In situ preparation of CsPbBr₃/black phosphorus heterostructure with optimized interface and photodetector application

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Figure S1. BP NSs: TEM image (a); HRTEM image (b); FFT image of panel b (c); Raman spectrum (d); AFM image (e); the height profile measured at the correspondingcolor solid line in panel e (f).



Figure S2. CsPbBr₃ NCs: TEM image (a); HRTEM image (b); FFT image of panel b (c); (d) XRD patterns of CsPbBr₃ NCs (red), BP NSs (blue), CsPbBr₃/BP heterostructure (yellow), and CsPbBr₃/BP nanohybrid (green). The asymmetrical peaks of CsPbBr₃ NCs indicate their orthorhombic structures.¹ Due to the relative weak peak intensity of BP NSs, it is hard to find obvious peaks in the CsPbBr₃/BP nanostructures. However, the present of BP NSs can be proofed by TEM results, as shown in Figure 1 and Figure S3.



Figure S3. CsPbBr₃/BP nanohybrid synthesized using simple mixing process: TEM image (a); HRTEM image (b).



Figure S4. TEM images of CsPbBr₃/BP nanostructure after three washing cycles: CsPbBr₃/BP heterostructure (a); CsPbBr₃/BP nanohybrid (b).



Figure S5. HR-XPS spectra of various elements: CsPbBr₃/BP heterostructure (red); CsPbBr₃/BP nanohybrid (blue).

Table S1. Charge transfer dynamic lifetime of different samples.

Sample	A ₁	A ₂	τ_1	$ au_2$	$ au_{avg}$	η_{ET}
CsPbBr ₃	0.29	0.71	3.75	22.59	21.39	
CsPbBr ₃ /BP (Hybrid)	0.48	0.52	4.61	8.32	7.07	0.69
CsPbBr ₃ /BP(<i>In situ</i>)	0.57	0.43	0.91	5.61	4.77	0.78

Note: The lifetimes were bi-exponentially fitted as $y = A_1 exp(-\frac{\tau}{\tau_1}) + A_2 exp(-\frac{\tau}{\tau_2})$,

and the lifetimes were calculated using the following equation: $\tau_{avg} = \sum A_i \tau_i^2 / A_i \tau_i = \frac{A1\tau_1^2 + A2\tau_2^2}{A1\tau_1 + A2\tau_2}$



Figure S6. *I-t* curve of photodetector devices based on CsPbBr₃/BP nanohybrid.



Figure S7. *I-V* curve of photodetector devices based on CsPbBr₃/BP nanohybrid with higher concentration of BP (The precursors mole ratio of P:Cs was also set as 57:1).

P _{in} (mW cm ⁻²)	On/off	R (mA/W)	D* (Jones)
0.2	13.27	357.2	2.62×10 ¹¹
0.5	19.98	220.9	1.62×10 ¹¹
1	38.61	208.9	1.53×10 ¹¹
3	103.36	198.6	1.46×10 ¹¹

 Table S2. Important parameters of the as-fabricated photodetector devices.

References

1. A. Swarnkar, R. Chulliyil, V. K. Ravi, M. Irfanullah, A. Chowdhury and A. Nag, *Angew. Chem.*, 2015, **127**, 15644-15648.