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Outdoor study of photovoltaic mini modules with different perovskite compositions

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☐ Oral presentation preferred ☒ Poster presentation preferred

Perovskite mini modules with different structures have been installed outdoors to detect differences in their long-term performance that can be attributed to their composition. Four (4) perovskite mini modules with composition $Cs_{0.18}FA_{0.82}PbI_{2.82}Br_{0.18}$ and four (4) perovskite mini modules with composition $Cs_{0.05}FA_{0.85}MA_{0.10}Pb(I_{0.97}Br_{0.03})_3$ have been exposed outdoors in the period between the end of May 2022 and the end of July 2022. Several identical mini modules of the same structure were tested to have better statistical data from samples of the same type. Alongside the current-voltage (IV) traces of the devices, environmental sensors have been used to collect the solar irradiance in the plane of the array, the ambient and device temperatures, the wind velocity, and the humidity/precipitation levels. The IV traces were recorded every 10 minutes and both forward and reverse sweeps were implemented each time. Between each IV scan, the devices were kept at open circuit while a sweep rate of 1 V/sec was applied during the IV scans. Control mini modules of each structure were kept indoors in the dark. Spatially resolved Electroluminescence (EL) and Dark Lock-In Thermography (DLIT) measurements were performed on the mini modules before and after outdoor exposure to detect defects and hotspot evolution attributed to outdoor exposure.

Statistically significant differences in the efficiency degradation between the two different types of perovskite composition could not be detected. Significant degradation occurs in most mini modules over the first two weeks of outdoor operation. However, most of the three-cation perovskite mini modules showed greater degradation than the two-cation perovskites ones over the same testing period. The performance degradation of the three-cation perovskite mini modules is mainly associated with voltage losses obtained in the first days of outdoor operation. Voltage losses up to 37% were detected in the samples indicating ion migration, which results in defect formation. The presence of methylammonium (MA) species likely boosts ion migration effects in the three-cation devices. Another possible reason for the accelerated degradation of the three-cation perovskite mini modules could be the utilisation of a gas quenching technique that is not optimised for the specific composition. Short-circuit current losses were found to be significant in all the two-cation perovskite mini modules. On the other hand, comparable short-circuit current losses were not detected in all the three-cation perovskite mini modules. EL imaging of the mini modules before and after field testing revealed significant changes in the EL emission of devices.

In summary, greater degradation was obtained in most 3-cation perovskite devices and is attributed to substantial voltage losses. The presence of MA species boosts ion migration effects and defect formation which results in accelerated performance degradation. Better outdoor performance stability was obtained in the two-cation perovskite devices over the testing period.

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