Supporting Information

Fast fabrication of μm-thick perovskite film by one-step doctor-blade coating method for the direct X-ray detectors

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Experimental section:

Perovskite precursor preparation: The $MAPbBr_3$ perovskite precursor was delicately prepared inside an N_2-filled glovebox with ppm levels of oxygen and moisture. The Methylammonium bromide (MABr, GreatCell Solar) was prepared using a mixture of GBL (JT Baker) and DMSO (JT Baker) solution. Then, the lead bromide ($PbBr_2$, TCI) was sequentially added. The perovskite precursor was heated at 70 °C and stored in a dark N_2-filled glovebox.

Device Fabrication: A fluorine-doped tin oxide (FTO) substrate (approximately 10 Ω per square, PILKINGTON) was cleaned sequentially with deionized (DI) water, ethanol, and acetone in an ultrasonic bath. An ultrathin TiO_2 blocking layer (b-TiO_2) was fabricated at less than 70 ℃ by employing the technique used in the published paper [1]. The TiO_2 blocking layer followed by annealing at 500 ℃ for 60 min. Before depositing the perovskite, the substrate was treated with UV-Ozone for 10 min and preheated for 10 min on the blade track. The gap between the blade coater and the substrate was 500 μm. The operating temperature was 145 ℃, and the blading speed was 10 mms^{-1}. We used ceramic heaters (MAXTHERMO, 650 W) to post heat the top side of the perovskite film with a temperature of 110-115 ℃ The growth of perovskite can be facilitated to be more uniform. [2] The distance between the ceramic heaters and the substrate was 5 cm. After the precursor solvent being evaporated, the perovskite film completed crystal growth and film formation on the track. Then, perovskite films moved to the self-design chamber to underwent vacuum-heat treatment at 80 ℃. After that, the perovskite film was annealed for 15 min at 100 ℃ and then cooled to room

temperature. Subsequently, 125 nm of gold was thermally evaporated on the perovskite layer as the top electrode for the PSCs under a pressure of 2.5×10^{-5} mbar.

Characterization: Scanning electron microscopy (SEM) images were obtained using a field-emission scanning electron microscope (ZEISS SUPRA™ 55VP; EDS mapping: AMETEK EDAX PV77-58120ME). The OM image was analysis by 3D measurement laser confocal microscope (LEXT, OLS4000). Field emission gun was used for the electron source and the resolution can be down to 1.5 nm at 15 kV. X-ray diffraction (XRD) patterns of perovskite film was characterized by a Grazing x-ray diffractometer using Bruker D8 Advanced ECO XRD spectrometer with Cu Kα radiation at a scan rate of 10° min^{-1}. Photoluminescence (PL) spectral mapping was conducting using a micro Raman/fluorescence spectroscopy system (UniDRON, CL Tech. Co., Ltd.) with a 532-nm laser beam and a confocal microscope with a 10× objective lens. The *J-V* and *J-t* characteristic measurement was conducted by illuminating the device with an X-ray irradiation and the device was connected to a source meter (Keithley 2401) for tracing the data. An integrated X-ray table system (MyVet table X500) with an X-ray tube (E7239X, Toshiba) was employed as the X-ray irradiation source. The X-ray dose was calibrated by the dose meter (Cobia Flex R/F).

References:

[1] K.-W. Huang, Y.-H. Chen, M.-H. Li, Y.-S. Wu, P.-T. Chiu, Y.-P. Lin, Y.-L. Tung, S.- Y. Tsai, Peter Chen, *Org. Electron.* **2019**, 75, 105379.

[2] K.-W. Huang, M.-H. Li, P. T. Hsieh, C.-F. Lin, R. Rajendran, Y.-L. Tung, Peter Chen *J. Mater. Chem. C*, **2022**,10, 16016-16027.

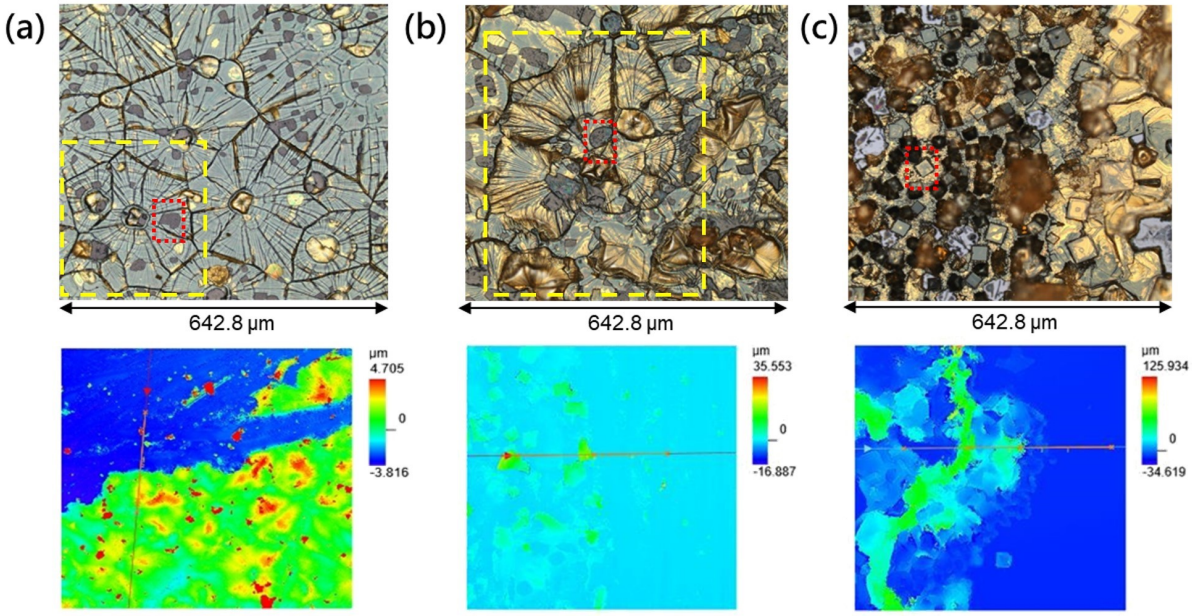

Figure S1. 2D OM images (top row) as well as 3D OM images (bottom row) of doctor-bladed $MAPbBr_3$ perovskite films with a concentration of (a) 2.0 M, (b) 3.0 M, and (c) 4.0 M.

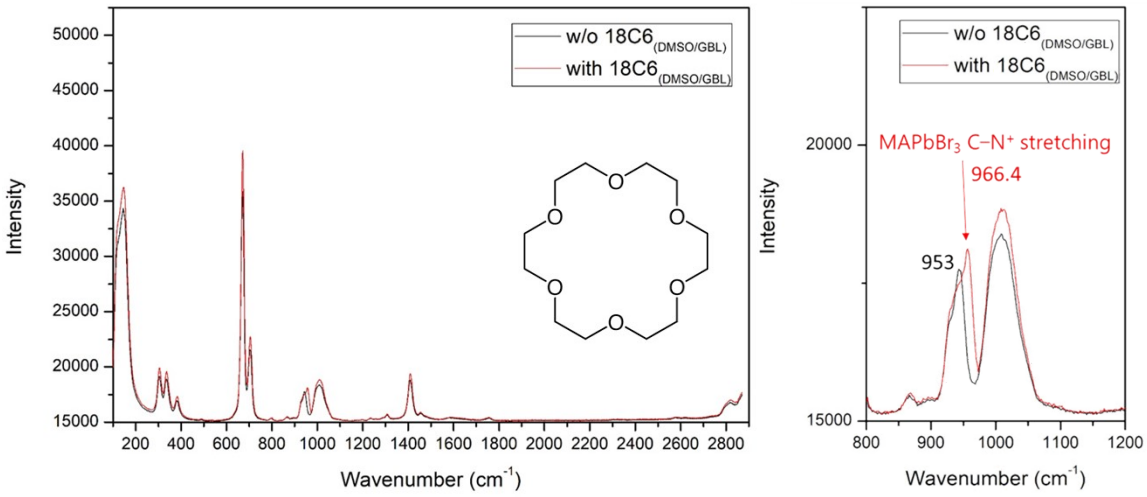

Figure S2. Raman spectra of perovskite precursor with and without 20-wt% 18C6. Inset is the molecular structure of 18C6.

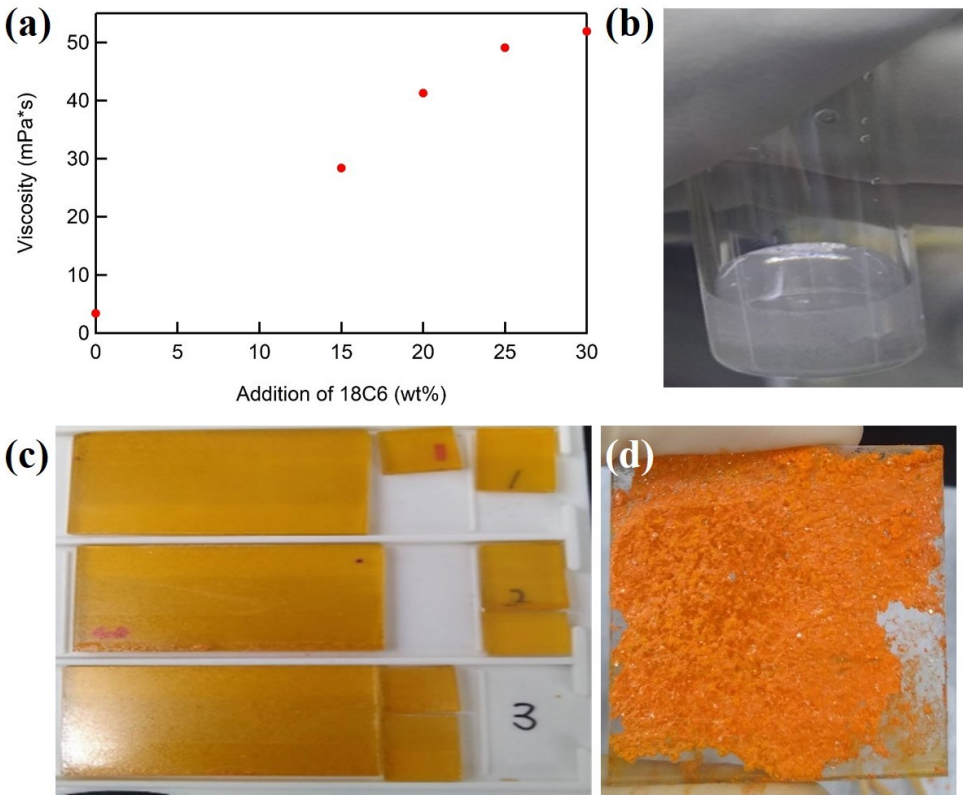

Figure S3. (a) Average viscosity of perovskite precursor with a concentration of 2.0 M added with different wt% of 18C6. Photo of (b) 2.0-M perovskite precursor added with 25 wt% 18C6, (c) doctor-bladed perovskite films with 20 wt% 18C6, and (d) doctor-bladed perovskite film with 25 wt% 18C6.

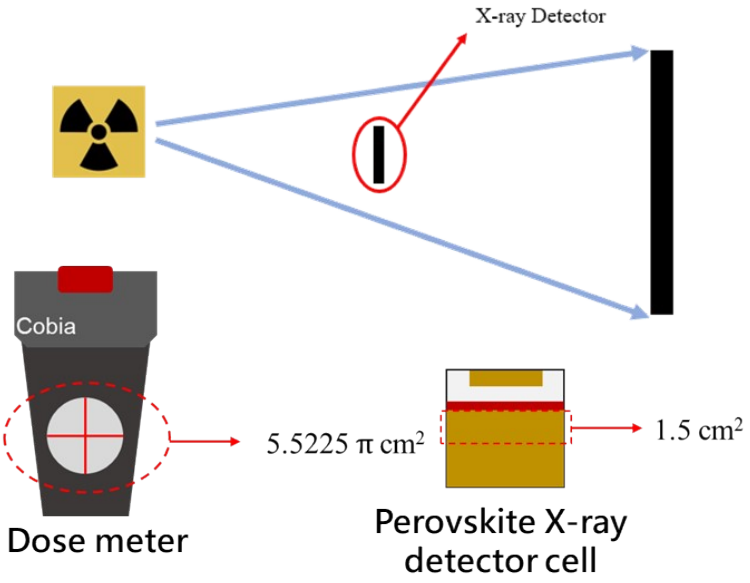

Figure S4. Schematic illustration of X-ray detection method and component measurement area.

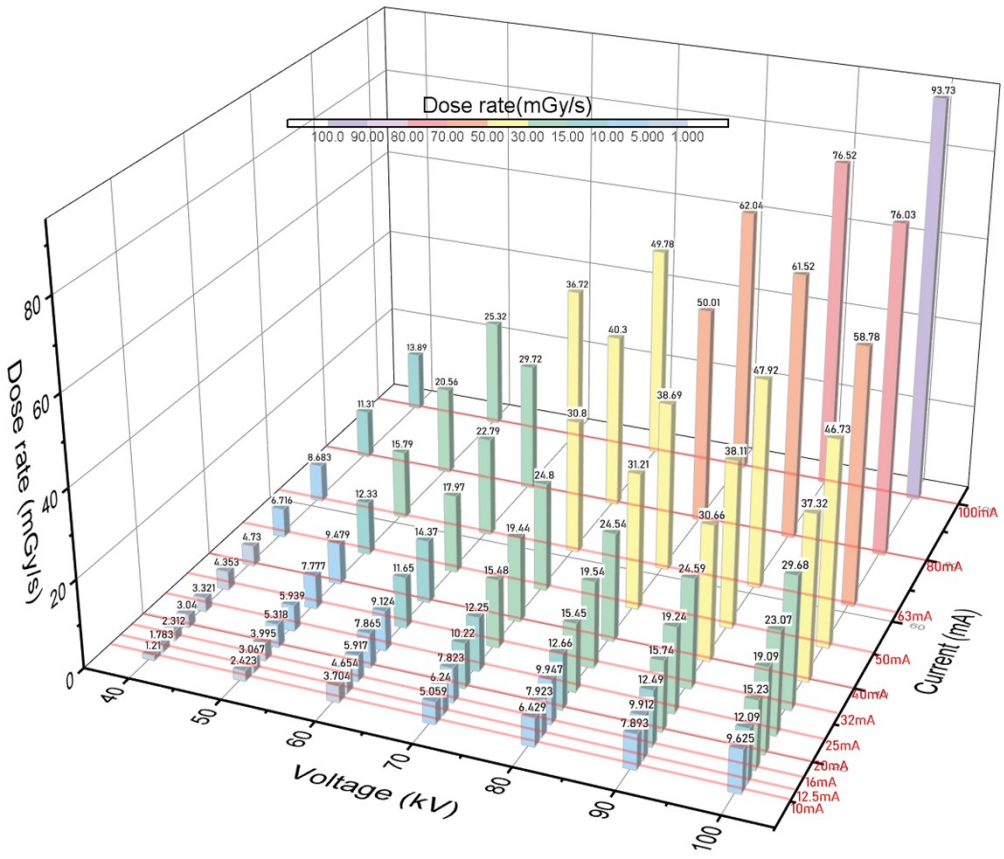

Figure S5. The X-ray tube used in this study, the three-axis diagram of the operating voltage and operating current corresponding to the dose rate value.

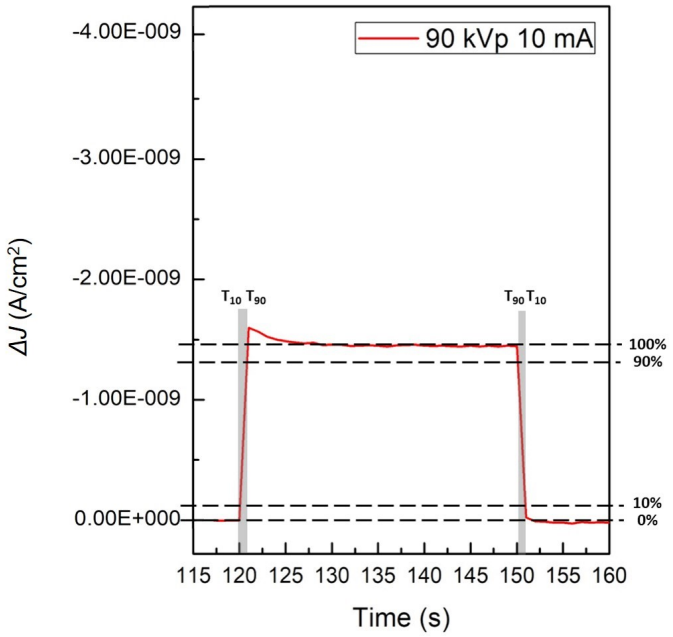

Figure S6. Schematic diagram of the response time for the device exposed to X-ray irradiation with a period of 30 s.

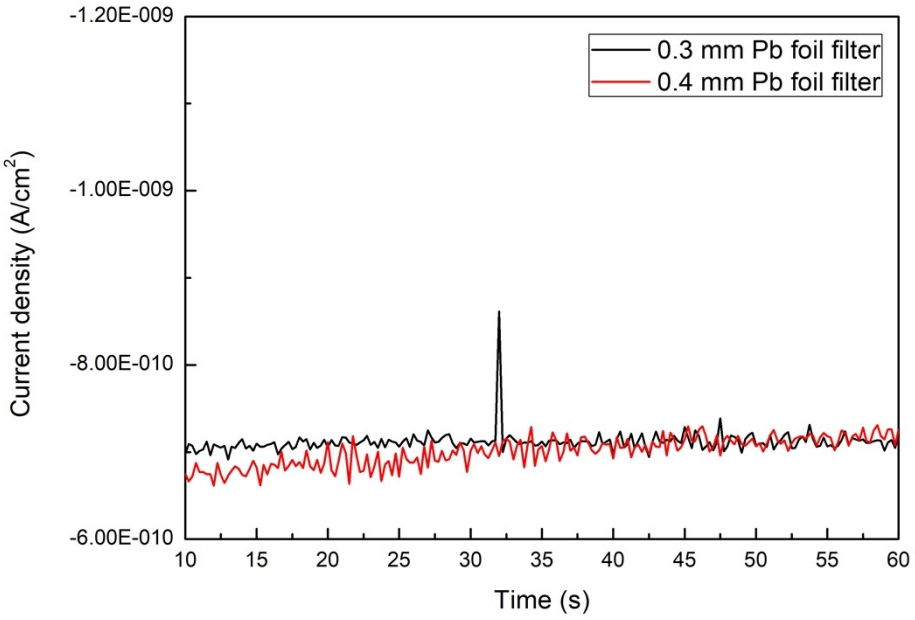

Figure S7. *J-t* curves for perovskite direct-type X-ray detector under 50 kVp with different thickness of Pb foil filter.