Development of halide perovskite single-crystal-based thin film for photodetector application

A photodetector (PD) is a device that can convert light into electrical signals. The ideal PD should exhibit high responsivity, detectivity, quantum efficiency, stability and signal-to-noise ratio, low dark current and fast response time. In the current market, the majority of PDs are based on Si and GaInAs semiconductors. However, the fabrication process of these types of PDs requires very high temperatures and expensive growth facilities, which limits their versatility towards broad eco-friendly applications and affordable electronics.

The photodetection potential of lead halide perovskites (LHPs) have been the subject of research for the last decade because of their robust and low-cost synthesis, easy bandgap tunability, which facilitates a wide range of applications. The PD research was primarily focused on $MAPbBr_3$ single crystals (SCs) due to the robust synthesis, the absence of grain boundaries, the high charge carrier mobility, and the reduced trap state density. Nevertheless, due to the substantial thickness of the SCs, the device applications are rendered challenging due to the difficulty of incorporating them into the devices. To overcome the issue by retaining the properties of SCs is to make SC-based thin films. Research has been conducted on the development of SC-based thin films, however, in-depth studies on these devices, as well as studies into the tailoring of their properties, are yet to be conducted. Despite the advantages in terms of performance and affordability, the toxicity of lead (Pb) to living organisms can act as an effective barrier against the widespread commercialization of this material. The selection of bismuth (Bi)-based halide perovskite, with a formula of $A_3Bi_2X_9$ (where A = cesium (Cs) or methylammonium (MA) and X = I, Br, or Cl), can be regarded as a triumphant successor to the Pb-based perovskite. In this system, $Cs_3Bi_2I_9$ has become a popular choice due to its high-power conversion stability and chemical stability.

This proposal aims to develop single crystal based thin film photodetectors using $MAPbBr_3$ and $Cs_3Bi_2I_9$ perovskite compositions. I will thoroughly analyze the optoelectronic properties of the resulting photodetectors under various bias voltages, light intensities, and wavelengths. Using different methods like UV-visible absorption, photoluminescence spectra, and electrochemical impedance spectroscopy, along with X-ray diffraction, I will better understand the photodetection properties of perovskite-based photodetectors. Finally, I will investigate how to transition from traditional photodetectors, which need external power, to self-powered ones that operate without it by forming a Schottky junction. These studies will help to understand how changes in the materials' structure affect the performance of these devices. Ultimately, findings during the realization of project will provide useful guidelines for creating efficient perovskite-based photodetectors.

The outlined research tasks demonstrate a high degree of novelty, contributing to both fundamental understanding and potential practical applications, ultimately leading to discoveries and attracting considerable attention from the scientific community and possible commercialization of perovskite-based optoelectronic devices.