

Study of the impact of heterojunctions on photomodulated luminescence for the characterization

Institution : IP Paris

Doctoral School : IP Paris n°626

Specialty : Physics

Lab : UMR-IPVF (UMR9006)

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Application deadline: 15th of april.

Keywords

Photovoltaics, Instrumentation, Semiconductors, Defects, Multi-Junctions

Research Project

European photovoltaic industry renewal by the mean of innovation is a major challenge of our energetic sovereignty. Development of technologically new cells, the study of their performances and durability need a deep knowledge of photovoltaic materials and system, and especially the characterization of the recombinant centers which can be responsible of severe efficiency losses.

Present contactless techniques are not sufficiently reliable to distinguish several centers with different activation energies and most often work in pulsed regime, being really far from real working conditions.

IPVF and GeePs work together to develop characterization tools based on modulated signals, either contactless based on the photoluminescence, or with contact such as admittance spectroscopy. They develop a novel technique in modulated regime with large frequency bandwidth, the MPL. The semiconductor is submitted to an illumination created by temporally intensity modulated laser with a variable frequency in the [10Hz -200MHz] range and the PL signal at the different harmonics is recorded, with a focus on the amplitude and phase shift versus excitation. The MPL appears to give complementary information with respects to other techniques, with the specificity to study slow (de-trapping [1]) and fast mechanisms, with a measurement close from the working point of the cell [2]. The MPL theory, which was developed for single layer [3-4], needs to be extended to complete devices. First simulation trials show the influence of junctions on the MPL signal but a quantitative analysis of

the MPL signatures is mandatory. It has to be validated by numerical simulations and a comparison of the results of admittance spectroscopy tests.

The thesis would begin with the study of the influence of the temperature on the signal of single layers to extend the model.

The final goal would be to be able of analyzing multi-junction devices, being the new generation of high efficiency cells.

Thematic

Photovoltaic, Material science, physics of condensed materials, optical spectroscopies

Goals

To develop analysis methodology of MPL measurement in single then multi-junction devices

Methods

Theoretical: development of analytical simplified formula, comparison with homer made Matlab code or commercial software based on finite elements, comparison with MPL and Admittance spectra

Expected results

Firstly, being able to separate the influence of defects and junction on the signal.

Finally: analysis of multi-junction (perovskite or CIGS on silicon tandems, III-V triple cells)

Bibliography

[1] B. Bérenguier *et al.*, « Defects characterization in thin films photovoltaics materials by correlated high-frequency modulated and time resolved photoluminescence: An application to Cu(In,Ga)Se₂ », *Thin Solid Films*, vol. 669, p. 520-524, janv. 2019, doi: 10.1016/j.tsf.2018.11.030.

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[3] N. Moron, « Modélisation analytique et simulation numérique de la technique de photoluminescence modulée appliquée à des matériaux semi-conducteurs », These de doctorat, université Paris-Saclay, 2021. Consulté le: 23 mars 2022. [En ligne]. Disponible sur: <https://www.theses.fr/2021UPAST116>

[4] N. Moron, B. Bérenguier, J. Alvarez, et J.-P. Kleider, « Analytical model of the modulated photoluminescence in semiconductor materials », *J. Phys. Appl. Phys.*, vol. 55, n° 10, p. 105103, mars 2022, doi: 10.1088/1361-6463/ac39c4.

Application process:

The candidate for the PhD position « Study of the impact of heterojunctions on photomodulated luminescence for the characterization » must apply to the PhD competitive exam from IP Paris before the 15th of April. He (She) need to connect to <https://www.ip-paris.fr/education/doctorat> and provide the following documents:

- Application form
- CV
- Motivation letter
- A presentation of the PhD topic, the context and outlook, the working roadmap, the supervising team (including percentages)
- Copies of diploma before Master and academic transcripts
- Academic transcripts of the two years of master and certificates of scolarity signed by the master supervisors (if relevant)
- 2 reference letters which has to be join to the pdf form or sent at audrey.lemarechal@polytechnique.edu with the following tittle LetterRecommendation_CandidateName_ProfName.pdf

One student can apply to two topics only.