Large Area 4-Terminal Tandem PK/Si Outdoor Testing

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The emerging solar cell technology based on metal halide perovskite materials has unlocked a new potential for revolutionizing the PV field. Indeed, extensive research has been carried out on the improvement of the photovoltaic conversion efficiency by optimizing the different layers of the stack and/or the manufacturing process. Currently, the certified conversion records are set at 25.5%[1] and 29.5%[2] single junction and monolithic tandem PK/Si cells respectively.

However, other characteristics must be met in order to reach the commercial level such as long-term stability. Due to the problems related to scaling up, mainly studies are conducted with small single junction samples (<1 cm²) with a focus on indoor conditions. A recent study[3] has shown that the degradation mechanisms observed between aging under indoor and outdoor conditions can be different depending on the perovskite technology. Pronounced degradation is observed for cycling performed at outdoor than in indoor conditions. Hence the interest to study the behavior of this technology in realistic working conditions.

In order to investigate the effect of real operating conditions, a 2x2 cm² perovskite mini-module with four cells connected in series and a 4-terminal tandem PK/Si of 4x4cm² were used. The perovskite solar modules were developed and fabricated at IPVF in a mesoporous n-i-p configuration (FTO/TiO_2/PSK/PTAA/Au). In the case of tandem PK module, ITO is used for back contact due to its semi-transparency. The Si bottom sub-cell in the tandem module is set as reference.

Outdoor performances were measured in the city of Palaiseau on the SIRTA[4] platform (see Fig. 1-left) where the samples were placed facing South at an angle of 30°. The irradiance profile was measured using a calibrated Si photodiode on the Plane-Of-Arrays (POA). Additional detectors such as pt100 thermocouples were placed at the back surface of the modules for temperature recording during daily variation. As for the electrical characterization, I-V measurements were conducted each 10 min with V_{OC} tracking. This experimental set-up corresponds to the ISOS-O-2 protocol defined in the consensus statement for PSCs reliability testing[5].

Fig. 1 shows the main I-V electrical parameters variation (normalized I_{SC} and FF) as a function of time of the day (irradiance intensity) on a typical sunny day. Taking the example of the normalized I_{SC}, it shows stable values at intensity higher than 500 W/m². However, at low intensity it increases by increasing the irradiance intensity. This can be explained by the non-linearity of the I_{SC} at low intensity. In the case of fill factor, low hysteresis is observed at middle of the day compared to the beginning/end of the day. This behavior is most likely related to the intensity level rather than the temperature variation. For the first time the behavior of large area tandem PK/Si devices was studied in real operating condition. We have shown through this study a good stability of this architecture for 800h.

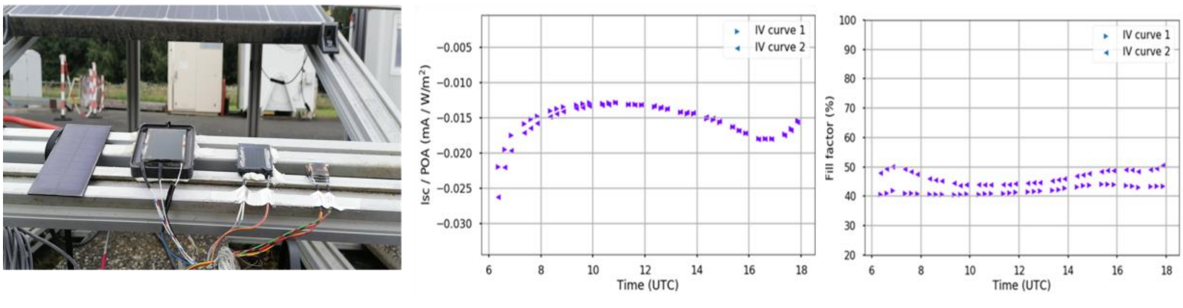

Fig. 1 Left: photograph of the perovskite samples placed on the SIRTA platform for outdoor testing. Right: variation of normalized I_{SC} to the POA and FF as a function of time of the day for FW and RV I-V curves.

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