Development of strategies for improving stability of perovskite solar cells

Solar energy is one of the most promising and renewable energy sources that has minimum harmful impact on the environment, as compared to other sources like fossil fuels or nuclear energy. A solar cell is a solid-state electrical device, which converts the energy of light into electricity as a result of photovoltaic effect. The most common material for solar cells construction is monocrystalline silicon. The constant electric current is generated due to the presence of a semiconductor in the form of a thin silicon layer and the p-n semiconductor junction. Solar cell technology based on silicon has advanced considerably, but still suffers from high fabrication costs. A few years ago, research interests of the photovoltaic community have focused on hybrid organic–inorganic metal halide perovskites for photovoltaic application. Along with confirmed power conversion efficiency of 25.2%, perovskite solar cells (PSCs) show a level of performance comparable to CIGS-based cells, and are approaching the maximum efficiency of commercial monocrystalline silicon. In addition, perovskites appear also as promising materials for many efficient optoelectronic devices i.e. LEDs, field effect transistors, ferroelectric random access memories (FRAMs).

Perovskites belong to a class of inorganic or inorganic-organic compounds with the general formula of ABX_3 and exhibits a cubic crystal structure, where B ions sit in the center of a simple cube, the X ions are at the faces and the A ions are at the cube corners. The name of this class of compounds is derived from a naturally occurring mineral, calcium titanate (IV) $CaTiO_3$, named perovskite in honor of the Russian geologist Lev Perovski. Currently, the most commonly studied perovskite compound is methylammonium lead iodide $(CH_3NH_3)PbI_3$, which structure has an octahedral coordination around the Pb ions, and the methylammonium cations occupy the interstices (the A sites) within the perovskite lattice. The lead halide perovskite compositions can be easily tuned by forming various multication and mixed-halide systems. These semiconductor materials have attracted increasing attention and exhibit unique physicochemical properties such as low band gaps, high extinction coefficients and high carrier mobilities. The method of formation perovskite thin films plays a key role in their chemical and physical properties, i.e. crystallinity, phase purity, morphology, grain size dispersion. Despite the success in boosting the efficiency of PSCs, the devices are still facing several critical challenges that hinder their commercialization e.g. low stability of perovskites under high relative humidity. In this context, developing methods to produce new perovskite systems with desirable chemical and physical properties for applications in photovoltaic market continues to be a still challenging task.

The overall goal of this project is to develop advantageous methods for the preparation of new lead halide perovskite compositions showing high stability in high humidity conditions for application in photovoltaic. To realize the aims, perovskite systems with mixed 3D/2D structure systems and all-inorganic lead-halide $CsPbI_{3-x}Br_x$ compositions will be designed and synthesized. Next, the resulted perovskite materials will be used as components for the fabrication of laboratory perovskite solar cells. In turn, the surface engineering of the electron transport layers (ETLs) with novel fullerene derivatives and hybrid 3D porous metal organic-framework materials would promote the development of stable and efficient PSCs. The relationship between optoelectronic properties of the newly developed perovskite compositions and modification of ETL with the device performance will be systematically investigated, which would shed light on the further exploration of new materials for photovoltaics.

The proposed research tasks within this project belong to current global research trends and open new perspectives and possibilities for the formation and characterization of lead halide perovskites. As a result, the resulting compounds will contribute to the fabrication of stable and efficient photovoltaic devices.