Supporting Information

Acetate based Crystallization Kinetics Modulation of $CsPbI_2Br$ for Improved Photovoltaic Performance

Linfeng Ye,[†] Hongyue Wang,*[,†] Yang Wei,[†] Pengfei Guo,[†] Xiaokun Yang,[†] Qian Ye,[†] Hongqiang Wang*[,†]

[†]State Key Laboratory of Solidification Processing, Center for Nano Energy Materials, School of Materials Science and Engineering, Northwestern Polytechnical University and Shaanxi Joint Laboratory of Graphene (NPU), Xi'an, 710072, P. R. China

Email addresses: hongyue.wang@nwpu.edu.cn; hongqiang.wang@nwpu.edu.cn

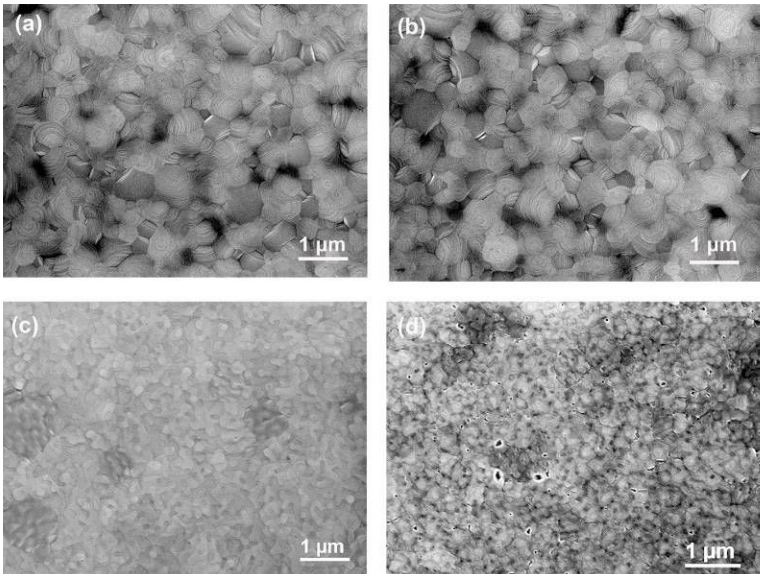

Figure S1. SEM images of the $CsPbI_2Br$ films with different concentration of $Co(Ac)_2$. **(a)** 0.1%. **(b)** 0.25%. **(c)** 0.5%. **(d)** 1.5%.

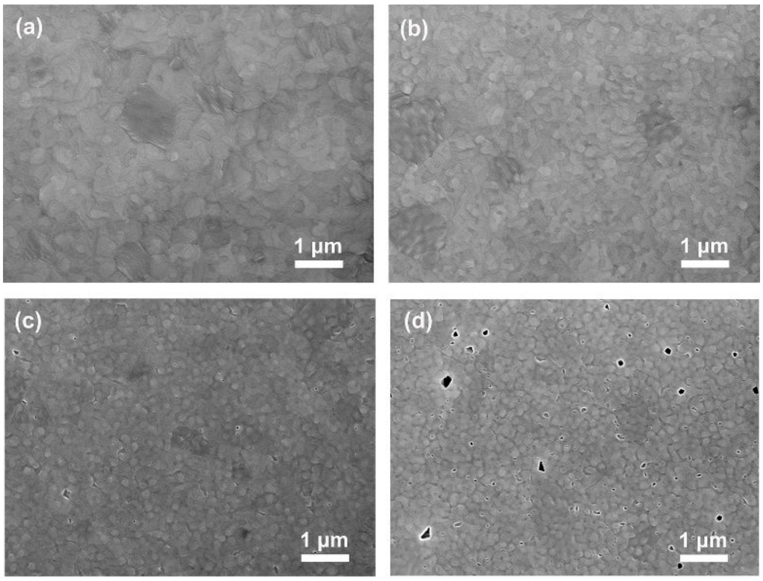

Figure S2. SEM images of the $CsPbI_2Br$ films with different concentration of $Zn(Ac)_2$. **(a)** 0.5%. **(b)** 1.0%. **(c)** 1.5%. **(d)** 2.0%.

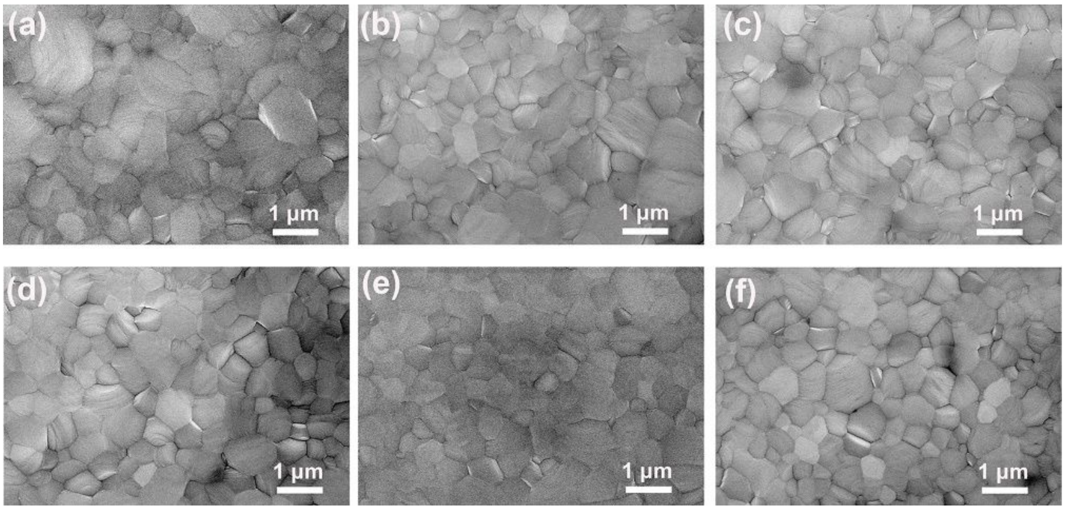

Figure S3. SEM images of the $CsPbI_2Br$ films with different concentration of $CoCl_2$ or ZnI_2. **(a)** 0.5% $CoCl_2$. **(b)** 1.0% $CoCl_2$. **(c)** 2% $CoCl_2$. **(d)** 0.5% ZnI_2. **(e)** 1.0% ZnI_2. **(f)** 2% ZnI_2.

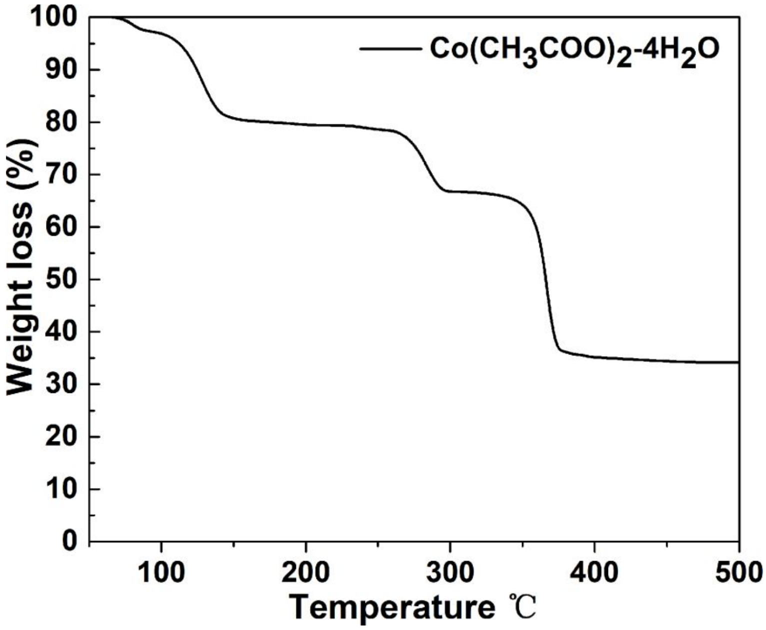

Figure S4. Thermogravimetry (TG) of $Co(Ac)_2$-$4H_2O$ was measured in nitrogen atmosphere at a temperature rate of 10 °C min^{-1}.

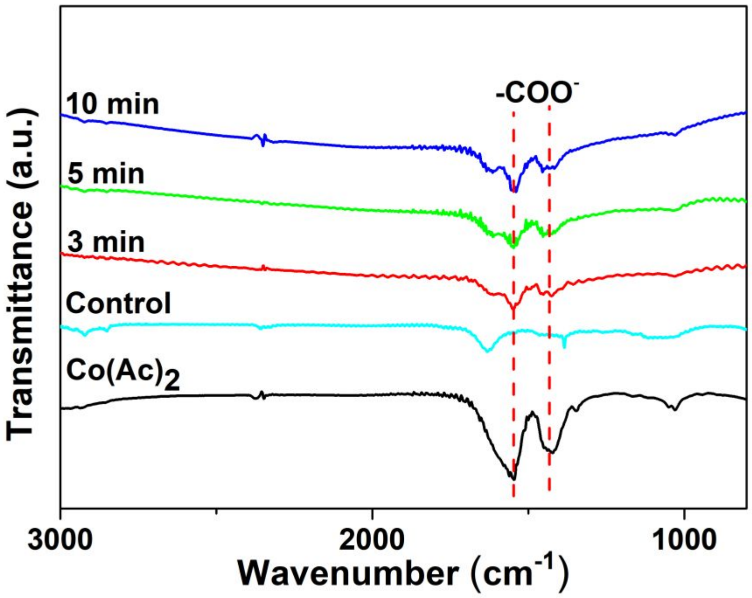

Figure S5. FTIR spectra of $CsPbI_2Br/Co(Ac)_2$ films with different annealing times at 270 °C.

As indicated in FTIR spectrum of $Co(Ac)_2$ treated at 270 ℃ for 3 min, two prominent peaks at 1542 and 1413 cm^{-1} belonging to the asymmetric and symmetric stretching of the carboxylate ion can be observed. To further investigate the thermal stability of Ac^- at such temperature, the annealing time was prolonged to 10 min and the carbonyl signal still remained, which is in agreement with the TG results (Figure S4). This further indicates that $Co(Ac)_2$ is not decomposed in our procedure of preparing the perovskite film at 270 ℃ for 3 min.

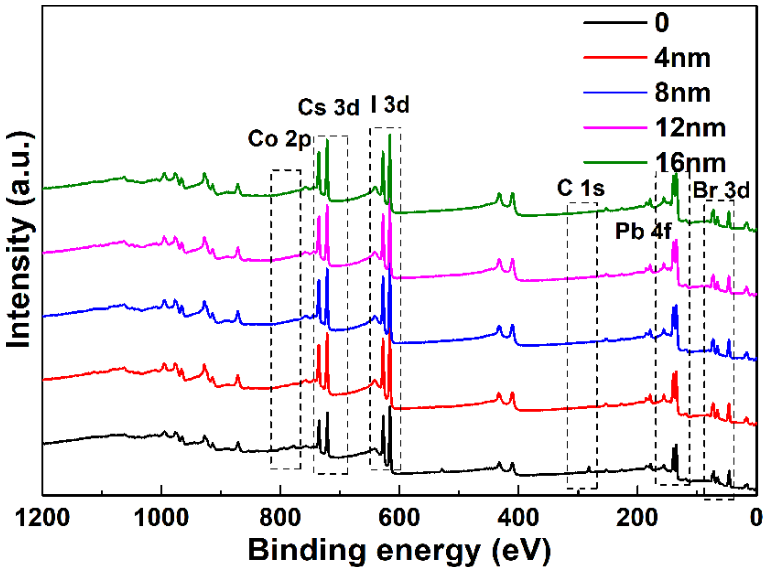

Figure S6. XPS spectra of the $CsPbI_2Br/Co(Ac)_2$ film in different depth.

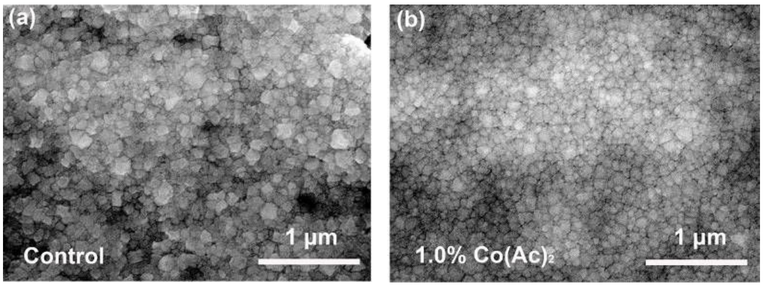

Figure S7. SEM images of the **(a)** control film and **(b)** $CsPbI_2Br/Co(Ac)_2$ film annealing at 50 ℃.

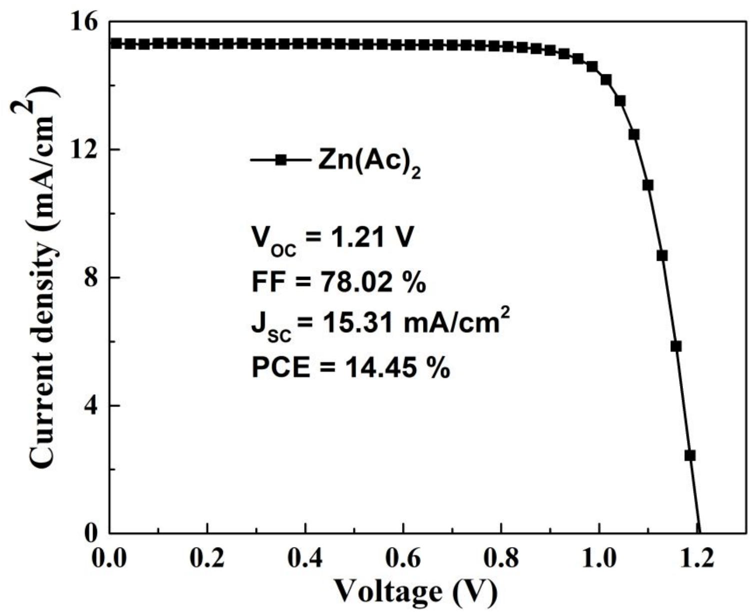

Figure S8. *J-V* characteristics of the best $CsPbI_2Br/Zn(Ac)_2$ PSCs under reverse scan directions.

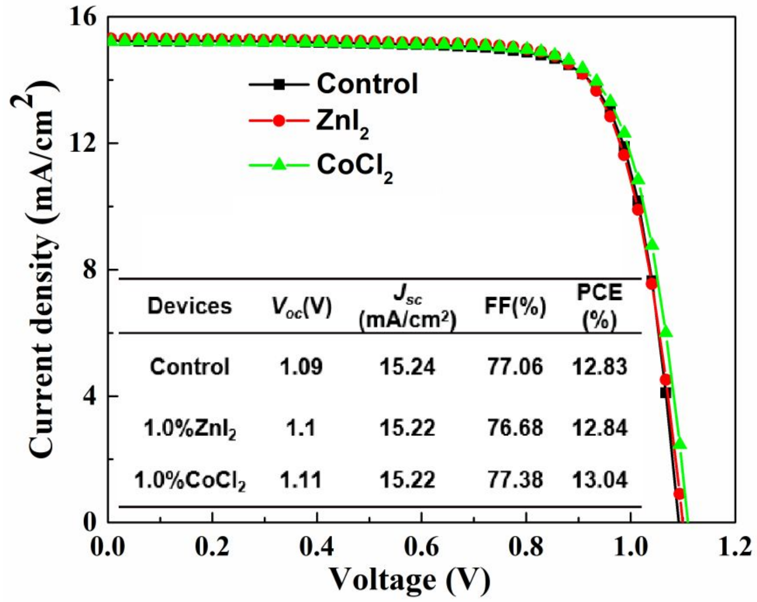

Figure S9. *J-V* characteristics of the best $CsPbI_2Br$ PSCs with ZnI_2 and $CoCl_2$.

The *J-V* characteristics for $CsPbI_2Br$ PSCs doped with $CoCl_2$ and ZnI_2 were almost the same as the control device. By comparing the PCE performance of $CoCl_2$ and ZnI_2 induced $CsPbI_2Br$ PSCs, it is demonstrated that add a little of Co^{2+} or Zn^{2+} in the precursor solution has also no influence on the performance on the $CsPbI_2Br$ solar cells.

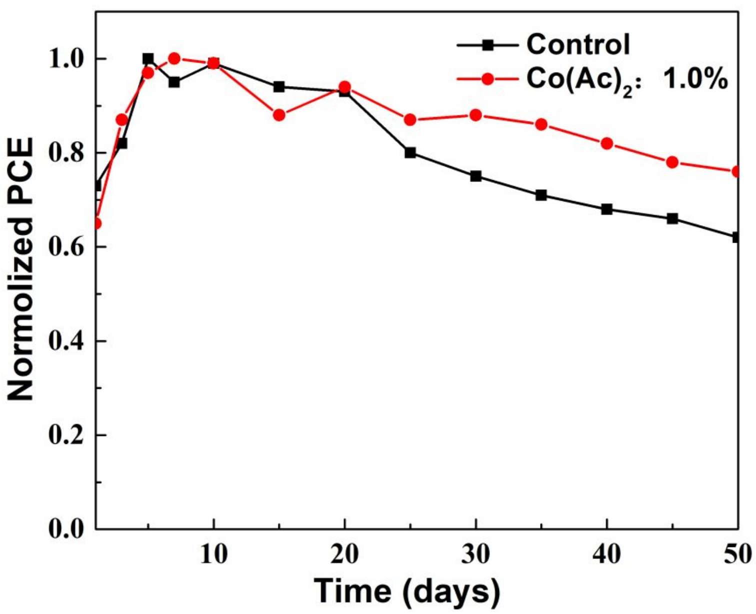

Figure S10. Long-time storage stability of PSC in N_2 glove-box.

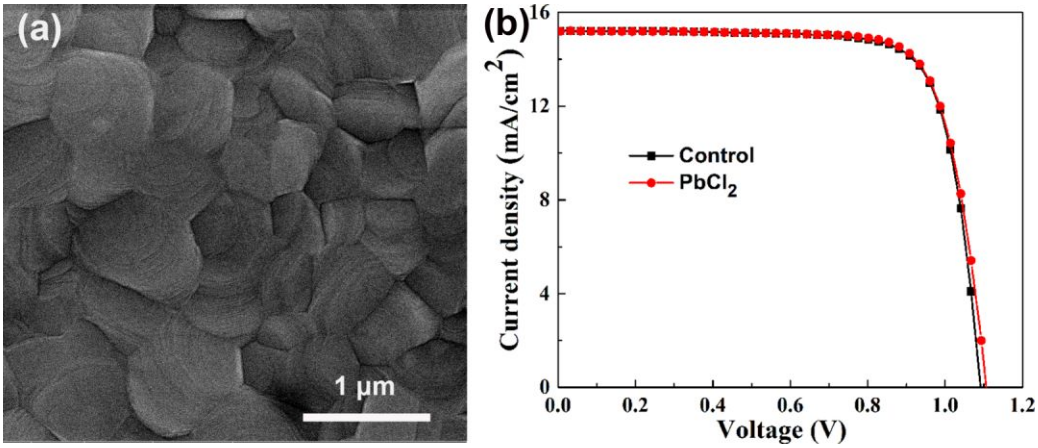

Figure S11. (a) SEM images of the $CsPbI_2Br/PbCl_2$ film. **(b)** *J-V* characteristics of the best $CsPbI_2Br$ PSCs with 1.0% $PbCl_2$.

Figure S11a shows SEM images of $CsPbI_2Br$ film with $PbCl_2$ addition. The morphology of film has not significant change with $PbCl_2$. The *J-V* characteristics for $CsPbI_2Br$ PSCs with $PbCl_2$ (shown in Figure S11b) demonstrate that the Cl^- has no modification on the performance of $CsPbI_2Br$ PSCs.

Table S1. PL lifetime for the control and $CsPbI_2Br/Co(Ac)_2$ film.

Samples	A_1(%)	τ_1(ns)	A_2(%)	τ_2(ns)	τ_{avg}(ns)
Control	0.85	2.98	0.16	7.73	4.53
1%-$Co(Ac)_2$	0.59	5.19	0.42	11.11	9.57