Outdoor Long-Term Stability of Perovskite Modules

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Extensive research were conducted to enhance the efficiency of perovskite solar devices, where they are achieving performance record of 25.7% and 33.7% for single junction and tandem PK/Si respectively [1]. Nonetheless, the challenge for their commercial remains on the long-terms stability [2]. Predominantly, research efforts have been focusing upon aging under controlled environments, namely, light soaking (ISOS-L) and damp heat (DH)[3]. In contrast, as reported in literature that the degradation trend observed under continuous illumination may be different than those experienced in real-world operating environments [4]. Accordingly, this study focuses on assessing the stability and performances of perovskite solar modules on outdoor conditions. A comparative analysis with the behavior of silicon-based technology will also be presented.

A 16 cm² NIP perovskite modules developed at IPVF was used in this study, that correspond to the following stack: glass substrate, fluorine-doped tin oxide (FTO), titanium dioxide (TiO2), mesoporous titanium dioxide (mp-TiO2), triple-cation perovskite absorber, poly(triarylamine) (PTAA) hole transport layer (HTL), ITO electrode. Outdoor tests were conducted in collaboration with the SIRTA platform. Samples were placed at a 27° south-facing angle in Palaiseau, a Cfb climate zone. In addition to electrical performance measurements, irradiance and temperature are monitored during the whole test duration.

Results of electrical parameters, irradiance, and temperature evolution as a function of exposure time are presented in figure 1-left, for a duration of 2000 hours. A stable behavior in time is observed for both V_{OC} and normalized J_{SC}, where the values at the beginning of the test are more dispersed compared to those at the end of the test. However, in case of FF, a slight degradation is observed after 200 hours. Then it starts recovering in the form of steps where it reaches initial values after 1600 hours. Through I-V curves analysis the degradation was linked to the presence of the s-shape distortion. This type of behavior can be due to charge accumulation or an increase of surface recombination [5]. The initial recovery phase (depicted in blue) was linked to the elimination of the S-shape distortion, while the second phase (illustrated in black) corresponded to the mitigation of the series resistance impact. Consequently, the efficiency is primarily influenced by the behavior of the FF, which maintains over 80% of its original values. To explore the dependence of the module at both hourly and daily scales, data are plotted against the local time (see fig. 1-right). In the case of FF, slight degradation is observed at the midday that was attributed to effect of series resistance due to higher current. However, the normalized J_{SC} show quick increase and decrease at the beginning/end of the day, while remaining considerably stable in between. As a result, on daily scale, the efficiency trend is driven by the J_{SC} one. Further analysis will be presented namely, (i) temperature effect (ii) UV index and (iii) DNI/GHI effect. It is worth noting that the modules have passed ISOS-O3 test, achieving remarkable 2000-hour for T80.

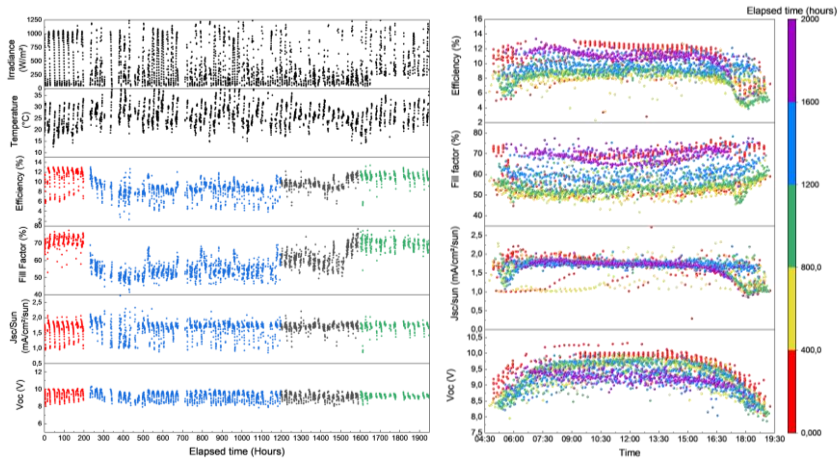

Fig. 1 Left: electrical parameters, irradiance and temperature as a function of elapsed time (right): electrical parameters as a function of local time.

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