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硕士学位论文

平面异质结钙钛矿太阳能电池关键材料的低温制备及其光电性能的研究

Research on low-temperature preparation and optoelectronic properties of key materials for planar heterojunction perovskite solar cells

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摘 要

钙钛矿材料凭借优异的吸光性能、较长的载流子扩散长度、 简便节能的合成加工工艺等亮点吸引了世界各国科学家们的广泛关注。钙钛矿太阳能电池的能量转化效率从最初的 3.8%发展到 22.1%仅仅历经数年的时间，呈现出光明的商业化前景。

基于对钙钛矿光伏器件研发现状的调研，本文对低温条件下制备高性能电子传输、钙钛矿吸光材料的成分优化途径以及钙钛矿器件磁滞效应的消除方法三个方面开展相关研究，为实现在低温条件下制备高性能钙钛矿太阳电池奠定基础。

首先，从钙钛矿材料成分和制作工艺的优化入手， 本文重点探究由两步法制备(FAPbI3)x(MAPbCl3)1-x 混合钙钛矿吸光层的最佳制备工艺， 明确了 PbI2 前驱体的干燥温度和时间、 PbI2 前驱体与 FA+/MA+混合溶液之间的转速搭配以及钙钛矿退火工艺对钙钛矿吸光层晶粒大小、表面形貌、 组成成分的影响，由此确定钙钛矿吸光层的最佳制备工艺。

其次， 着力于低温下合成高性能电子传输材料的研究， 本文通过溶胶-凝胶技术在低温常压环境下制备水溶性锐钛矿 TiO2 纳米晶， 实现在 25℃下制成无需加热后处理即可具备优异的光电性能的纳米晶薄膜。以此为电子传输层结合钙钛矿吸光层的制备工艺组装正向平面结构的钙钛矿光伏器件，探究不同厚度的纳米晶薄膜对器件性能的影响，由此确定纳米晶薄膜的最佳厚度。

最后， 以消除钙钛矿太阳电池的磁滞效应为目标， 本文尝试向钙钛矿吸光层中掺入 CuIn(SxSe1-x)2 系列纳米粒子的思路。前期， 本文利用热注射法通过调整反应物 S/Se相对比例制备出禁带宽度可调控的高稳定性的 CuIn(SxSe1-x)2纳米粒子，并使用乙酰丙酮置换产物中残留的油胺络合剂。后期， 本文将所得的纳米粒子掺入钙钛矿吸光层并组装成器件，探究 CuIn(SxSe1-x)2 纳米粒子中不同的 S/Se 相对比例、残留的络合剂对钙钛矿薄膜及其器件性能的影响。

关键词：钙钛矿吸光层；TiO2 纳米晶；磁滞效应

Abstract

Organic-inorganic hybrid perovskite materials have drawn increasing attention for its outstanding performance in terms of light absorption coefficient, diffusion length of carriers and processing technology. The photoelectric conversion efficiency of perovskite solar cells (PSCs) has grown from the initial 3.8% to 22.1% for only a few years, showing a bright future of commercialization. Based on the understanding of research status of perovskite solar cells, this paper conducted some research in three aspects: the way to optimize the component of perovskite, prepare high-performance electron transport layer at low temperature and eliminate the hysteresis effect of perovskite device.

First of all, this paper investigated the optimum conditions for the preparation of (FAPbI3)x(MAPbCl3)1-x mixed perovskite by two-step method. The drying temperature and time of PbI2 precursor, the rotation speed of PbI2 precursor and FA+/MA+ mixed solution and the annealing process were explored, which can affect the grain size, surface morphology and composition of perovskite film. Thus, the optimum preparation process of perovskite thin films was determined.

Secondly, focused on the research on the synthesis of high-performance electron transport materials under low temperature and atmospheric pressure, this paper developed a water-soluble anatase TiO2 nanocrystals prepared by sol-gel method, which can be made into annealed-free TiO2 nanocrystalline film with excellent

photoelectric properties at room-temperature. Then, the effect of different nanocrystalline thickness on the performance of planar heterojunction PSCs was investigated by combining the preparation process of the absorption layer, and the optimum thickness of the nanocrystalline film was determined.

Finally, in order to eliminate the inherent hysteresis effect of PSCs, this paper attempted to dope CuIn(SxSe1-x)2 series nanoparticles into perovskite materials.

Previously, extremely stabilized CuIn(SxSe1-x)2 nanoparticles with suitable band gap were prepared by adjusting the S/Se relative ratio in reactants by hot injection method,
and the remaining oleylamine in the product was replaced by acetylacetone.

Subsequently, the obtained nanoparticles were doped into perovskite materials to assemble devices and the effect of the relative S/Se ratio of CuIn(SxSe1-x)2 nanoparticles and residual complexing agents on the performance of perovskite films and PSCs was studied.

Keywords: perovskite; TiO2 nanocrystal; hysteresis effect

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