low-cost and high-performance polymeric sealants are used to address the moisture and heat instability. Results of a "Calcium Test" demonstrated the superb effectiveness of the encapsulation against moisture ingress. The PSC's used as the device-under-test have a structure of glass/FTO/c-TiO_2/mp-TiO_2/$Cs_{0.05}FA_{0.80}MA_{0.15}PbI_{2.55}Br_{0.45}$/PTAA/gold and suffered no PCE degradation after the encapsulation process. We subjected the encapsulated PSC's to three relevant IEC61215:2016 accelerated lifetime tests. Ex-situ current-voltage measurements were performed regularly under simulated AM1.5G sunlight to monitor changes in PCE. We managed to pass: i) Thermal Cycling test (-40 °C ←→ 85 °C, 200 cycles), ii) Damp Heat test (85 °C/85% RH, 1000 hours), and iii) Humidity Freeze test (-40 °C ←→ 85 °C/85% RH, 30 cycles, preconditioned with 50 thermal cycles). We believe these are so far the best accelerated lifetime testing results on metal halide organic/inorganic perovskite solar cells.

We also investigated the effect of post-fabrication processes on device PCE. The effect of pressing (which is inherent in an encapsulation process) at room temperature on the PCE of mesoporous PSC's was studied. Cells with the structure glass/FTO/c-TiO_2/mp-TiO_2/$(FAPbI_3)_{0.85}(MAPbBr_3)_{0.15}$/spiro-OMeTAD/gold and with as-fabricated PCE of 17-18 % were used. It is found that pressing is beneficial for most state-of-the-art PSC's improving their PCE (over 10% relative). The effect of pressing was characterised by light current density-voltage measurement (LJV), cross-sectional scanning electron microscopy (SEM), X-ray diffraction (XRD) and electrical impedance spectroscopy (EIS). It is also found that pressing-induced degradation can occur for PSC's depending on cell structure. This work shows the benefit of pressing which is an essential part of an encapsulation process on PSC's, and inspires future development of encapsulation and packaging for PSC's which involves pressurisation.