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Easily Attainable, Efficient Solar Cell with Mass Yield of Nanorod Single-Crystalline Organo-Metal Halide Perovskite Based on a Ball Milling Technique

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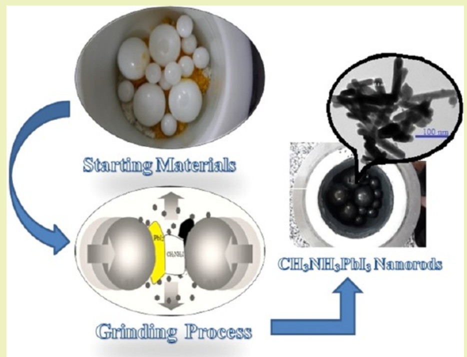
Supporting Information

ABSTRACT: Generally, nanoparticles of $CH_3NH_3PbI_3$ (MLI) powders are increasingly recognized for their applications in solar cells. In this article, a new substitutional path to efficient mass yield with crucial reaction rates was proposed for the synthesis of MLI using a ball milling technique. We compare between the condensation reflux strategy (RM) and the ball milling (BM) technique as synthetic routes to produce microparticles (RM-MLI) and nanoparticles (BM-MLI) from MLI microcrystalline powder. The change in crystal structures, microstructure, and optical characteristics was investigated using X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), and photoluminescence emission (PL). FESEM micrographs showed a plummet straight down in particle size from 10 μm to ~30 nm. The nanorods morphology was elucidated with transmission electron microscope (TEM). Optical absorption measurements indicate that compounds behaved with the characteristic of direct band gap with E_g recorded at 1.50 and 1.56 eV for RM-MLI and BM-MLI, respectively. The two samples exhibited an intense near-IR photoluminescence (PL) emission in the 700−800 nm range at room temperature. The Hall effect was displayed as p-type semiconductors resulting from the positive sign of the Hall coefficient. Typically, with Cu_2ZnSnS_4 (CZTS) as a hole transport material, the perovskite-sensitized TiO_2 film showed power conversion efficiencies (PCE) of 7.33 and 9.63% with fill factor records of 0.61 and 0.66 for RM-MLI and BM-MLI, respectively. Meanwhile, the results gave a maximum external quantum efficiency (EQE) of 65% at 530 nm at AM 1.5G 1 sun intensity (100 mW cm^2). Overall, this work gives an exceptionally simple, efficient methodology to synthesize MLI nanoparticles with efficient power conversion.



KEYWORDS: *Perovskite solar cell, Green chemistry, Processing, Nanorods, CZTS, Hall effect, High power conversion efficiency*

INTRODUCTION

Photovoltaic (PV) devices that include organic and inorganic nanomaterials to create new hybrid structures have attracted increasing interest because of their low cost and high efficiency.[1] Accordingly, the use of organometal halide perovskite materials as organic−inorganic hybrid materials has been explored for efficient light to electricity conversion in solar cells.[2−4] The extensive flexibility of the perovskite material, likewise, adds to the immense interest attracted.[5−10] Generally, the synthesis techniques for perovskite materials assume a pertinent part on their physical and chemical properties. The variation of the homogeneity, crystallinity, stage virtue, morphology, grain size-scattering, surface zone, and numerous different parameters can be effectively adjusted by just changing material development route.[11−13]

Recently, green chemistry for the synthesis of materials has turned out to be a powerful and straightforward method without including high temperature treatment and consumed solvent for the synthesis of nanocrystalline powders, with compound procedures and items by creating novel responses that can optimize the wanted products and minimize byproducts.[14,15] In this manner the grinding process is considered as a type of green chemistry. Where the raw powders were caught between dynamic impacting balls, the internal surface of the vial causes misshaping, rewelding, and discontinuity of premixed powders bringing about the development of fine, scattered particles in the grain-refined matrix.

In this manner maintained endeavors have gone into the advancement of productive systems for perovskite arrangement. Moreover, syntheses using ball milling techniques (BM) are desirable methods for environmentally friendly, immaculate, and energy efficient synthesis. Examinations of the characteristics of $CH_3NH_3PbI_3$ (MLI) showed that the morphology and crystallinity play a large part in device execution.[16,17] The

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