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PEROVSKITE MATERIALS FOR OPTOELECTRONICS APPLICATION: SOLAR CELLS AND PHOTODETECTORS

by

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Abstract

Perovskite materials have emerged as promising candidates for optoelectronic applications, particularly in solar cells and photodetectors, due to their remarkable properties such as high carrier mobility, tunable bandgap, and low-cost fabrication. This thesis explores two novel approaches, namely monovalent doping and bulk as well as surface passivation, to enhance the performance and stability of perovskite-based devices.

The primary goal of this research is to enhance the properties of perovskite materials to improve their optoelectronic performance, aiming to broaden their use in solar cells and photodetector devices. Specifically, this study seeks to evaluate the effectiveness of Cu doping and Zinc porphyrin passivation techniques in improving the efficiency and stability of perovskite solar cells. Additionally, the research aims to enhance the performance of photodetectors by employing the Zinc porphyrin passivation method.

To achieve the objectives, a systematic approach involving synthesis, characterization, and device fabrication was employed. Perovskite films were synthesized using a cost-effective spin-coating technique. Cu doping was achieved through controlled incorporation of Cu^+ ion during synthesis, while Zinc porphyrin passivation was implemented through the bulk as well as surface modification using the antisolvent engineering techniques. Various characterization techniques, including X-ray diffraction, UV-Vis spectroscopy, photoluminescence spectroscopy, and electrical measurements, are employed to assess the structural, optical, and electronic properties of the modified perovskite materials.

Experimental results demonstrate the successful incorporation of Cu dopant into the perovskite lattice. Optimizing the amount of Cu has been found to significantly enhance crystalline quality and grain size, leading to improved light absorption and higher efficiency. Consequently, the power conversion efficiency (PCE) of Cu-doped $MAPbI_3$ perovskite solar cells increased from 16.3 % to 18.2 %. However, Zinc porphyrin passivation enhances the grain size and reduces defects, improves the optical properties, and charge transport efficiency of $FA_{0.95}MA_{0.05}PbI_{2.85}Br_{0.15}$ perovskite solar cells. This approach significantly boosts the PCE from 15.38 % to 19.11 % while ensuring exceptional stability, retaining over 91 % of initial efficiency.

The bulk passivation of perovskite single crystal was also made possible during the inverse temperature crystallization process. Photodetectors integrated onto single crystal surfaces were also fabricated, and their performance in photodetection was assessed. Photodetectors utilizing Zinc porphyrin passivation demonstrated enhanced photodetection properties and rapid response speed, leading to superior performance in low-light conditions compared to un-passivated devices. The Photodetector devices passivated with 0.05% Zn-PP exhibited the best performance with a responsivity of 2.54 (A/W) and external quantum efficiency (EQE) of about 778 % whereas the un-passivated sample exhibited a responsivity of 1.06 A/W and EQE of 324 %. Furthermore, the photocurrent for the un-passivated sample has shown a rise time (t_r) of 7.5 µs and fall time (t_f) of 84.8 µs as a function of time. However, with a 0.05% Zn-PP passivation, the t_r and t_f were reduced to 2.6 µs and 57.9 µs, respectively.

This thesis contributes to the advancement of perovskite-based optoelectronic devices by introducing novel strategies for improving material properties and device performance. The successful implementation of monovalent doping and metal porphyrin passivation demonstrates the potential of these approaches in enhancing the efficiency and stability of perovskite solar cells and the performance of the photodetector devices. The insights gained from this research pave the way for further optimization of perovskite materials and the development of high-performance optoelectronic devices.

Keywords: Perovskite solar cells, Perovskite Single crystal, Metal doping, Passivation, Zinc porphyrin, Photodetector.