

High-stable and controllable lasing actions from PVDF encapsulated

CsPbBr₃ perovskite microcrystals

Lin Nie¹, Xue Yu^{2,*}, Yicen Ge¹, Dongxu He¹, Xuanyu Zhu¹, Haoze Liu¹, Haihong Guo¹, Feng Zhao², Siufung Yu^{4,*}, Jianbei Qiu³, Xuhui Xu^{3,*}, Ting Wang^{1,4,*}

¹College of Materials and Chemistry & Chemical Engineering, Chengdu University of Technology, Chengdu 610059, China

² School of Mechanical Engineering, Institute for Advanced Study, Institute for Advanced Materials Deformation and Damage from Multi-Scale, Chengdu University, Chengdu, 610106, P. R. China

³ Faculty of Materials Science and Engineering, Key Laboratory of Advanced Materials of Yunnan Province, Kunming University of Science and Technology, Kunming, 650093, Yunnan, P. R. China.

⁴The Department of Applied Physics, The Hong Kong Polytechnic University, Hong Kong 999999, China

Email address: wangtkm@foxmail.com (WT); yuyu6593@126.com (YX); xuxuh07@126.com (XXH); sfyu21@hotmail.com (SFY)

Experimental sections:

Raw Materials: Caesium bromide (CsBr, 99.90%, Aladdin), lead (II) bromide (PbBr₂, 99.99%, Aladdin), N,N-dimethylformamide (DMF, 99.80%, Aladdin), and Polyvinylidene fluoride (PVDF, Aladdin). All raw materials were used as received without further purification.

Preparation of precursor colloidal solution: 0.20 mmol of CsBr and PbBr₂ were added to 5 mL DMF, respectively, and stirred on a magnetic heating stirrer until completely dissolved to prepare the CsPbBr₃ precursor. Then 1 g PVDF was added to 10 mL DMF, and magnetically stirred at 120 °C until it was completely dissolved into a transparent solution. Then, 2 mL of the CsPbBr₃ precursor solution and PVDF colloidal solution (DMF as a solvent) were thoroughly mixed at 120 °C to prepare the precursor colloidal solution.

In situ growth CsPbBr₃ microcrystals in PVDF: the above-mentioned precursor colloidal solution (1 g) was coated on a glass substrate to form a precursor solution layer with uniform thickness. Then, the glass substrate with precursor solution coating was placed into a heater at a high temperature (40-80°C) to accelerate the evaporation of DMF with the promotion of the crystallization of the perovskite microcrystals from the PVDF matrix. After holding onto a heating stage for 30 min, a bright green-emitting CsPbBr₃@PVDF composite film was formed.

Materials Characterization: Powder XRD data were recorded on a Bruker AXS D2 phaser with graphite-monochromatized Cu K α radiation (1.5406 Å). Transmission electron microscopy was performed on a JEOL-JEM 2100F transmission electron microscope operating at an acceleration voltage of 200 kV. SEM images and elemental mapping analysis were captured with a JEOL Field Emission SEM. The absorption curves were measured using a HITACHI U-4100 UV-vis-NIR spectrophotometer with BaSO₄ as a standard reference. PL spectra were collected by a Hitachi F-7000 fluorescence spectrophotometer. Time-resolved photoluminescence (TRPL) decay kinetics were collected using a TCSPC module (Pico Harp 300) and a SPAD detector (IDQ, id100).

Optical measurement: The lasing emission of the CsPbBr₃ microparticles wrapped by PVDF under 800 nm femtosecond (fs) pulsed laser excitation. Here, a Ti: sapphire laser (coherent Libra) was used as the excitation source and used to generate the 800 nm fs pulses (1kHz). The samples were placed on an X-Y-Z translation stage of a dark-field optical microscope (Leica DM1000 LED) for the optical (PL and lasing spectra) characterizations. A 40 \times objective lens was used to excite and collect light emissions

from microparticles. The recorded emission from the surface of the CsPbBr₃ microparticles was recorded by an optical fiber (600 μm in diameter). The optical fiber was coupled to a monochromator (Princeton Spectra Pro 2750 integrated with a Pro EM EMCCD camera with a spectral resolution of less than 0.1 nm) for spectral analysis.

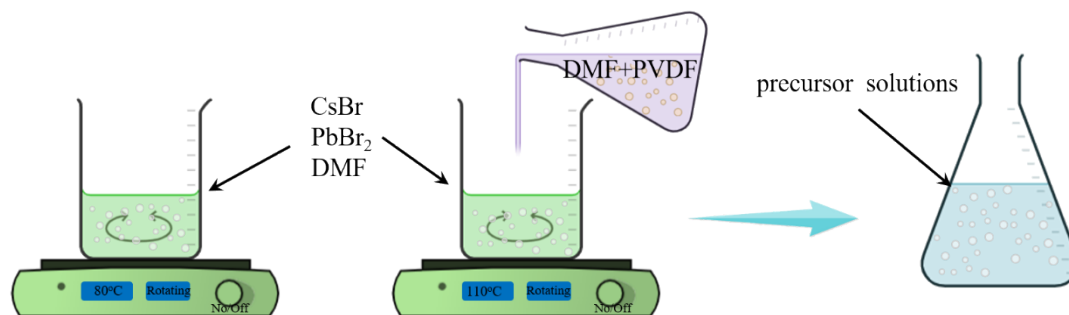


Figure S1. Schematic illustration of the method for the preparation of precursor solutions.

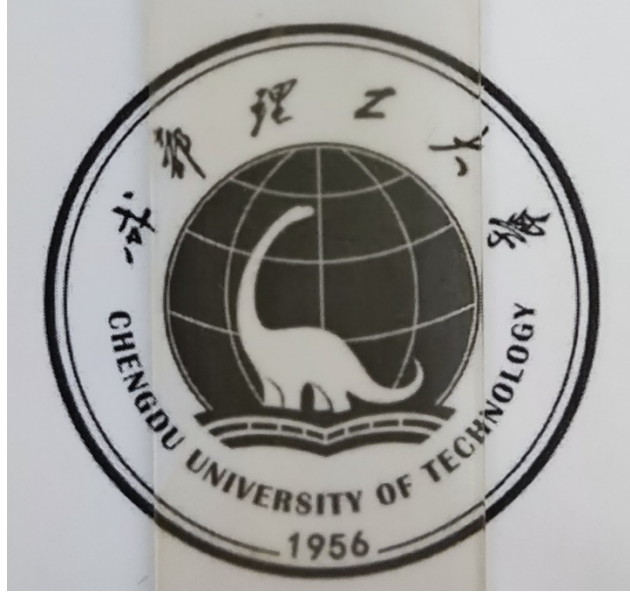


Figure S2. The photographs of CsPbBr₃@PVDF composite film were recorded under sunlight.

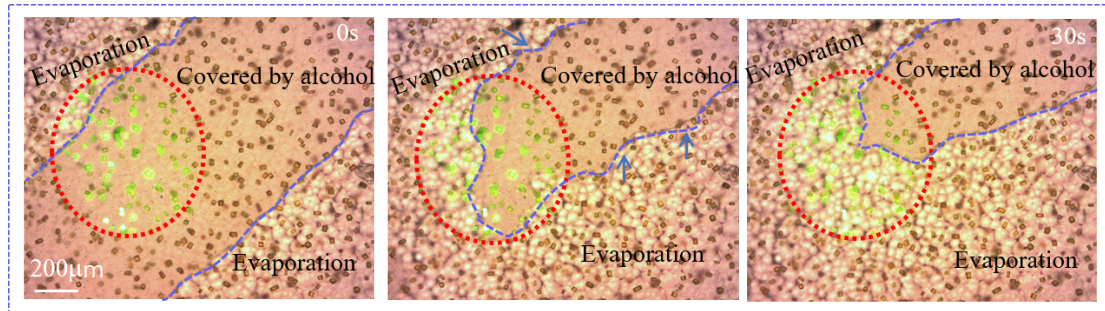


Figure S3. Luminous photographs of CsPbBr₃@PVDF composite film spilled by alcohol under 800nm fs laser excitation.

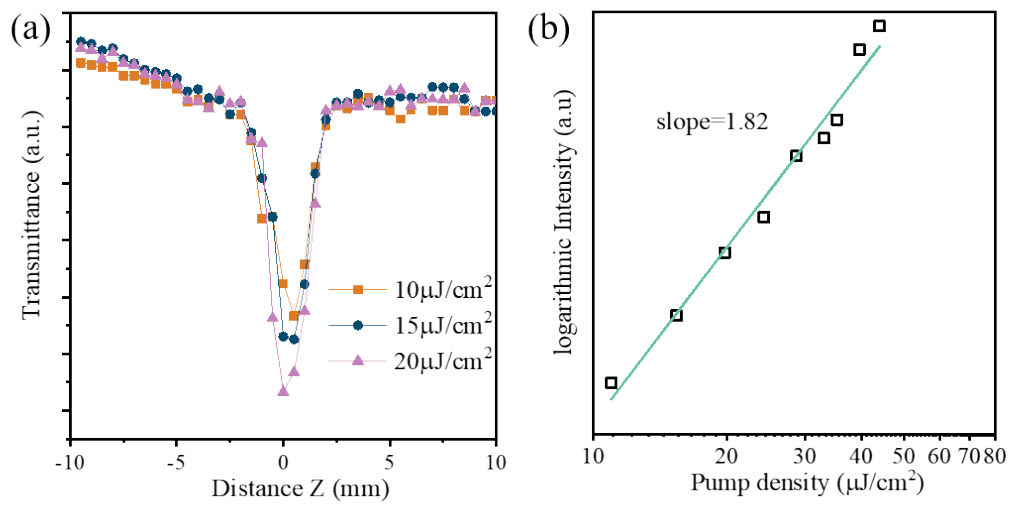


Figure S4. (a) Measured open-aperture z-scan curves and (b) emission intensities versus excitation power of the CsPbBr₃@PVDF composited film.

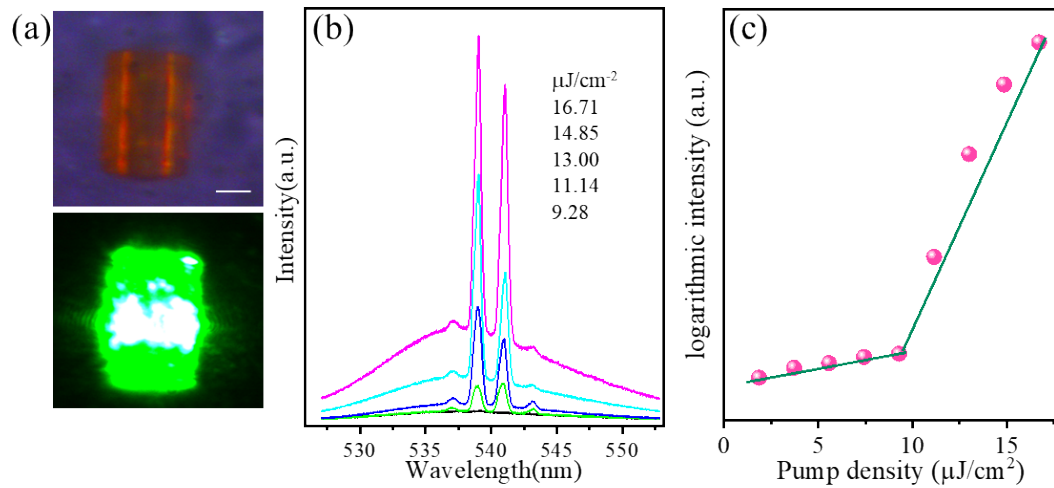


Figure S5. (a) Optical microscopy image of the CsPbBr₃ microcavity without and with the 400 nm fs laser excitation (scale bar is 10 μm). (b) Output spectra from the CsPbBr₃ microcavity, and the (c) corresponding integrated emitting intensity of the CsPbBr₃ microcavity as a function of pump density.

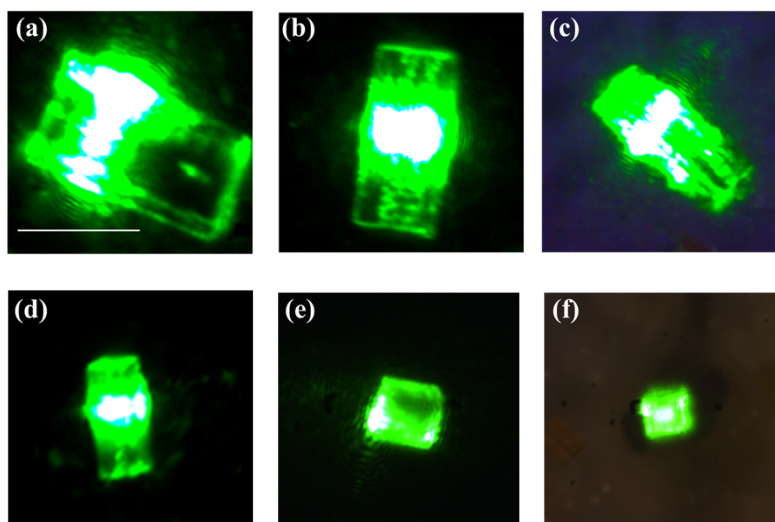


Figure S6. The enlarged lasing photograph of the PVDF wrapped CsPbBr₃ microparticles with width (W) is to be of 34, 20, 15, 13, 11, 8 μm respectively, scale bar is 30 μm .

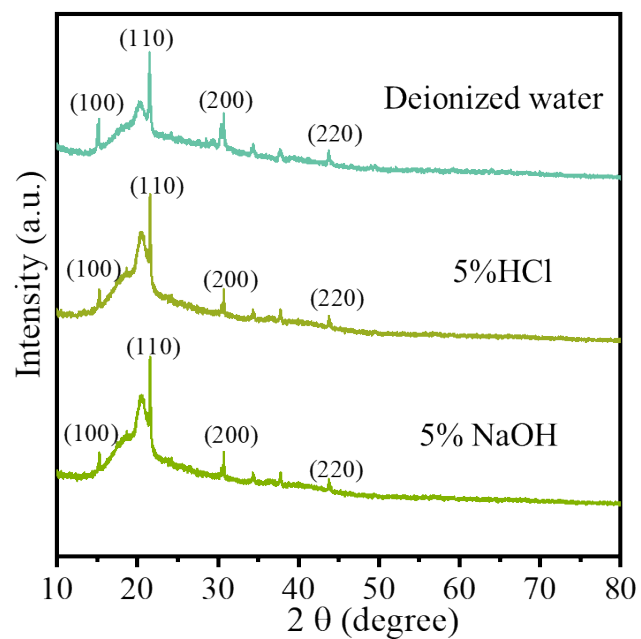


Figure S7. XRD patterns of the CsPbBr₃@PVDF composite film after being immersed in water, 5% HCl and 5% NaOH for 35 days.