Supplementary information

Long Photocarrier Lifetimes in $CsPbBr_3$ Films Deposited by Machine-learning-assisted IR-Laser Molecular Beam Epitaxy

Shizuka Suzuki [1], Toshihiro Sato [2], Hideomi Koinuma [3], Ryuzi Katoh [4], and Ryota Takahashi [1, *)]

[1.] College of Engineering, Department of Electrical and Electronic Engineering, Nihon University, Fukushima, 963-8642, Japan

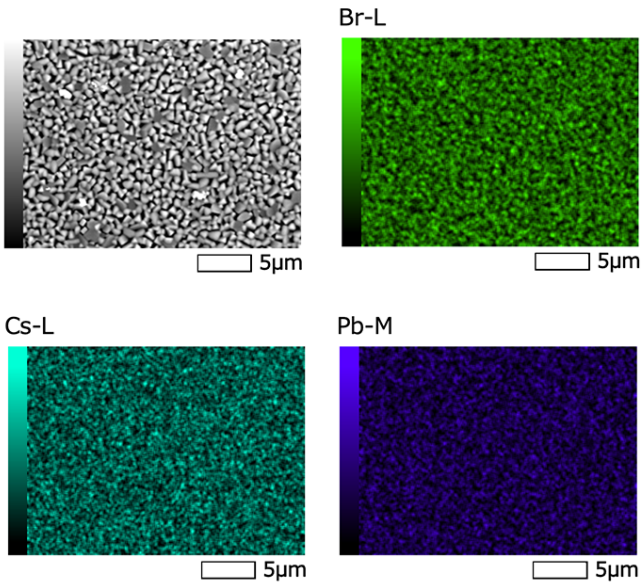
[2.] Vacuum Products, Tokyo, 187-0012, Japan

[3.] Smart Combinatorial Technology, Tokyo, 105-0014, Japan

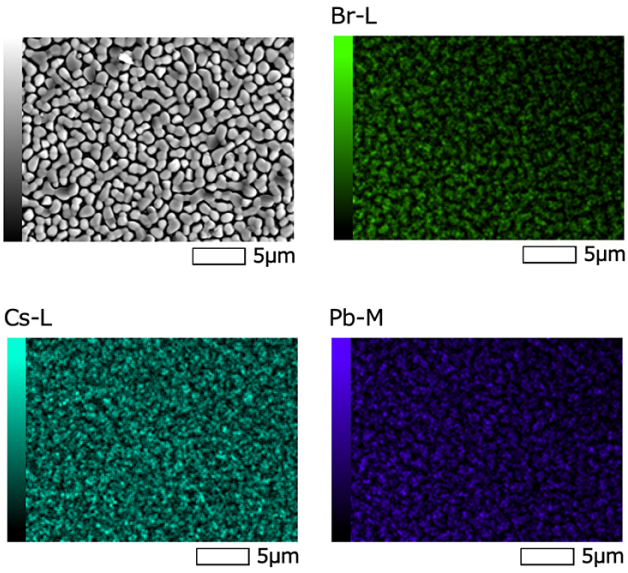
[4.] College of Engineering, Department of Chemical Biology and Applied Chemistry, Nihon University, Fukushima, 963-8642, Japan

* Author to whom correspondence should be addressed: takahashi.ryota@nihon-u.ac.jp

Condition A



Condition B



Condition C

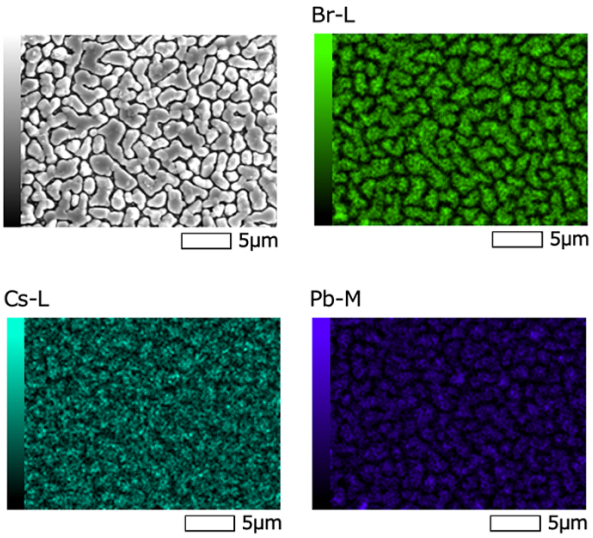


Figure S1：SEM-EDS mappings of $CsPbBr_3$ films grown under condition A, B, C. The Cs/Pb ratios of $CsPbBr_3$ films grown under conditions A, B, C were measured to be 0.997, 0.995, and 0.921, respectively.

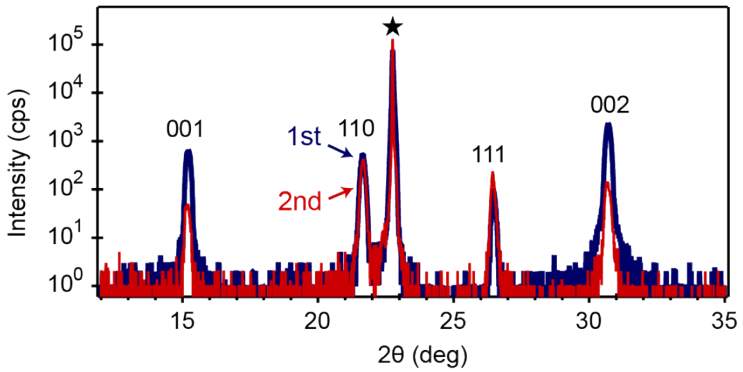


Figure S2 : XRD patterns to investigate the reproducibility of two $CsPbBr_3$ films grown under condition A. By the deposition under the growth window, no impurity peak originated from $CsPb_2Br_5$ phase were visible.

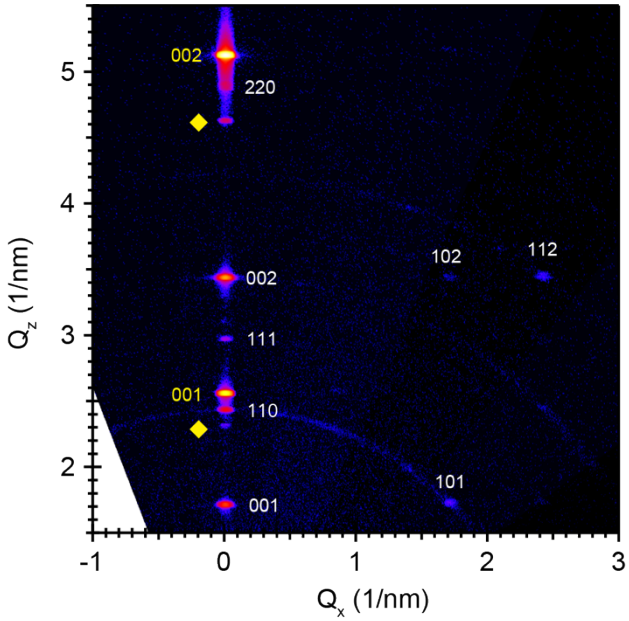


Figure S3：Wide-range reciprocal space mapping along the HHL direction of a $CsPbBr_3$ film grown under condition A on a $SrTiO_3$ substrate. White and yellow characters denote the reflections of the film and substrate, respectively. "◆" denotes the K_β reflection of the substrate crystal.

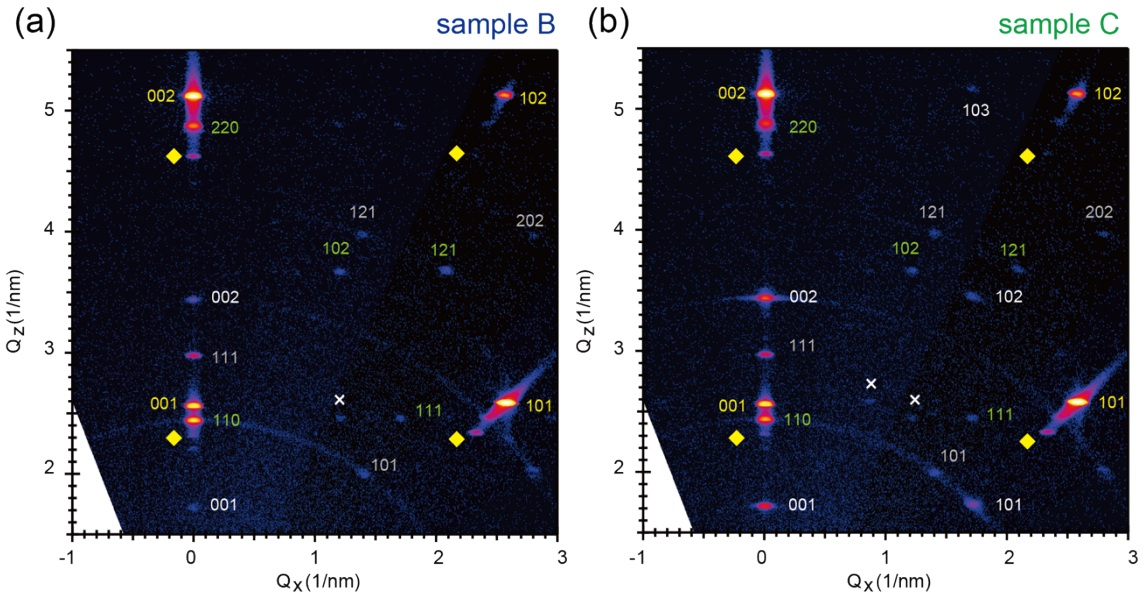


Figure S4 : Wide-range reciprocal space mappings along the HOL direction of $CsPbBr_3$ films grown under conditions B (a) and C (b) on $SrTiO_3$ substrates. White, green, gray, and yellow characters denote the reflections of the c-axis, (110)-oriented, (111)-oriented $CsPbBr_3$, and $SrTiO_3$ substrate, respectively. "◆" and "×" denotes the K_β reflection of the substrate crystal and unknown phase, respectively.

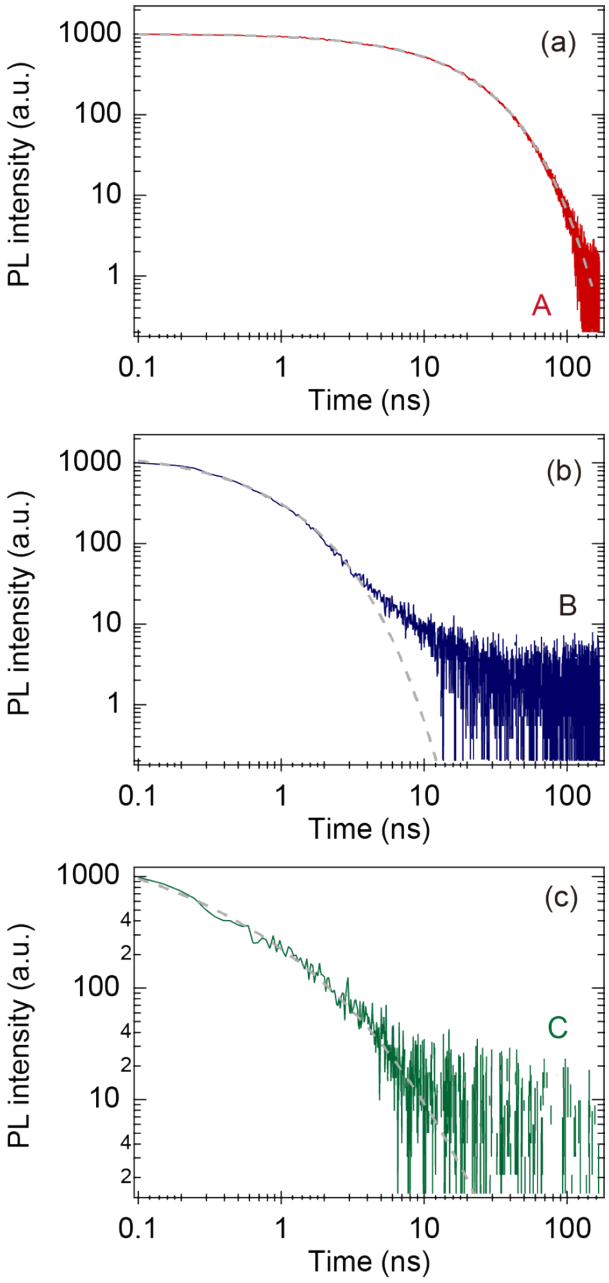


Figure S5 : Transient TRPL profiles of a $CsPbBr_3$ film grown at conditions A (a), B (b), and C (c), respectively. The gray dotted line denotes the fitting results.

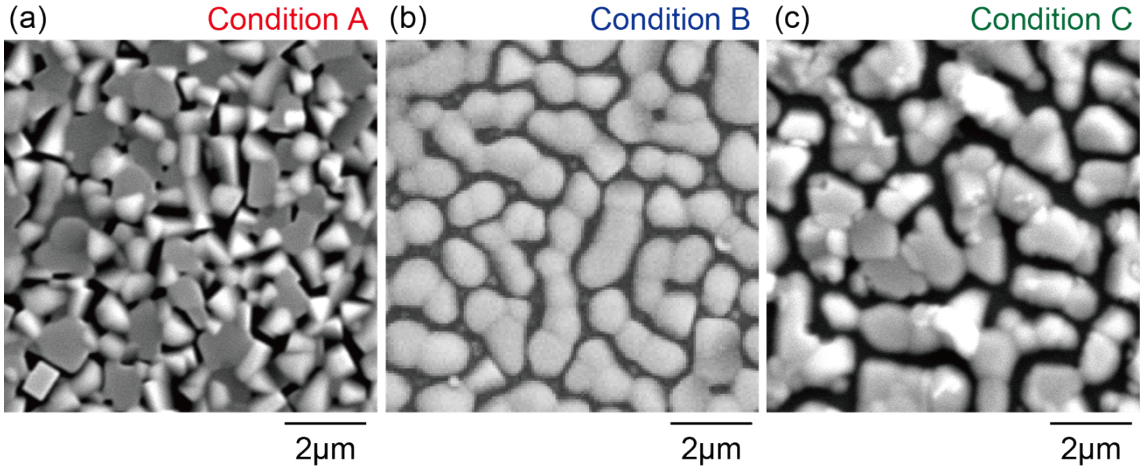


Figure S6：SEM images of $CsPbBr_3$ films grown under conditions A (a), B (b), and C (c).