Title : Quantitative characterization of solar cell from bias-dependent electroluminescence imaging

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The electroluminescence is a versatile tool to investigate semiconductors devices such as solar cells and many developments have occurred during the last decade. One major advantage of this technique, apart its simple setup, is that 2D data can be produced, providing access to inhomogeneity analysis. A wide range of study have already been proposed ways to quantify either series resistance or diffusion length, or recombination current density, however often limited by the lack of absolute calibration. The solutions proposed involves assumptions or additional setups and experiments that minor their interest.

Our works aims at proposing a way to calibrate the electroluminescence images in an absolute manner and obtain from one single voltage-dependent EL images a wide set of 2D quantitative characteristics of the cell like diffusion length, recombination current, effective lifetime, local voltage and series resistance. The experiment consists in acquiring the EL images for a range of voltage from 0 V to 100 mV - 200 mV more than the Voc. This makes the influence of the spatial series resistance visible on the EL intensity. In addition we derive the relevant equations modelling the EL(V) curves of each pixel of the cell images. It allows to fit them and extract two parameters. One of this is a pseudo-recombination current J_0^* and the other a pseudo-series resistance R_S^*. From the first and provided a secondary modelling linking this parameter to the (effective) diffusion length, we obtain a calibrated (effective) diffusion length cartography of the cell. It is then straightforward to map the (effective) lifetime of the majority carriers and the map of the recombination current density in the base. The second parameter R_S^* give access to the map of series resistance and also the local voltage. Some results obtained for a classical Al-BSF silicon solar cell are depicted in figure 1.

This very effective method is based on relatively few assumptions or prior quantification, like the spectral reflection coefficient of the cell, homogeneous and quantified surface recombination velocity, a homogeneous sensor of the camera, and the quantification of optical characteristics of the setup.

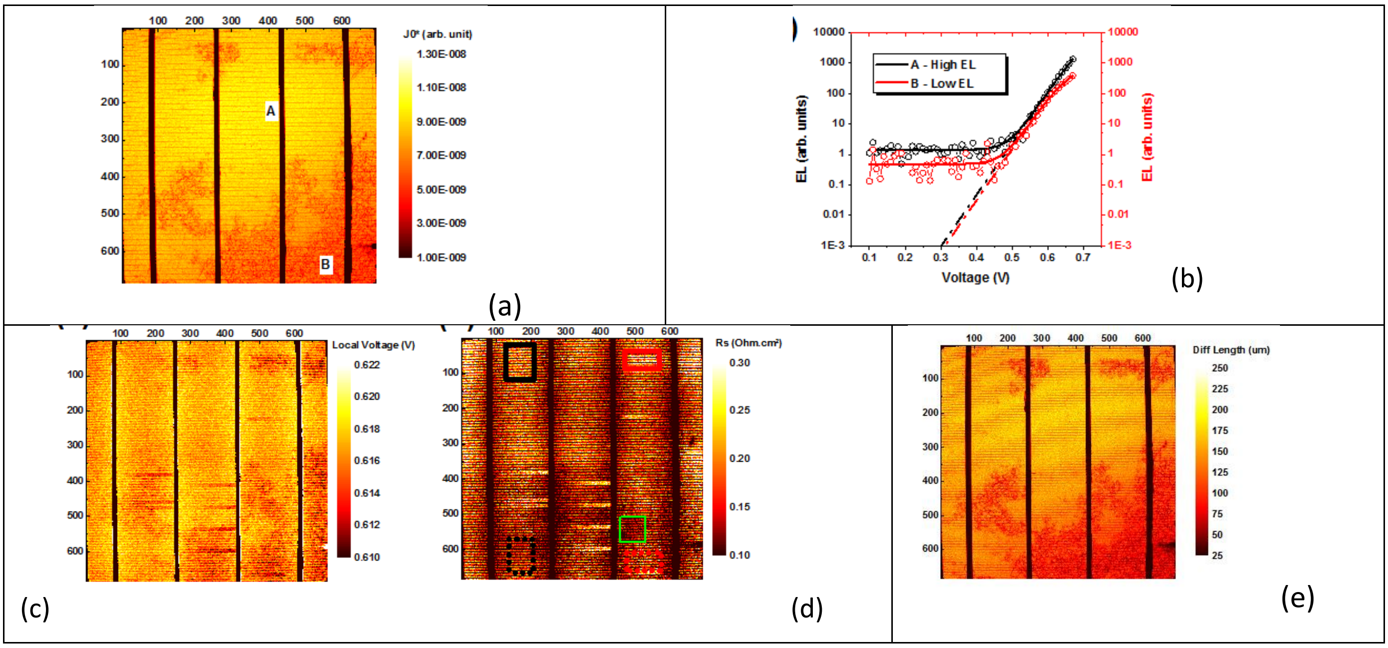

Figure 1. (a) EL image at 0.68V, (b) EL(V)data and fit curves at 2 different places as in (a), (c) local voltage map at Voc, (d) Series resistance map, (e) Diffusion length map