

## Supporting Information

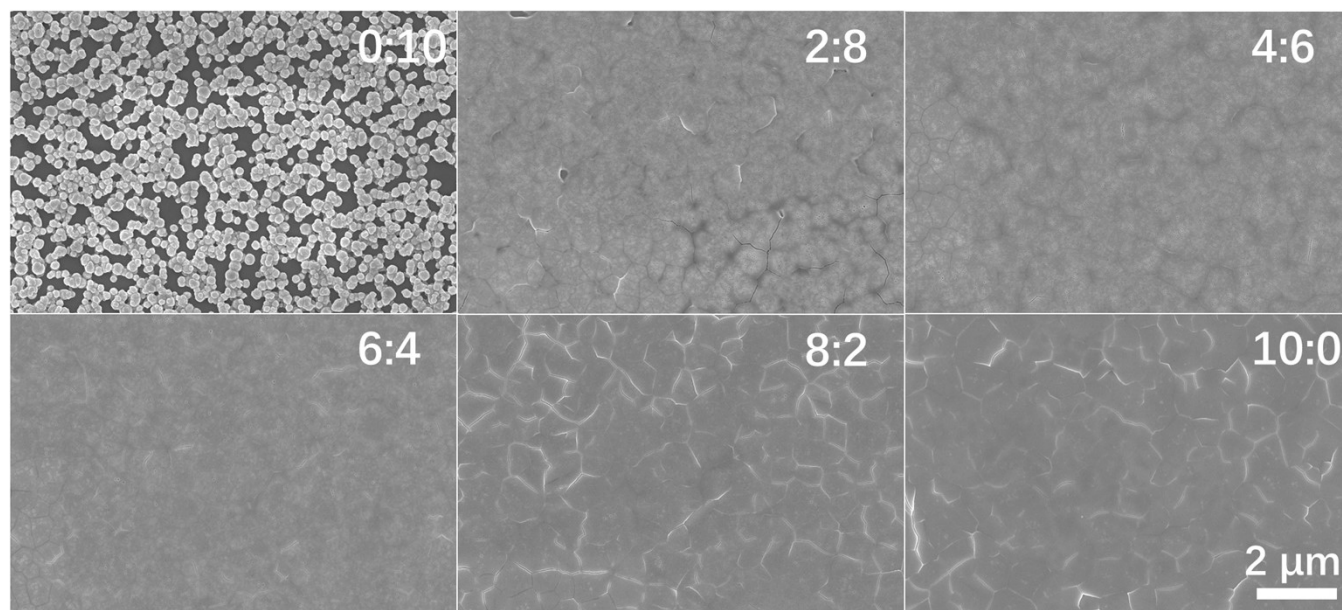


Figure S1. SEM images of RP/DJ mixed perovskite films with different ratios. All images use the same scale bar.

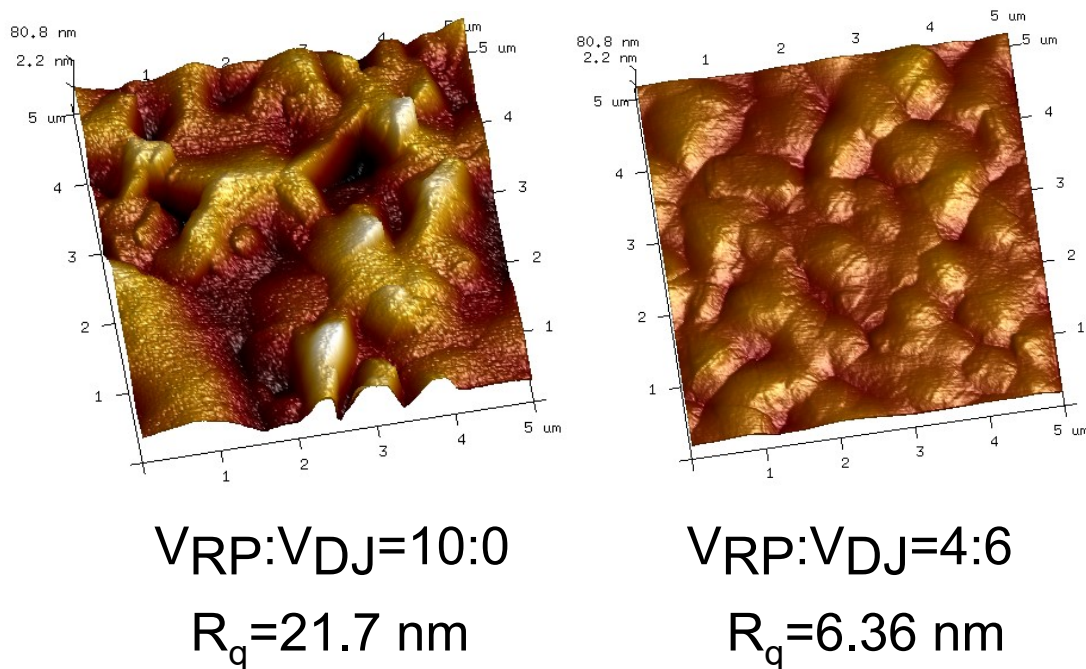


Figure S2. AFM 3D image of RP and RP/DJ films.

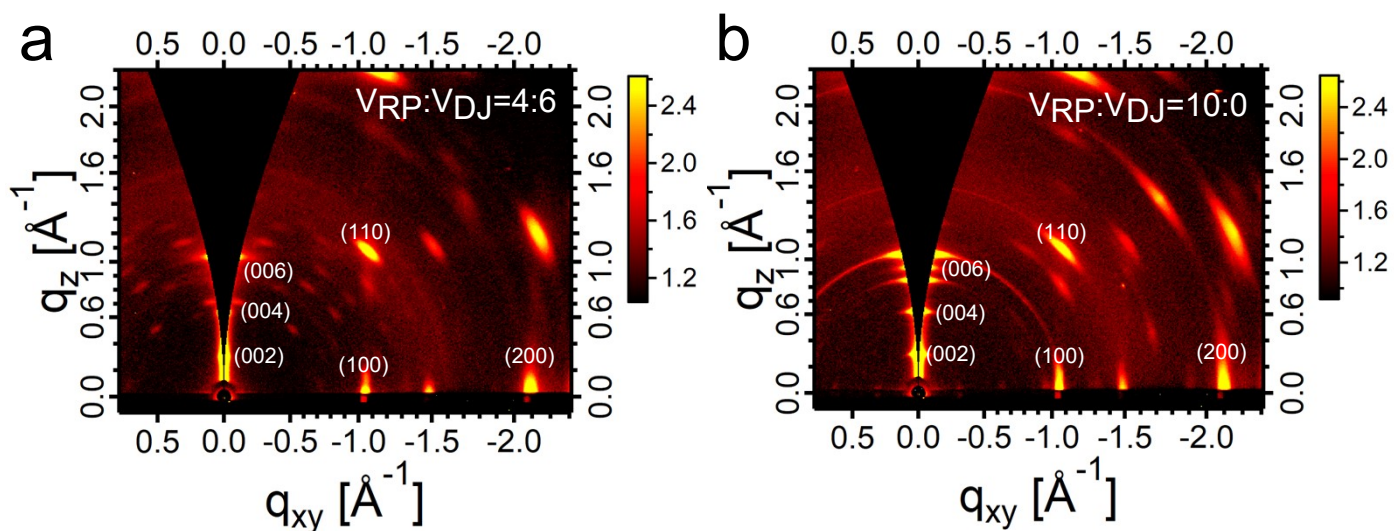


Figure S3. GIWAXS of RP/DJ hybrid film (a) and RP film (b).

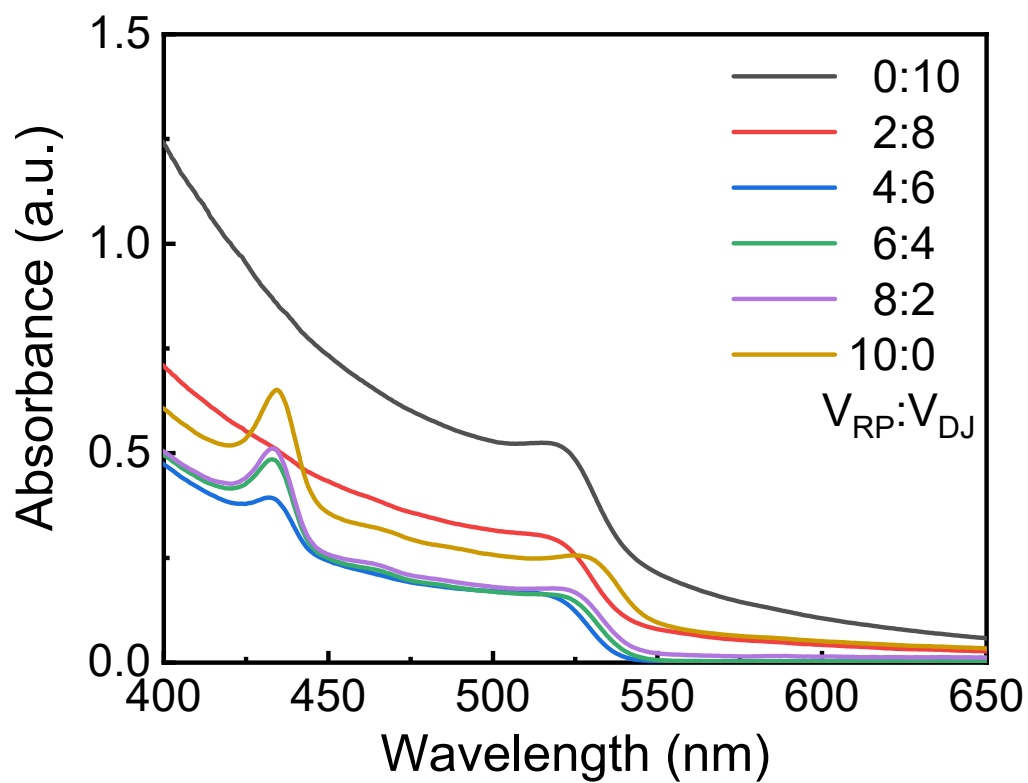


Figure S4. Abs. spectra of RP/DJ mixed perovskite films with different RP:DJ ratios.

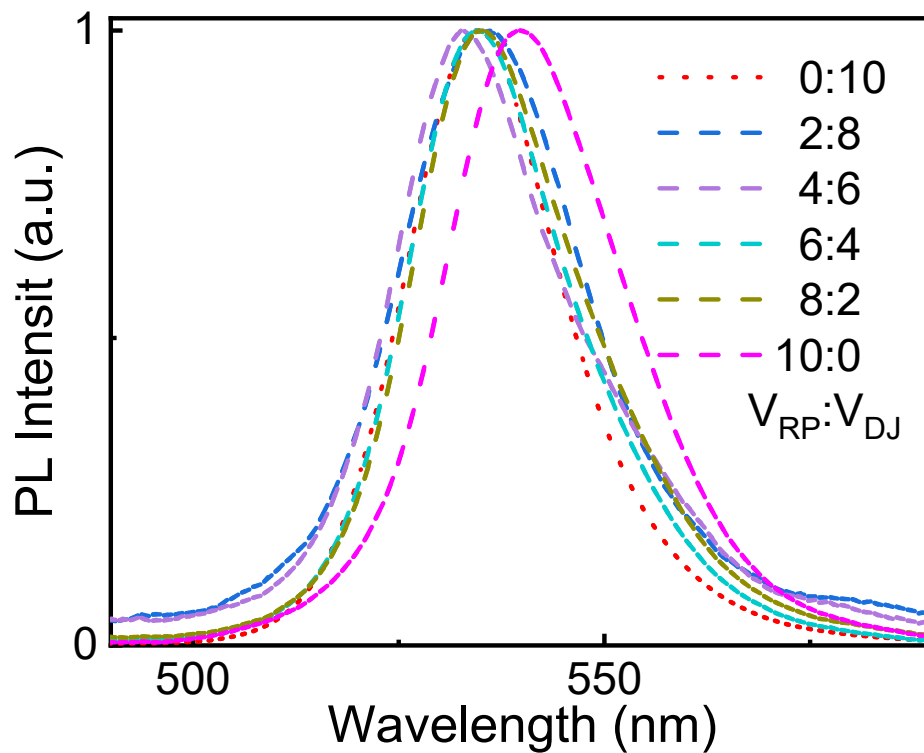


Figure S5. PL spectra of RP/DJ mixed perovskite films with different ratios.

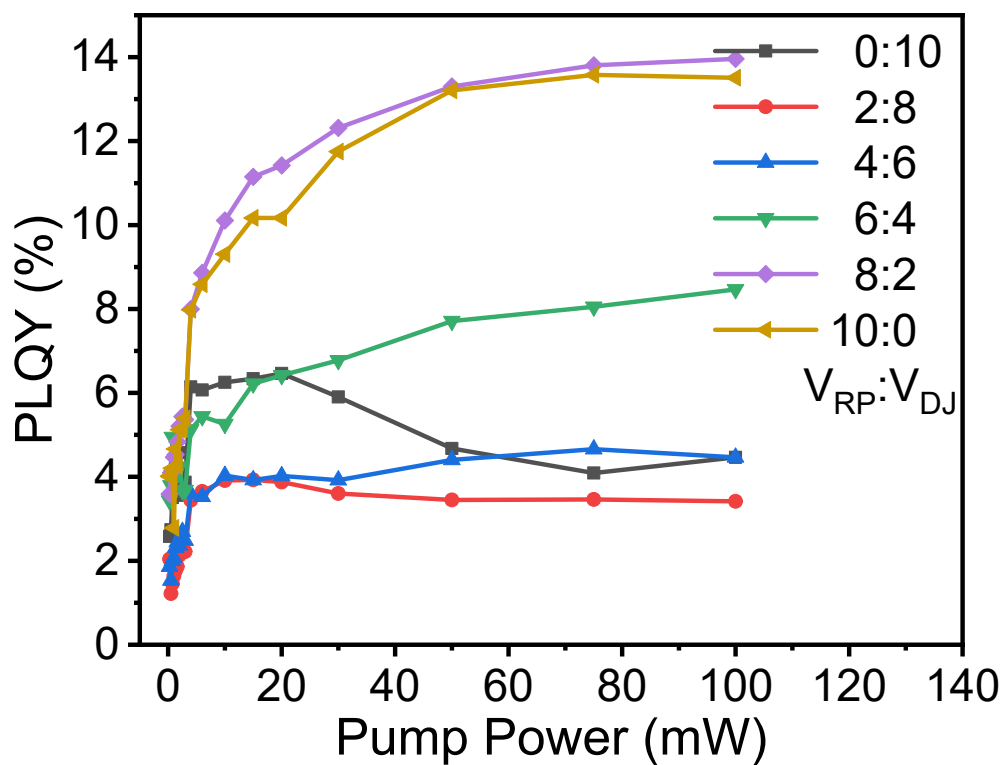


Figure S6. PLQY of RP/DJ mixed perovskite films with different ratios.

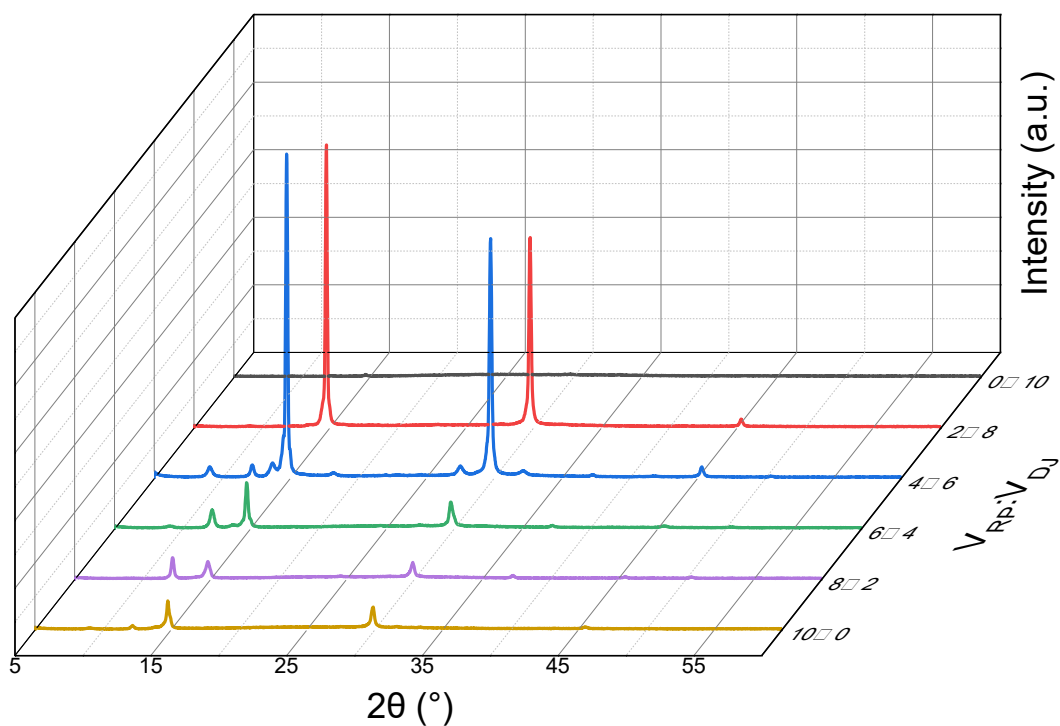


Figure S7. XRD patterns of RP/DJ mixed perovskite films with different ratios.

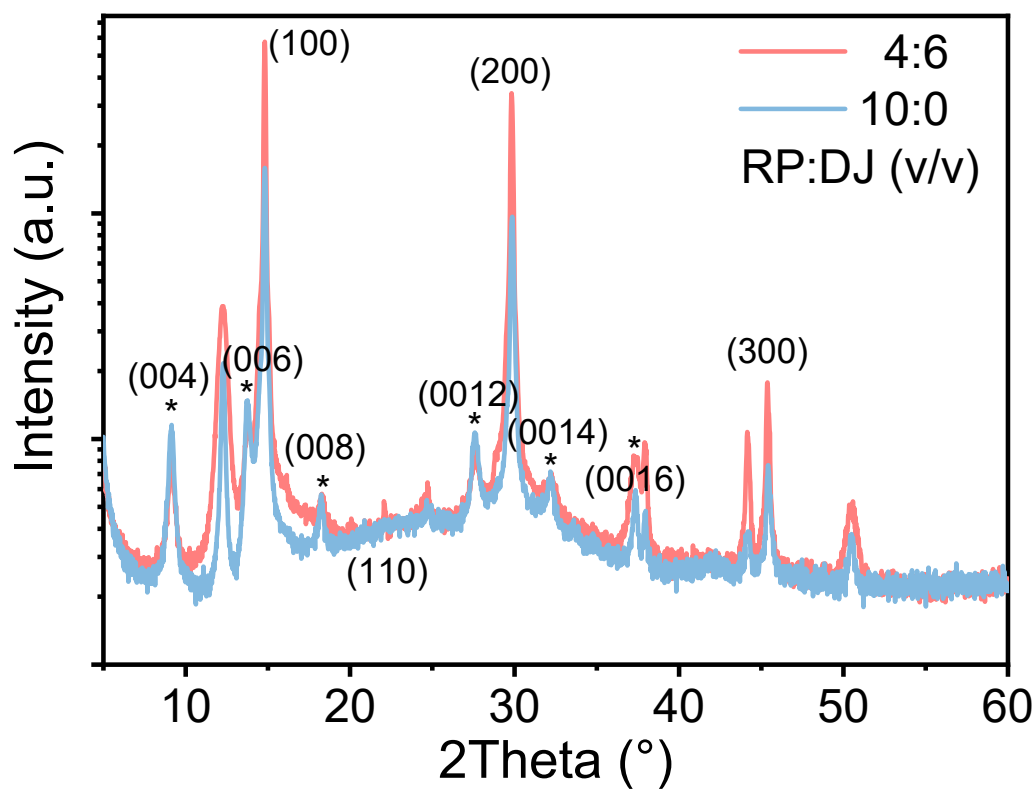


Figure S8. XRD patterns on log-scale. star: 2D phase with  $n=2$ .

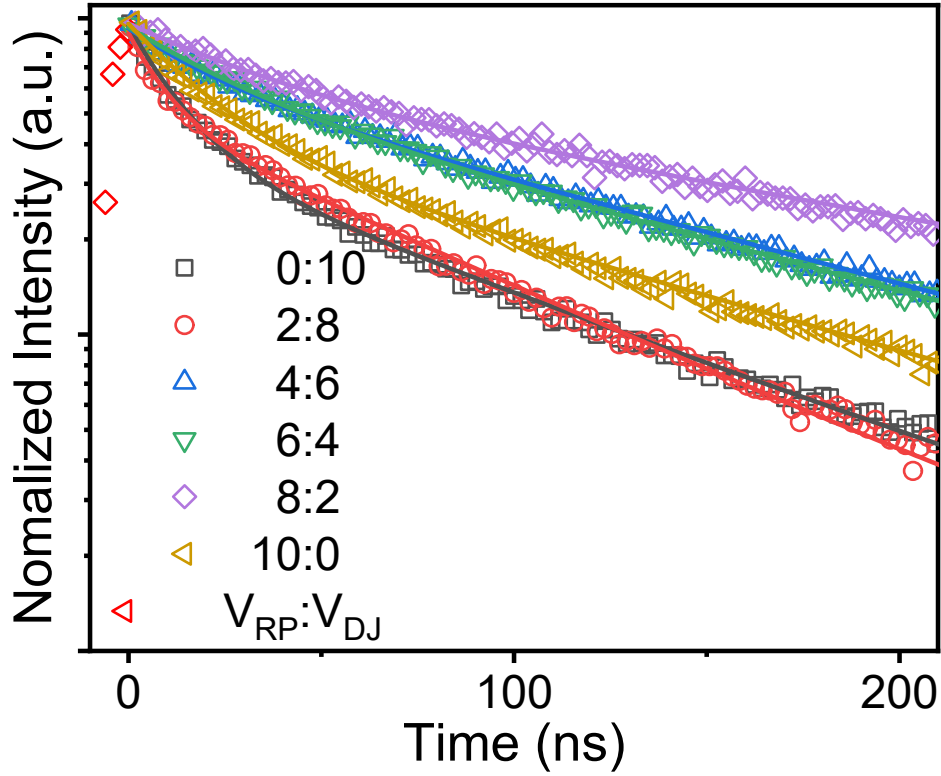


Figure S9. TRPL pattern of RP/DJ mixed perovskite films with different ratios.

Table S1. The fitting data of TRPL of RP/DJ mixed perovskite films with different ratios.

	$a_1$	$\tau_1$ (ns)	$a_2$	$\tau_2$ (ns)	$\tau_{avg}$ (ns)
0:10	0.56	13.16	0.38	93.56	45.66
2:8	0.40	9.59	0.49	78.54	47.79
4:6	0.28	22.13	0.65	131.22	98.45
6:4	0.33	28.63	0.61	132.84	96.19
8:2	0.36	38.31	0.61	219.78	152.09
10:0	0.51	20.60	0.44	120.09	66.85

The curves are fitted by a bi-exponential decay function:

$$f(t) = y_0 + a_1 e^{-t/\tau_1} + a_2 e^{-t/\tau_2}$$

where  $\tau_1$  and  $\tau_2$  correspond to the time of the fast and slow decay components, and  $a_1$  and  $a_2$  correspond to the weights of the fast and slow decay components, respectively.

Table S2. The summary of threshold and gain coefficient of RP/DJ mixed perovskite films

RP/DJ	0:10	2:8	4:6	6:4	8:2	10:0
$P_{th}$ ( $\mu\text{W}/\text{cm}^2$ )	none	none	30.1	47	35	52.2
$g$ ( $\text{cm}^{-1}$ )	none	none	785	335	523	379

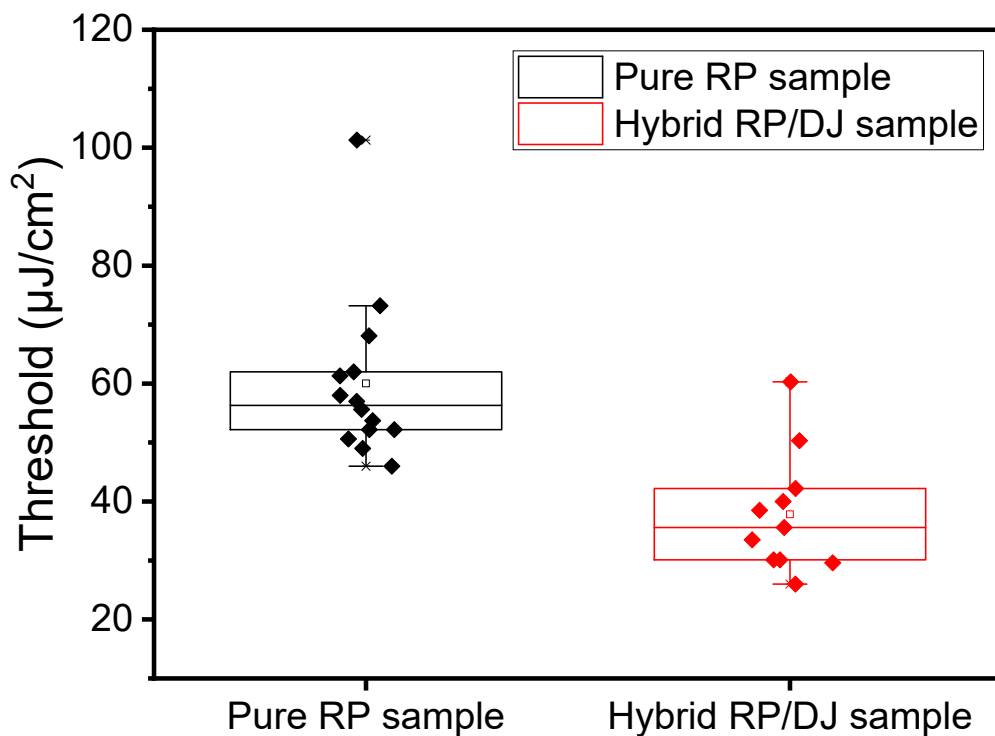


Figure S10. Statistical data of the threshold of RP and RP/DJ hybrid films

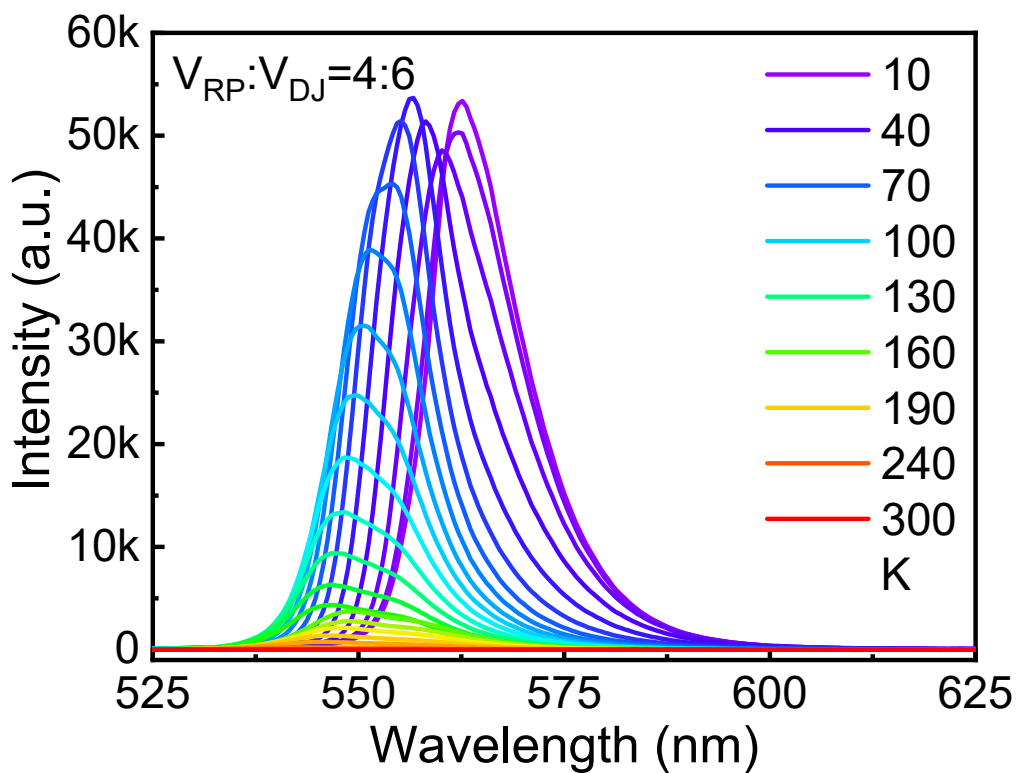


Figure S11. PL spectra of RP/DJ mixed perovskite films with ratio of 4:6 at different temperatures.

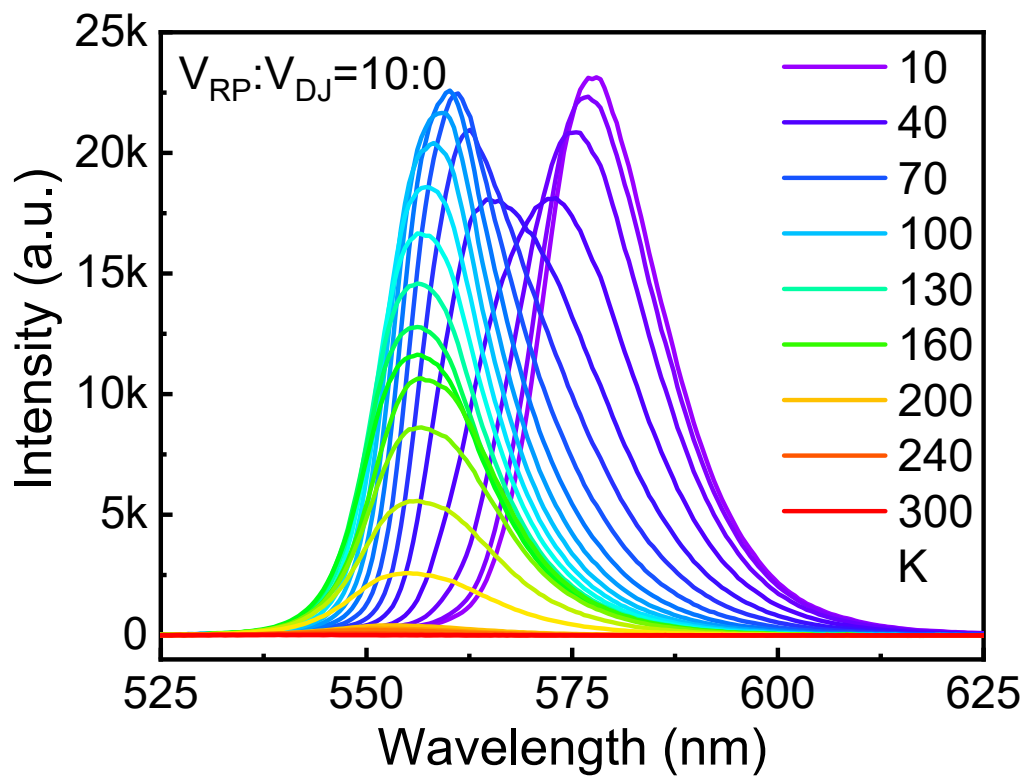


Figure S12. PL spectra of RP/DJ mixed perovskite films with ratio of 10:0 at different temperatures.