Unveiling local grain-dependent optoelectronic properties in perovskites solar cells via characterization techniques for mapping & imaging

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In perovskite solar cells, local variations in photoluminescence (PL) response could sometimes appear brighter or dimmer, redshifted or blueshifted. This can be linked either to differences in grain size, local compositional inhomogeneity during crystal growth, or even compressive strain due to the deposition of upper layers and interfacial modifications[1,2]. Using correlated hyperspectral PL, electroluminescence (EL), and scanning electron microscopy (SEM) imaging, we spatially map and connect optoelectronic variations to morphological features such as surface deformations, often resulted of mechanical stress points and local thickness variations due to various defect densities. This is clearly noticeable in figure 1(a), where the dark red dots on the shunted cell indicate electrical conduction without corresponding optical activity and may be a signature of shunt defects[3]. These underlying morphological causes affect both electric field distribution, carrier extraction and even can create shunts[3,4]. Our multimodal imaging approach thus provides direct insight into how local structural, composition (see figure 1(b)) and electronic properties are interrelated, enabling a deeper understanding of perovskite film formation and offering new pathways for detecting and minimizing defects in next-generation solar cells.

Therefore, to gain a comprehensive understanding of each of these following mechanisms impacting the p-i-n; FTO/NiOx/SAM/double cation perovskite/C60/SnO_2/ITO/Ag architecture, we applied various imaging characterization techniques (such as, PL, confocal microscopy, SEM, EDX, AFM etc.) as shown in figure 1(b). These analyses were performed both at the beginning of life (BOL) and end of life (EOL) stages following the ISOS-L1 aging test and were complemented by optoelectronic measurements.

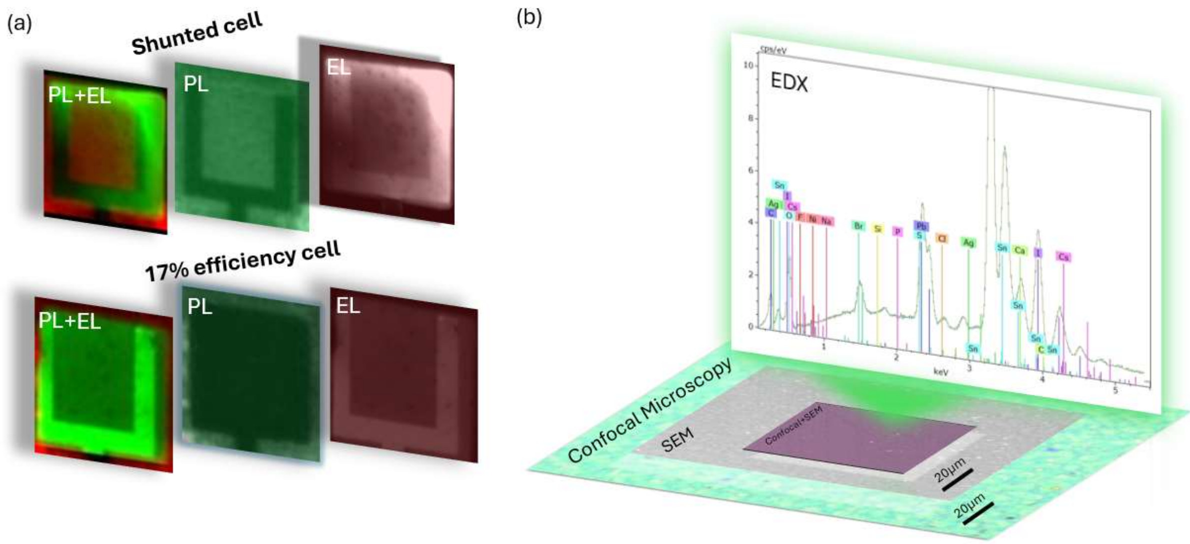

Figure1. ***(a)*** *Comparison of a shunted perovskite solar cell (top row) and a 17%-efficient device (bottom row) using multimodal imaging. Each row displays the PL+EL superposition (green = PL, red = EL), standalone PL, and standalone EL images.* ***(b)*** *3D schematic of correlative surface characterization combining SEM, confocal*

microscopy, and EDX analysis. The EDX spectrum reveals the elemental composition of the absorber region, supporting the spatial mapping of morphology, defects, and compositional inhomogeneities.

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4- de Quilettes, Dane W., et al. "Impact of microstructure on local carrier lifetime in perovskite solar cells." *Science* 348.6235 (2015): 683-686.