Thermal Behavior of Perovskite Solar Cells

Karim Medjoubi[1], Yves Abou Khalil[2], Marion Provost[1], Estelle Cariou[1], Iwan Zimmermann[1], Muhammed Kunnummal Mangott[1], Armelle Yaiche[2,1], Jean Rousset[2,1], Jorge Posada[2,1]

[1] Institut Photovoltaïque d'Ile-de-France (IPVF), 18 boulevard Thomas Gobert, 91120 Palaiseau, France

[2] EDF R&D, IPVF, 18 boulevard Thomas Gobert, 91120 Palaiseau, France

Perovskite solar cells (PSCs) have garnered significant attention within the photovoltaic community in recent years. Currently, the certified conversion records are set at 25.7% and 33.7% single junction and monolithic tandem PSCs/Si cells respectively [1]. However, other characteristics must be met in order to reach the commercial level such as long-term stability and addressing thermal behavior for perovskite based devices [2].

The main objective of this study is to investigate the durability of halide-based PSCs when exposed to thermal cycling under illumination. The solar cells were subjected to 50 cycles, ranging from -40°C to 85°C (cells temperature reaching -5°C and 105 °C resp.), under an irradiance of $1000W/m^2$. To assess the changes in electrical performance, I-V characterizations were conducted every 5 minutes, while maintaining maximum power point tracking (MPPT) between measurements. This testing follows the ISOS-LT3 protocol outlined in the summit consensus report for stability testing [3]. Two analyses can be performed: (i) assessing the stability of PSCs withstand thermal stress by measuring their resistance against extreme temperatures and potential layers delamination; (ii) evaluating the temperature coefficient of the perovskite material used in these cells.

Figure 1-left illustrates the changes in normalized power over time, corresponding to different operating temperatures. When the temperature is above 50°C, there is an initial improvement in performance for the first 30 hours, followed by a stable period. In contrast, when the temperature is below 50°C, there is a gradual decline in maximum power as exposure time increases. It should be noted that others perovskite architectures and compositions have been studied and do not exhibit this same pattern of behavior. In order to determine the temperature coefficient, key electrical parameters are plotted with respect to temperature in Figure 1-right below. Diverse temperature coefficient values are computed across the specified temperature range. Regarding V_{OC} and J_{SC}, an inversion in temperature coefficients is evident at 40°C, with positive coefficients below this threshold. Dupré et al. reported that that the increase of V_{OC} with temperature can be explained by the increase of bandgap [4]. To explore the bandgap variation with temperature, Quantum efficiency measurement will be presented. Considering FF, three different positive temperature coefficients are derived within the intervals [-5°C-30°C], [30-80°C], and [80°C-105°C]. Furthermore, it is noteworthy that the inversion temperature is notably influenced by the degradation level. To the best of our knowledge, this behavior remains unreported in literature. The evaluation of the temperature coefficient plays a crucial role in gaining a comprehensive understanding of the performance of perovskite materials when subjected to real environmental conditions, with a specific emphasis on its applicability to 2T tandem devices optimization.

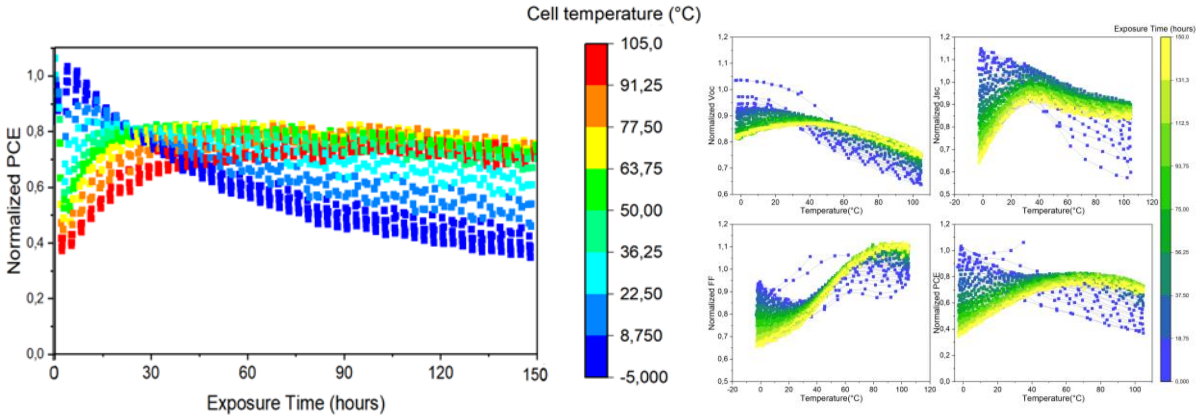

Fig. 1 Left: normalized Pmax as a function of exposure time color mapped to temperature. Right: electrical parameters variation with temperature.

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