Probing the structure–property relationships in single-crystalline lead halide perovskites for photodetector applications

Photodetectors based on semiconductors, which convert light into electric signals are widely used in optical communication and chemical/biological detection. The prerequisite for the fabrication of efficient photodetector is that the semiconductor material should possess a high absorption extinction coefficient to ensure sufficient light being absorbed by an active layer, the large charge carrier mobility for generating high photocurrent and low density of defects for diminishing the dark current density. In recent years, hybrid organic–inorganic lead halide perovskites have emerged as a new generation of promising materials for high-performance photodetectors.

Lead halide 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. These semiconductor materials have attracted increasing attention and exhibit unique physicochemical properties such as tunable band gaps, high absorption coefficients, high carrier mobilities and long carrier lifetimes. However, the low stability of lead halide perovskites under high thermal, moisture and operational conditions are issues that needs to be addressed. In this context, a great deal of current interest in the perovskite community and chemistry has been focused on the understanding of chemical instability of lead halide perovskites and developing strategies for making more robust perovskite-based optoelectronic devices.

The overall goal of this project is to probe the relationship between the structure and composition of the perovskite active layer and its charge transport properties to understand the physical processes that determine the photoresponse of perovskite single crystals (SCs) based photodetector under working conditions. To realize the aims, the additive and compositional engineering will be applied to develop the methods for crystallization of large and high quality perovskite single-crystals. Special attention will be put on the structural and optical characterizations and analysis of defect density, ion motions and activation energy levels in single-crystalline perovskites with the help of electrochemical impedance spectroscopy under different conditions of light and temperature. Finally, the complete photodetectors based on resulting perovskite single-crystals with a planar architecture will be fabricated and specifically characterized. These studies will provide a better understanding of how the changes in structural composition, conduction mechanism and dimensionality will affect the figure-of-merit parameters of resulting photodetectors.

The proposed research belongs to current global research trends and open new perspectives and possibilities for the synthesis and characterization of lead halide perovskites. As a result, these findings will provide insightful guidelines for making more robust and efficient perovskite-based photodetector devices.