Hybrid organic-inorganic perovskites modified with ion irradiation

M2 internship and Ph.D. topic – 10/2017-09/2020

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Hybrid organic-inorganic perovskites (HOP) have become one of the most promising low-cost alternatives to traditional semiconductors in the field of photovoltaics and light emitting devices. It combines both attractive features of organic and inorganic materials within a single composite, for instance with stronger excitonic properties and brighter luminescence than inorganic semiconductors together with high ambipolar mobilities, several orders of magnitude larger than in organic semiconductors. Since 2012, the structure of the type (CH₃NH₃)PbI₃ (3D perovskites) have led to the very fast emergence of a new class of solar cells, as after less than 3 years of research effort it has led to a conversion efficiency above 20 %, as shown in november 2014 (NREL efficiency chart). However, a number of issues related to structural, thermal and UV stability, as well as moisture sensitivity have to be solved and a better knowledge of the electronic properties of such materials is obviously a prerequisite for their use and optimization in opto-electronic devices.

The objective of the Ph.D. project will be to study the influence of point defects introduced by ion irradiation in HOP materials with the implanter IRMA at CSNSM. For instance, Helium ion irradiation will introduce strain in the crystallographic structure and induce changes in the electronic properties. The samples will be grown in polycrystalline (thin films) as well as monocrystalline types in collaboration with Emmanuelle Deleporte in Laboratoire Aimé Cotton. The crystallographic structure and irradiation induced strain will be studied using x-ray diffraction. We will study more specifically the modification of properties:

1- the possibility to dope the perovskite with irradiation defects (vacancies). As Helium is a light element, its interaction with the target material mainly leads to isolated point defects along the ion trajectory which could lead to n-type doping of the crystals. The electronic properties will be investigated using Hall effect measurements. The possibility to dope the hybrid perovskites with ion irradiation would represent a breakthrough, opening new possibilities for opto-electronic devices fabrication.

2- the influence of defects on the luminescence properties. HOPs present strong optical emission coming from free excitons and excitons bound on impurities. The CSNSM will soon be equipped with a new spectrometer (Quantamaster500, funded by Labex PALM and CNRS) for photoluminescence studies allowing to measure excitation spectra, emission spectra as well as decay processes. We will study the dynamical processes of light emission and their modification with ion irradiation. Low temperature measurements will bring insights in the fundamental mechanisms of light emission in HOP and the central role that surface or volume defects might play.

In materials science, as seen in particular in semiconductor physics in the past, it is important to work on the relationship between the structural, electronic and optical properties. The novelty of the approach proposed here, using ion irradiation, makes the attractiveness of this proposal in a very competitive context, as perovskites have emerged as one of the hottest topics in materials science today. The topic will be part of the newly proposed GDR (Groupement de Recherche) HPERO.