

Approaching the static energetic disorder limit in hybrid perovskites: a fundamental efficiency benchmark of thin-film optoelectronic structures (PeroDisorder)

The unprecedented rise in power conversion efficiency of perovskite photovoltaics in recent years sparked interest in fundamental research targeted at explaining the reasons for their extraordinary performance. Besides unique optical properties and low manufacturing cost, one of the key features making hybrid organic-inorganic halide perovskites a competitive semiconductor platform is their low energetic disorder, being a benchmark of good crystalline quality and low defect activity. The disorder level can be estimated from the steepness of the light absorption spectrum quantified by the Urbach energy, accessible by highly-sensitive experimental methods. Room-temperature investigations of that kind are a good benchmark for the efficiency of solar cells and light-emitting diodes, but do not provide the exact nature of the material disorder. It can originate from imperfections of the crystal, aggregation of neighbouring atoms, or effects activated by temperature, such as vibrations or fluctuations of charge carriers.

In this project, we are going to perform systematic studies of energetic disorder in hybrid perovskites used as the new class of semiconducting materials in thin-film technology. A combination of two experimental methods, namely photothermal deflection spectroscopy (contactless) and external quantum efficiency (device-based) will allow for comparing the properties of bare thin (tens-hundreds of nanometres – up to a thousand times thinner than a human hair) films before and after putting between transparent electrodes, forming a full working device prototype. The next big step will comprise performing the same experiments with the thermal excitations switched off by cooling the structures down to cryogenic temperatures, compatible with conditions met in outer space.

The materials used in the project will be made by solution-based processing as well as thermal evaporation, which adapts deposition technology resembling epitaxy used in traditional semiconductors. Some of them have been optimised as active layers of light-emitting diodes and tandem solar cells of record performance. We are also going to test the influence of device ageing (continuous operation for a prolonged time) on the energetic disorder, where we expect to tell the difference between the possible perovskite material degradation and diminished charge transport at the interface with the neighbouring transparent conductive layers, acting as electrodes. We hope that the results of this project will provide new insights into the factors limiting the efficiency of thin-film optoelectronic devices based on hybrid perovskites and set directions to overcome them.