What can we learn from Time-resolved fluorescence images ?

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Analysis Photoluminescence spectra gives access to various information of the investigated PV materials such as the absorption and defects properties. A quantitative analysis of such PL spectra can also offer an optical measurement of the maximum achievable voltage of the PV device, namely the quasi Fermi level splitting (QFLs). The latter is influenced by transport properties within the device and can spatially vary when looking at polycrystalline materials [1]. We show here that the analysis of the time-dependence of the luminescence signal offers new inputs towards the analysis of luminescence images.
We first investigate Time-Resolved Photoluminescence (TRPL) images on CIGS solar cells by means of scanning confocal microscopy (SCM). Each TRPL decay gives access to two different recombination events: bulk recombination and interface defects assisted recombination. Several samples are investigated and correlations are found with global PV performances [2,4]. Moreover, from the TRPL maps, we extract spatially-resolved interface defects within the sample. A comparison is made with QFLs map obtained by means of Hyperspectral measurement. A correlation between QFLs and interface defects is found. This quantitative analysis highlights one of the origins of the observed inhomogeneous PL map in such device [3].
As we know the local excitation used in SCM could be influenced by lateral diffusion of the locally photogenerated carriers, we developed a new imaging setup based on Ultra fast, time-gated camera (em-ICCD). Time Resolved Fluorescence Images (TRFLIM) are recorded on CIGS and III-V semiconductors. A time resolution of 0.5ns couple to a spatial micrometric resolution is achieved. Comparison with classical luminescence images (EL and PL) is done. It allows us to probe the recombination surfaces (front, back and edges), the recombination velocity at the contact and measure spatial variation of bulk properties. All these phenomena being influenced by the injection level.

[1] A. Delamarre, M. Paire, J.-F. Guillemoles, L. Lombez, Quantitative luminescence mapping of Cu(In,Ga)Se2 thin films solar cells" Prog. Photovolt: Res. Appl 10, 1002 (2014)
[2] El-Hajje, G., Ory, D., Paire, M., Guillemoles, J.-F., Lombez, L. Contactless characterization of metastable defects in Cu(In,Ga)Se2 solar cells using time-resolved photoluminescence, Solar Energy Materials and Solar Cells (145-3) 462–467 (2016)
[3] G. El-Hajje; D. Ory; J.-F. Guillemoles; L. Lombez, On the origin of the spatial inhomogeneity of photoluminescence in thin-film CIGS solar devices Appl. Phys Lett (2016)
[4] G. El-Hajje; D. Ory; E. Leite; J.-F. Guillemoles; L. Lombez, Quantitative luminescence-based measurement of trapping defects density in thin film solar cells (soumis)