Large-scale hyperspectral photoluminescence imaging applied on full-size perovskite mini-modules: focus on the effects of back contact (P1) patterning

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In the context of the research on the up-scaling of the perovskite-based solar cell technology, there is a need in characterizing samples which size can go up to industrial modules (160 x 160 cm² or even 185 x 185 cm²) in order to understand the mechanisms involved in their functioning at these scales. Especially important is the characterization of the large-scale homogeneity. Often used techniques to characterize it are visual inspection [1], Light-Beam-Induced Current (LBIC) [2], Dark Lock-In Thermography (DLIT) [3], ElectroLuminescence (EL) [3] or PhotoLuminescence (PL) mapping [4]. Rakocevic *et al.* [3] also performed Micro PhotoLuminescence Spectroscopy (µPLS) mapping on modules of size 4cm² and 100cm² with 200µm spatial resolution. Here, at IPVF, we set up a wide-field hyperspectral photo- and electro- luminescence imaging characterization technique. Its unique in Europe field of view, for this type of instrument, covers up to 185 x 185 cm² and thus is perfectly adapted for the need of large size characterizations. As µPLS mapping, it allows to determine the photo-(but also the electro-) luminescence spectrum at each pixel of the image with a spatial resolution of 150 µm. The difference with the µPLS mapping results of the acquisition of the signal coming from the entire field of view in each image and thus the illumination of the full sample and not only a localized spot. The photoluminescence part allows to perform contactless and non-destructive investigations on full modules but also on materials during the process, which helps to identify the steps to be optimized in order to maximize the module's efficiency. Whereas the electroluminescence part allows to take into account the electrical transport efficiencies. The spectral range covered by the instrument goes from 400 nm to 1600 nm allowing to analyse many kind of materials for solar cells as well as tandems.

In this work we used this instrument to study 5x5cm² perovskite mini-modules containing 10 cells, with a focus on the effects of the back contact (P1) patterning. We highlight the effects of presence of shunts on the inhomogeneity of PL intensities between the cells and on their different aging behaviours (see the Figure). We use absolute calibration to fit the spectra in order to perform a deeper analysis of the differences between the cells and their evolution with time.

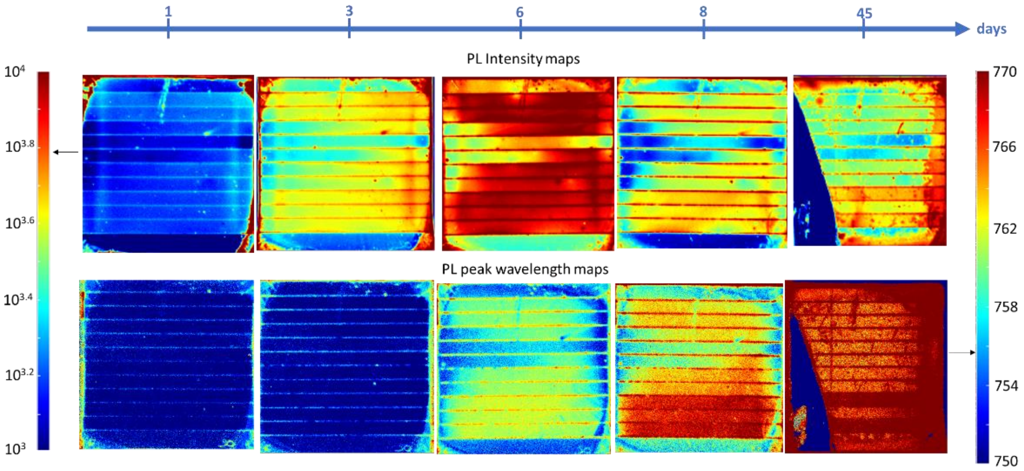

Figure 1 : PL Intensity (top) and peak position (bottom) maps of 5x5cm² perovskite mini-modules, and their evolution with time (from left to right). While differences between the cells are first visible in PL intensity maps, they also appear with time in peak position maps.

[1] Taherimakhsousi *et al.*, npj Comput Mater **7**, 190 (2021) ; [2] Matteocci *et al.*, ACS Appl. Mater. Interfaces **11**, 25195 (2019) ; [3] Rakocevic *et al.*, Sol. RRL **3**, 1900338 (2019) ; [4] Yang et al., Science Advances **7**, eabg3749 (2021)