

Synthesis and Characterization of CsPbBr₃ Perovskite Powder and Derived Thin Films

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Abstract: Facile synthesis protocol proposed in this study is capable to produce the orange CsPbBr₃ powder with the amount exceeding 10 g. The orthorhombic powder shows its photoluminescence peak centered at ~520 nm. The stabilities of the powder and films were demonstrated in the PL measurement and thermal cycling experiment, respectively.

Key Word-- Perovskite, CsPbBr₃, photoluminescence, stability.

1. Introduction

To deposit a lead halide film, a most popular form for optoelectronic applications, MAX, FAX, or CsX (X denotes the halogen) are typically used as the source of large cations to mixed with PbX₂, the source of small cations, in peculiar protic solvent to form the precursor solution based on the simple one-step method. With specific treatment or polymer-addition, the precursor solution is compatible for accessing a smooth film on substrates by any solution process [1-3]. However, the exact molar ratio of the monovalent large cations (MA⁺, FA⁺, or Cs⁺) to the Pb cation in precursors is crucial and not as straightforward as the stoichiometric ratio in ABX₃ halide perovskites. For instance, the ratio of MAX or CsX to PbX₂ larger than 1.0 even 2.0 is frequently adopted to prevent the formation of impurity phases (ex: Pb metal or Cs₂Pb₄X₆) which probably cause the exciton quenching in devices [2-4]. Therefore, when the precursor solutions are used for solid thin film preparation, those unreacted and non-coordinating precursors are deposited as well and irremovable via any post-deposited treatments, no matter the simple one-step or sophisticated two-step coating methods are used [4,5]. Being an alternative, Hoffman et al. successfully obtained the continuous and smooth CsPbBr₃ films by fusing the purified perovskite nanocrystals coated on TiO₂ films at 250 °C [6]. However, the thermal treatment entirely caused the photoluminescence (PL) quenching of the annealed CsPbBr₃ film.

In the present study, we demonstrated the facile synthesis of CsPbBr₃ powder by dropping hydrohalic acid into the CsBr and PbBr₂ precursor solution at room temperature. By further precipitation-redispersion procedure, those excess un-reactants can thus be removed. In this way, the synthesis of CsPbBr₃ powder is capable for mass production for optoelectronics industry. From the PL measurement, we found that not only the CsPbBr₃ powder but also the hereby spin-coated thin film are highly stable in air ambient and after thermal stress at temperature higher than 120 °C.



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Abstract:

Facile synthesis method proposed in this study is capable to produce the orange CsPbBr₃ powder with the amount exceeding 10 g. The orthorhombic powder shows its photoluminescence peak centered at ~520 nm and has a FWHM of less than 20 nm. The stabilities of the powder and films were demonstrated in the PL measurement and thermal cycling experiment, respectively.

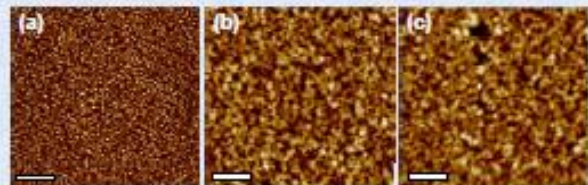


Fig. 4. AFM images of (a) evaporated and (b) spin-coated CsPbBr₃ films on silicon substrates and (c) the spin-coated one on ITO/glass substrate. The scale bar represents 1 μm.

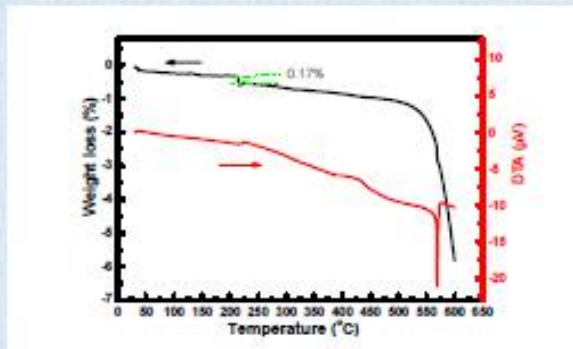


Fig. 1. TGA and DTA curves of perovskite powder.

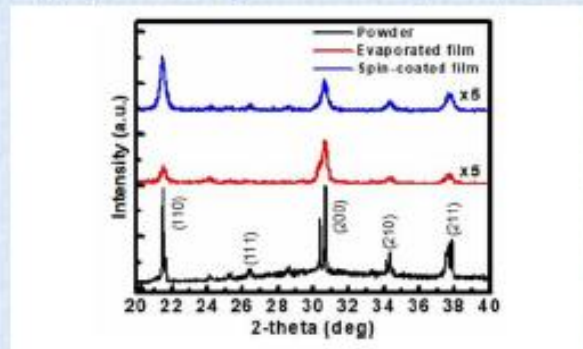


Fig. 5. XRD patterns of perovskite CsPbBr₃ powder and the derived films. The XRD spectra indicate the perovskites are with orthorhombic crystal structure.

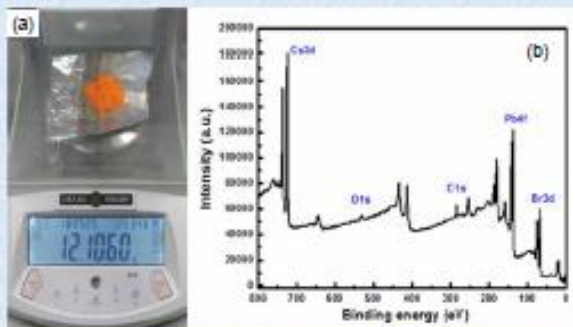


Fig. 2. (a) High quality CsPbBr₃ powder with a total weight of ~12.1 g can be produced in a single synthesis process by increasing the amount of precursor. (b) XPS survey scan

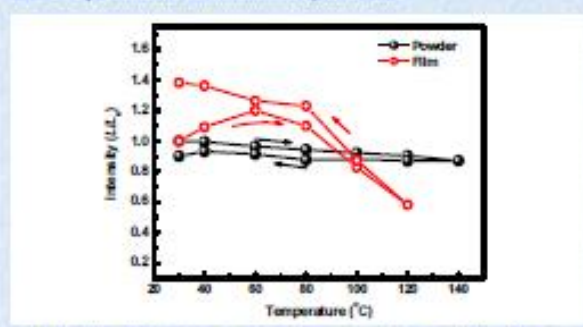


Fig. 6. Variation of PL intensity ratio of CsPbBr₃ powder and spin-coated film with measurement temperature. Arrows indicate the testing sequence. The PL intensity of the powder gradually reduced to 90% at 140 °C.

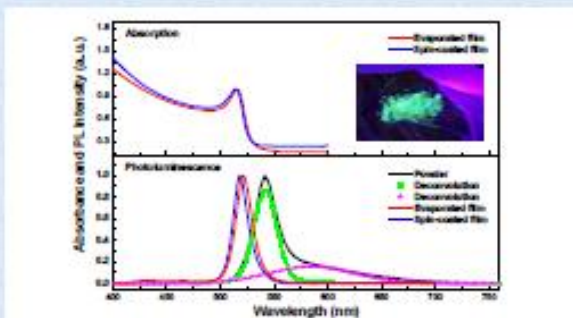


Fig. 3. Optical absorption and PL spectra of the CsPbBr₃ powder and the derived evaporated and spin-coated films. The Gaussian fittings of PL spectrum of the powder are also shown. Inset is an image of the CsPbBr₃ powder under UV irradiation.

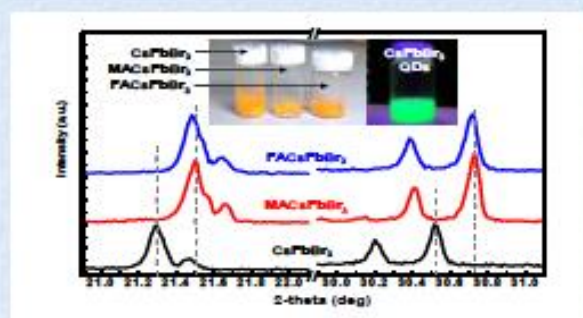


Fig. 7. XRD patterns of CsPbBr₃, MACsPbBr₃, and FACsPbBr₃ powder. Insets are the photographs of the powder under normal illumination and CsPbBr₃ QD solution under UV irradiation.