Supporting Information

Fig. S1 The image of I-Pure perovskite film which was fabricated by FAI/PbI$_2$ precursor solution
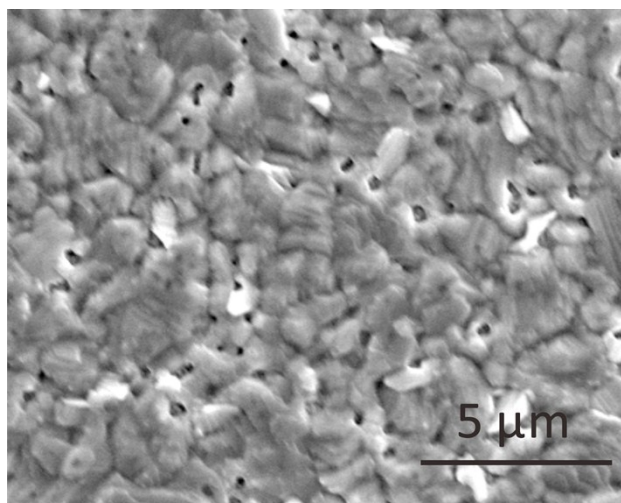
with anti-solvent treatment.

Fig. S2 The EDS images of two perovskite films. a) EDS of MABr doping perovskite shows that

Br element still remains in films after annealing. b) EDS of perovskite films made by HI-MACl
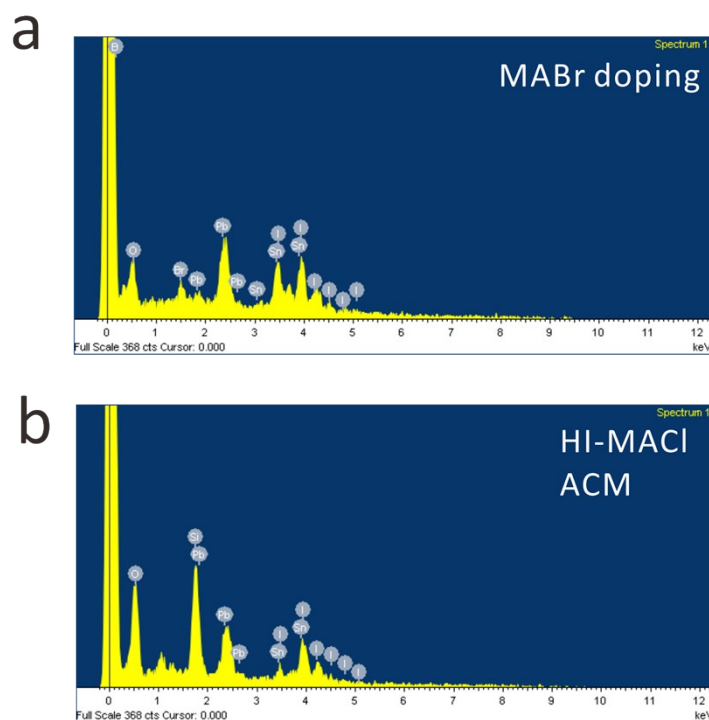
ACM. No Cl element remained as shown.

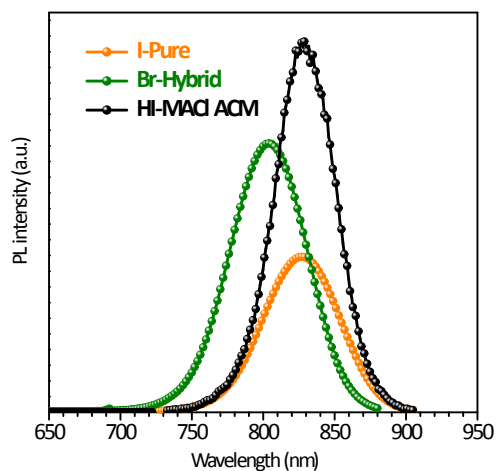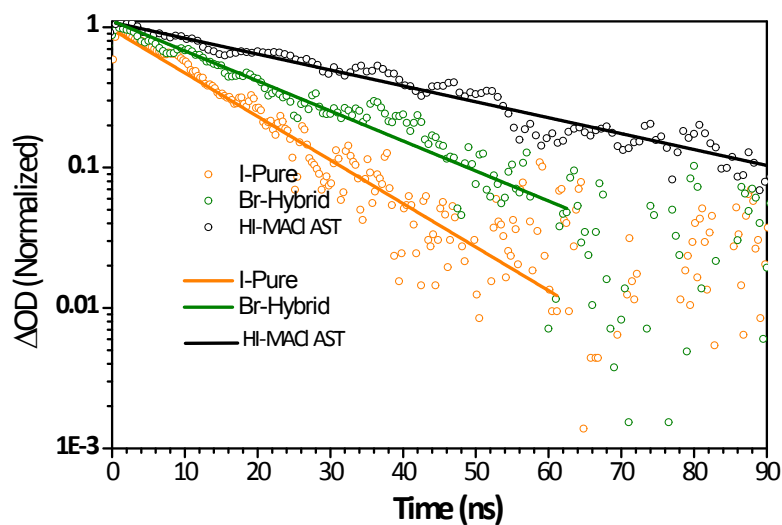Fig. S3 The full PL spectra of the three kinds of perovskite films is shown below.

Fig. S4 The full-time range of the time-resolved photoluminescence from three different layers is listed.

The fitting equation of the three simples (I-Pure,Br-Hyrid,HI-MACl ACM) are :

Y=-1.39X+188;

Y=-1.55X+276;

Y=-3.54X+470.

Fig. S5 The images of polarizing microscope are shown in Fig. 3(c-e). There are black

spots and matrix in the images. The state- photoluminescence (PL) spectra from three kind of films for black spots and matrix. Three sample films are measured. The black spots of films based on I-Pure, Br-Hybrid and HI-MACl ACM showed PL peaks at 810nm, 830nm and 810nm, respectively. The matrix of the three samples don't show any peaks.
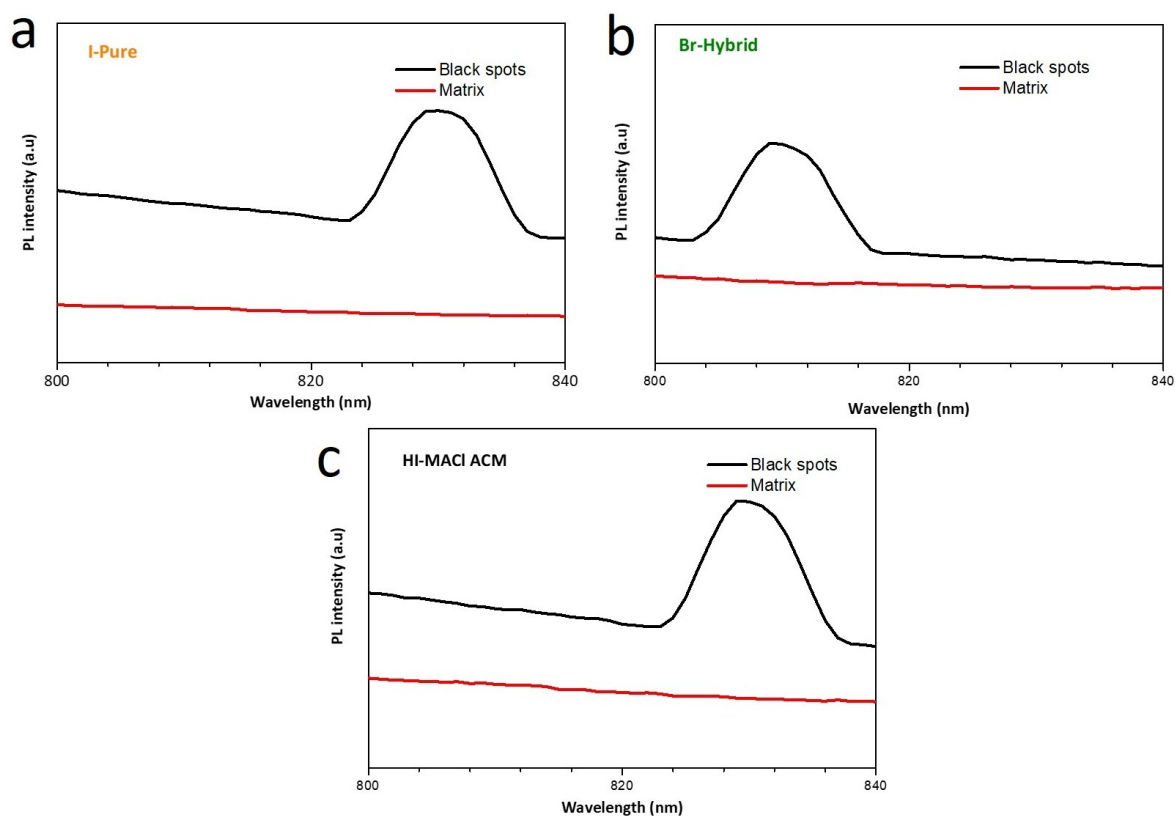

Table. S1 The spots number of polarizing microscope images at different annealing time.

Spots Number	t=0s	t=20s	t=40s	t=60s	t=100s	t=150s
I-Pure	152	178	202	204	218	220
Br-Hybrid	90	135	136	142	169	173
HI-MACl ACM	0	30	108	138	148	151

Formula S1

Debye-Scherrer formula

$$D = \frac{K\gamma}{B\cos\theta}$$

We use this formula to estimate the dimension of perovskite grain. D is the average thickness of grain perpendicular to the crystal face. B is the FWHM of XRD diffraction peaks of samples. θ represents the diffraction of angle and γ is X-ray wavelength. K is Scherrer constant.