On the mapping of absorption coefficient through photoluminescence imaging

Marie Legrand * (1,2), Baptiste Bérenguier (2,3), Guillaume Vidon (2,3), Daniel Ory (1,2), Jean-François Guillemoles (2,3)

(1) EDF R&D, France
(2) Institut Photovoltaïque d'Ile de France (IPVF), France
(3) UMR IPVF 9006, CNRS, Ecole Polytechnique Institut Polytechnique de Paris, PSL Chimie ParisTech, IPVF SAS, 91120 Palaiseau, France

The absorption coefficient determines the photonic transport and reflects the composition of a material through its link to the density of states. Hence, its assessment is of crucial importance in optical optimization and defects characterization of photovoltaic device. Notably, the sub-bandgap absorptivity reflects the impurity distribution[1] and may contain the signature of trap states[2]. The absorption coefficient exponential increases in the spectral region of interest induces an experimental challenge as ultralow coefficients still need to be measured accurately. Further outcome of its assessment concerns photoluminescence (PL) imaging where absorption variation has to be measured for a correct interpretation of the PL maps.

When describing PL, light absorption influences both the generation function - at the excitation wavelength - and the photons emission and propagation - close to the bandgap energy. We take advantage of these dependances to explore different techniques to obtain either the absorptivity or the absorption coefficient and discuss the link between these two quantities.

Firstly, photoluminescence excitation (PLE) measurement is used to determine the local absorptivity above the bandgap with both time-resolved imaging and hyperspectral imaging techniques. Preliminary results obtained with a pulsed excitation on a III-V cell show that the spectral shape of the collected signal changes substantially with the wavelength of excitation. Indeed, when the excitation source wavelength is changed from 532nm to 732nm, the apparent PL peak increases by 20 nm and the spectrum becomes narrower. We investigate this phenomenon by modelling the PL emission in transient regime. Our approach is based on a drift-diffusion model and takes into account photon reabsorption. It will be compared to continuous wave simulation and through transient spectroscopy experiments.

Secondly, the absorption coefficient can be obtained near the optical bandgap directly from the photoluminescence spectrum. In this frame, temperature studies have already allowed the determination of absorption coefficient with ultra-low values[3]. These different approaches are compared to reflection measurements classically used at the global scale[4]. The limitations and application scope of the different absorption determination will be described, as well as how they relate to one another. Finally, application to PL imaging will be discussed.

1. Katahara, J. K. & Hillhouse, H. W. Quasi-Fermi level splitting and sub-bandgap absorptivity from semiconductor photoluminescence. *J. Appl. Phys.* **116**, 173504 (2014).
2. Seitz, M. *et al.* Mapping the Trap-State Landscape in 2D Metal-Halide Perovskites Using Transient Photoluminescence Microscopy. *Adv. Optical Mater.* 2001875 (2021) doi:10.1002/adom.202001875.
3. Daub, E. & Würfel, P. Ultralow Values of the Absorption Coefficient of Si Obtained from Luminescence. *Phys. Rev. Lett.* **74**, 1020–1023 (1995).
4. Brittman, S. & Garnett, E. C. Measuring *n* and *k* at the Microscale in Single Crystals of $CH_3NH_3PbBr_3$ Perovskite. *J. Phys. Chem. C* **120**, 616–620 (2016).