Characterization of diffusion & recombination properties in perovskite using TR-FLIM

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The interest of the scientific community for organic-inorganic halide perovskite has been burgeoning in the recent years. Amongst a lot of applications in optoelectronic devices, they can act as light absorbers in thin film solar cells, which efficiency now peaks at 22.2%. This communication intends to model, measure and analyze the diffusion and recombination properties in different state-of-the-art perovskite absorbers. It notably focuses on the impact of partially replacing the organic cation with Cesium and/or Rubidium.

Our experimental set-up is based on the Time-Resolved Fluorescence Imaging (TR-FLIM) technique, which acquires time-resolved photoluminescence (PL) images using a wide-field homogeneous illumination. It measures the local PL decay with a micrometric resolution, without being influenced by lateral diffusion artefacts. Hyperspectral images from a complementary set-up are also used for comparison purpose[1].

The PL transients are fitted with a model including recombination and vertical diffusion. The recombination process displayed on Fig A includes a significant number of shallow traps, which induce a photo-doping as they trap electrons on the long term, whereas the direct recombination is quicker. We improve this model developed by Stranks et al[2] by considering the vertical diffusion of photo-generated carriers (represented on Fig B). It shows electrons accumulated at the front interface, where they recombine faster, at short times. Thanks to this more accurate description of the carriers dynamics, we determine precise values for the following physical parameters: (i) direct recombination coefficient R_{eh}, (ii) shallow traps concentration, (iii) front interface recombination velocity S_{front} (and S_{back} by turning the sample), and (iv) diffusion coefficient. Eventually, we are able to map the determined properties, to assess their homogeneity and their correlation with the sample's morphology (see Fig D)

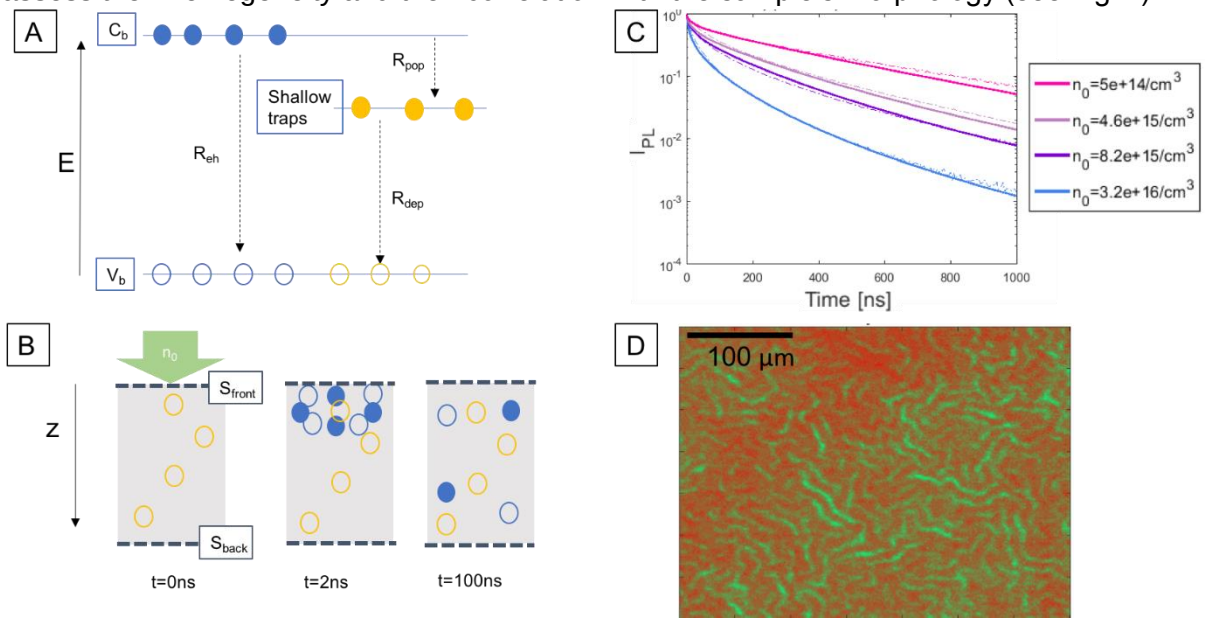

Figure (A) Sketch showing the energetic transitions in perovskite. C_b & V_b stand for conduction and valence band. R_{eh}, R_{pop} & R_{dep} are transition probability. Full (empty) circles stand for electrons (holes). (B) Sketch showing the vertical diffusion of photo-generated carriers after the laser pulse. (C) TRPL transients (dotted lines) and numerical simulations (plain lines) for perovskite deposited on FTO. (D) Morphology map of a perovskite absorber.

1. El-Hajje, G. *et al*. *Energy Environ. Sci.* **9,** 2286–2294 (2016).
2. Stranks, S. D. *et al*. *Phys. Rev. Appl.* **34007,** 1–8 (2014).