Higher Quantum Efficiency and Moisture Resistance of All-Inorganic Halide Perovskite Nanocrystals Film In-situ Fabricated with Cyclodextrin

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Chemicals and materials

$PbBr_2$ (98%,Aladdin), CsBr (99%,Macklin), β-cyclodextrin (β-CD, 99% Aladdin), Dimethyl sulfoxide (DMSO, anhydrous, ≥99.9%, Aladdin), Methanol (99%,Aladdin), Toluene (99.5%,Alfa Aesar) were used as received without further purification

Preparation of the $CsPbBr_3$-β-CD film

$CsPbBr_3$ precursor solution was prepared by adding CsBr (0.1 mmol) and $PbBr_2$ (0.1 mmol) in 2 mL DMSO/Methanol(V/V=1:1) solvent. For the $CsPbBr_3$:β-CD precursor solution, besides the addition of CsBr (0.1 mmol) and $PbBr_2$ (0.1 mmol),Different proportions of β-CD were also added into the 2 mL DMSO/Methanol(V/V=1:1) solvent. they were dissolved at ultrasonic for 30 min and stirred for 12 h at room temperature. Glass substrate soaked in Pinaha solution at 60 ℃ for 30 min, then rinsed with water and dried. After that, substrates were transferred into Spin coater and spin-coated with 100 μL $CsPbBr_3$ or $CsPbBr_3$: β-CD solution (1000 rpm for 30 s and then 2500 rpm for 60 s) at 75 ℃ by one-step method, and at 15 s before the last spin-coating step, 0.1 mL Toluene solvent was pipetted onto the substrate to wash out the solvent DMSO in the perovskite wet films and induce fast crystallization.Finally, the spin-coated films were annealed at 150 ℃ for 15 min to remove the residual solvent.

Characterization

Spin coater (IC5000, Jiangsu Leibo Scientific Instrument Co., Ltd, China) were used for preparation of perovskite film. Powder X-ray diffraction (XRD) patterns were performed on a Jordan Valley EX-Calibur X-ray Diffractometer at 40 kV and 35 mA using Cu Kαradiation, as shown in Figure S2.The morphologies were investigated using a HITACHI SU8220 (Japan) Scanning Electron Microscopy (SEM). Photoluminescence (PL) measurements were

performed using a Fluorescence spectrophotometer F97Pro, (Shanghai Lingguang Technology Co., Ltd.) in ambient conditions. PL quantum yield and time-resolved PL were characterized at room temperature using a Edinburgh Instruments FLS980 fluorescence spectrometer (United Kingdom). Fourier transform infrared (FTIR) spectra were measured by using a Thermo Fisher Scientific Nicolet iS50 (USA). UV-vis absorption spectra were recorded on a FLA6000 (Hangzhou Jingfei Technology Co., Ltd.) spectro- photometer. X-ray photoelectron spectroscopy (XPS) analysis was collected using an Thermo Fisher Scientific ESCALAB250Xi (USA). The TGA was carried out using a TGA/DSC/1600LF (Switzerland) with an operative temperature range 25-1600 ℃ and 0.1 microgram sensitivity. The samples were heated from 50 to 800 ℃, with an increase of 5 ℃ /min and under nitrogen flux of 40 mL/min.

Stability test

The prepared film is placed in a constant temperature and humidity chamber LHS-150HC-II (Shanghai Yiheng Scientific Instrument Co., Ltd.) at a controlled temperature of 27±2 ℃ and a controlled humidity of 80±3%.

Table S1. Detailed spectrum information, including emission peaks, FWHM,and QY of the samples with different β-CD concentration.

β-CD concentration (mM)	0	10	25	50	75
Absorption (nm)	515	510	508	503	505
Emission peak (nm)	/	523	521	519	521
FWHM (nm)	/	19	18	18	19
PLQY (%)	3.2	25.5	78.8	85.3	80.2

Table S2. Parameters of bi-exponential fitted time-resolved of the tow perovskite films.

β-CD concentration	A_1 (%)	τ_1 (ns)	A_2 (%)	τ_2 (ns)	χ^2	τ_{avr} (ns)
25 mM	42.32	47.53	57.68	358.47	1.054	226.88
50 mM	31.42	58.45	68.58	567.11	1.078	407.28

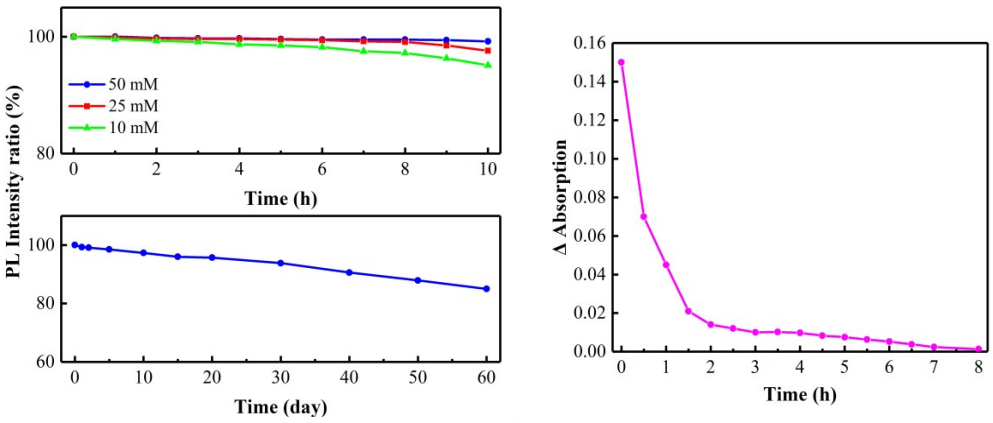

Fig. S1 PL (A) and UV-Vis (B) intensity change with time of the $CsPbBr_3$ perovskite film with different β-CD concentration exposing to the moisture with a humidity of 80 %(± 3 %) at room temperature (27 ± 2 ℃).

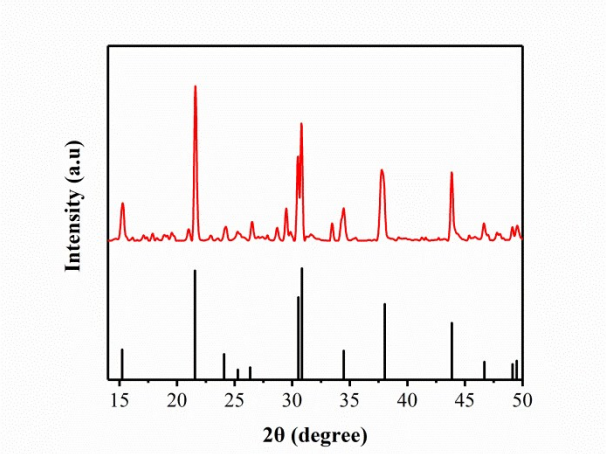

Fig. S2 XRD patterns of the as-prepared $CsPbBr_3$ perovskite film (50 mM β-CD, red) and the standard pattern of $CsPbBr_3$ (PDF#54-0751, black).

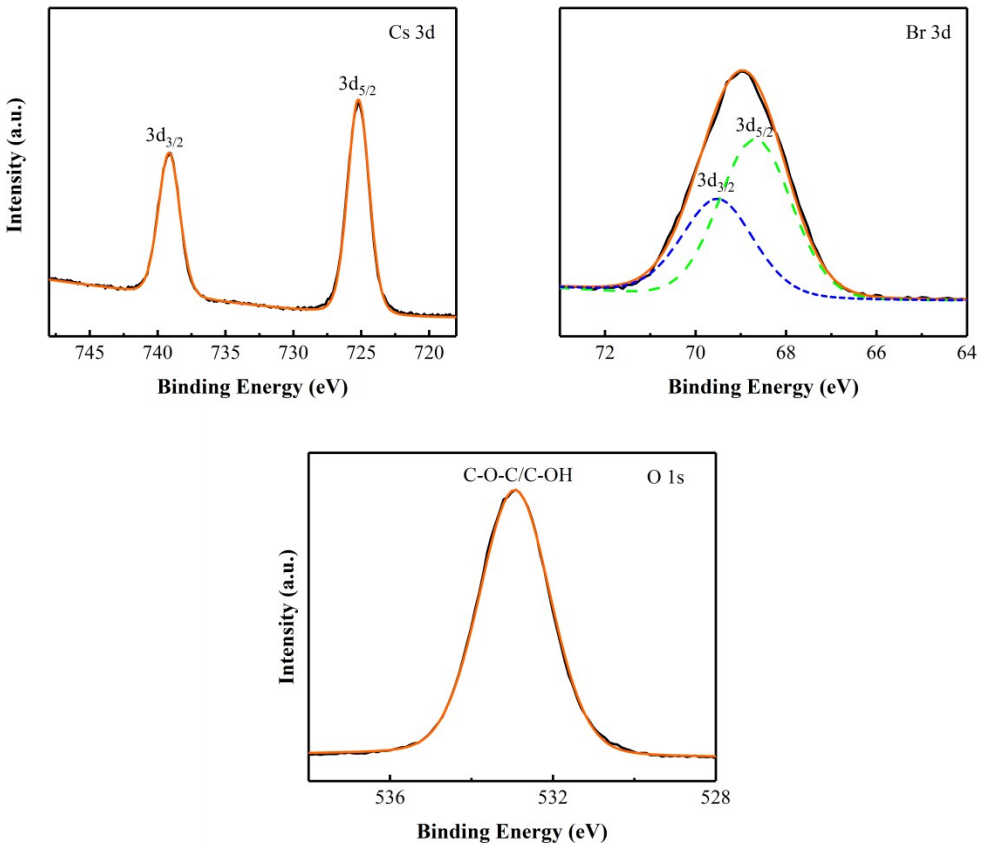

Fig. S3 XPS spectra with elements Br3d, Cs3d and O1s of the $CsPbBr_3$ perovskite film (50 mM β-CD).

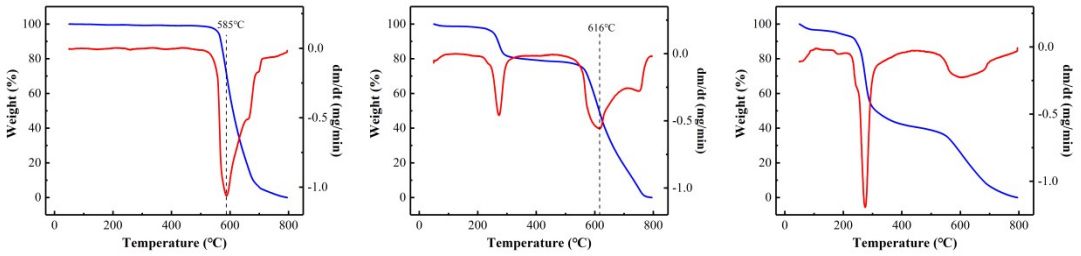

Fig. S4 TGA heating curves and the corresponding 1st derivatives curves of pure $CsPbBr_3$ (A), 10 mM (B) and 50 mM β-CD (C) encapsulated $CsPbBr_3$.