

Electronic Supplementary Information

Bandgap Engineering of a Lead-free Defect Perovskite Cs₃Bi₂I₉ through Trivalent Doping of Ru³⁺

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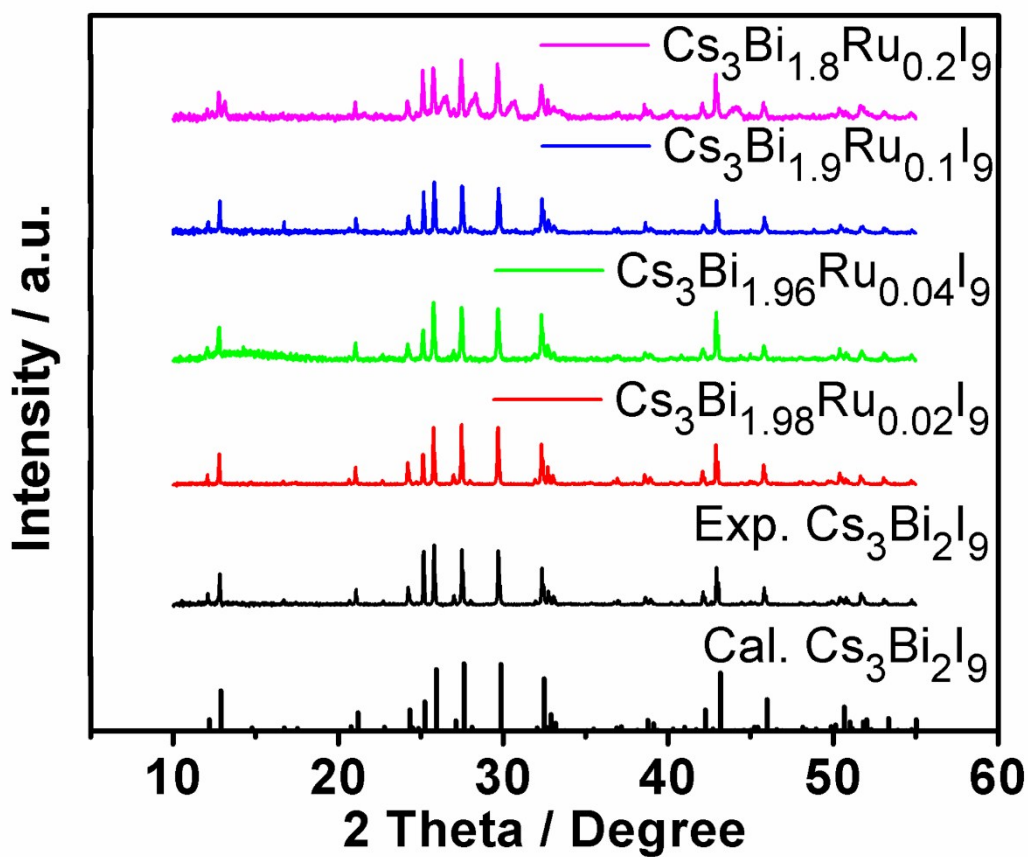


Figure S1. Powder XRD of $\text{Cs}_3\text{Bi}_2\text{I}_9$ and $\text{Cs}_3\text{Bi}_{2-x}\text{Ru}_x\text{I}_9$ with $x = 0.02, 0.04, 0.1, 0.2$

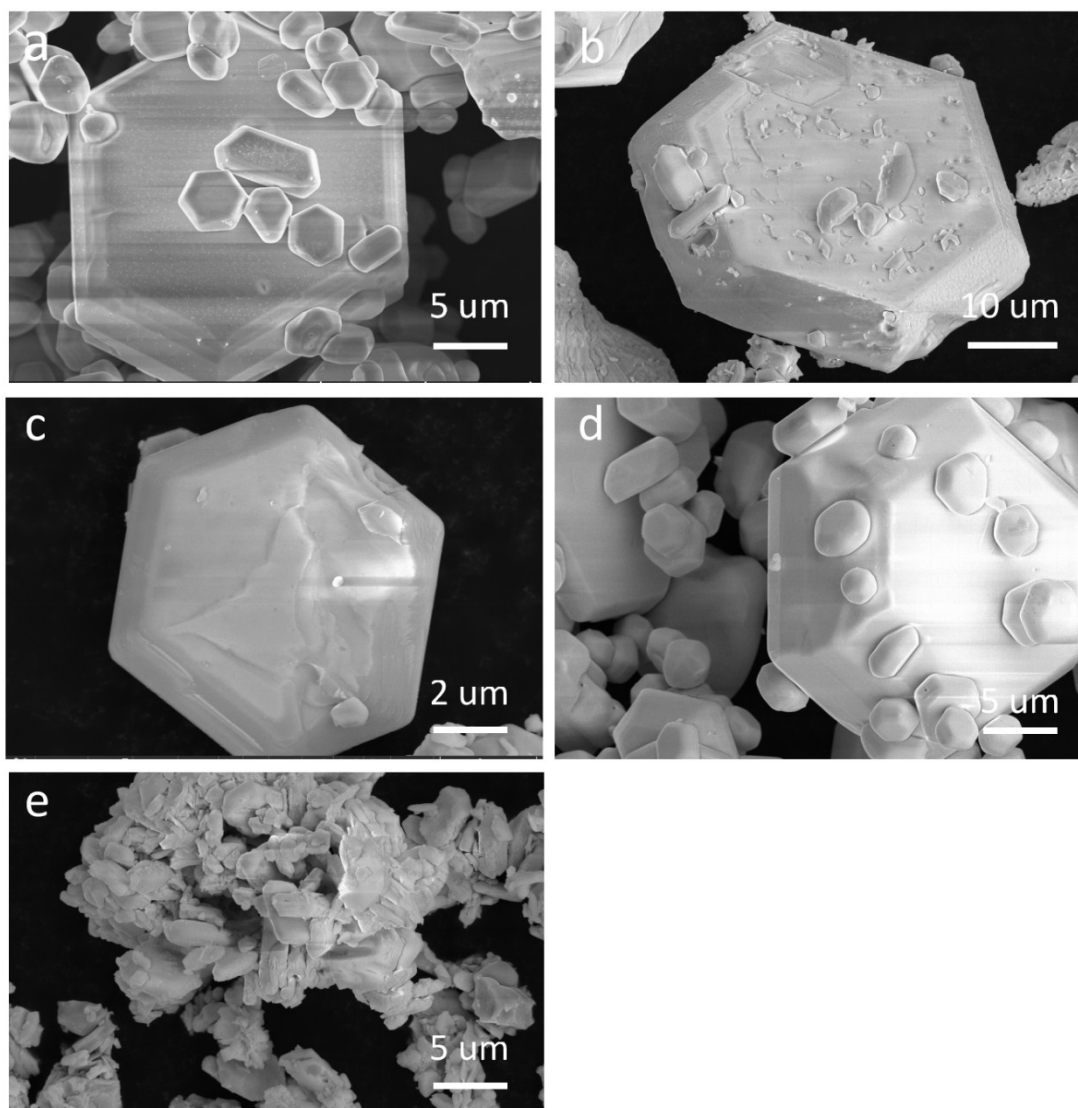


Figure S2. SEM images and of $\text{Cs}_3\text{Bi}_{2-x}\text{Ru}_x\text{I}_9$. (a) $x = 0$; (b) $x = 0.02$; (c) $x = 0.04$; (d) $x = 0.1$; (e) $x = 0.2$.

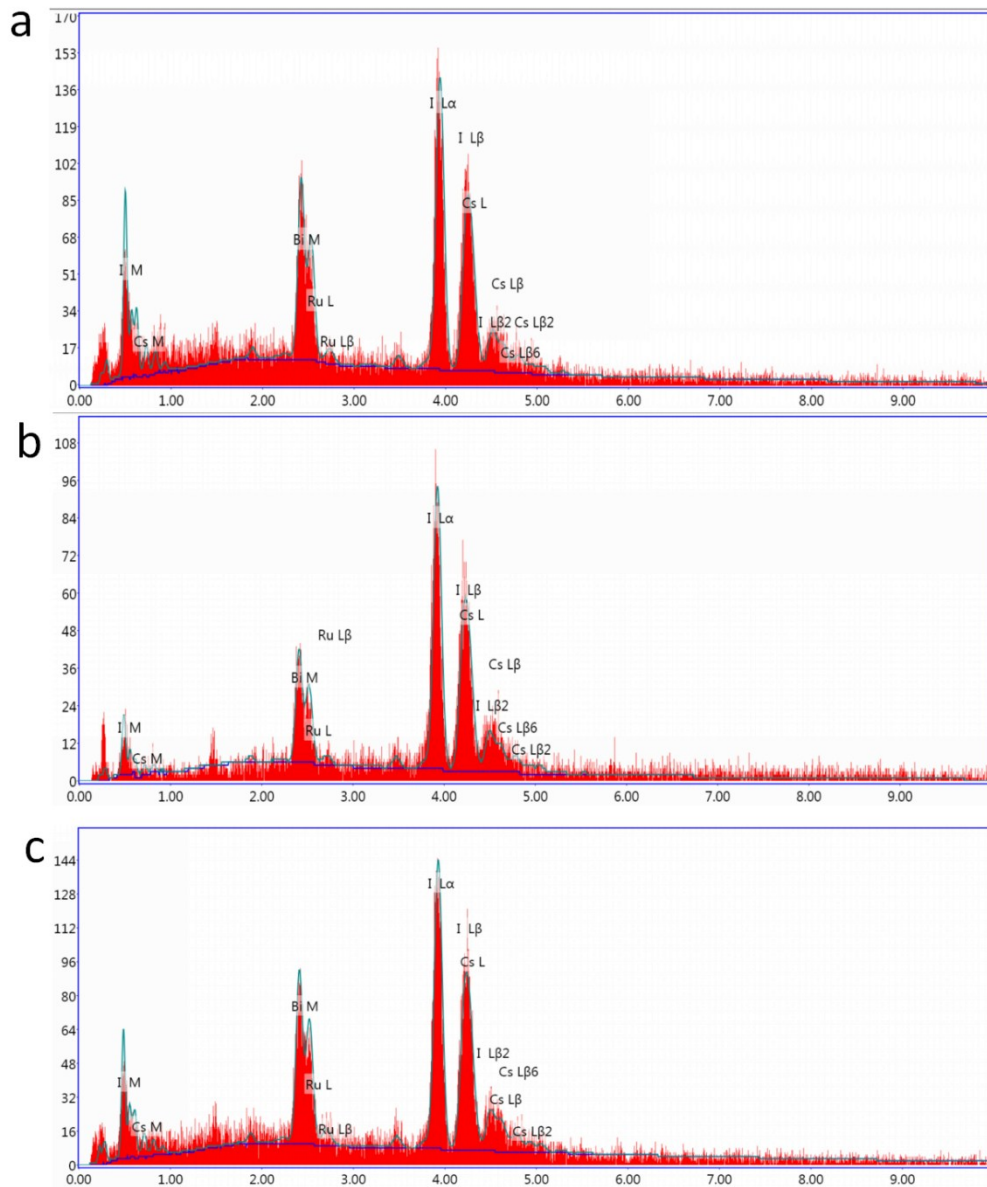


Figure S3. EDAX of $\text{Cs}_3\text{Bi}_{2-x}\text{Ru}_x\text{I}_9$. (a) $x = 0.02$; (b) $x = 0.04$; (c) $x = 0.1$.

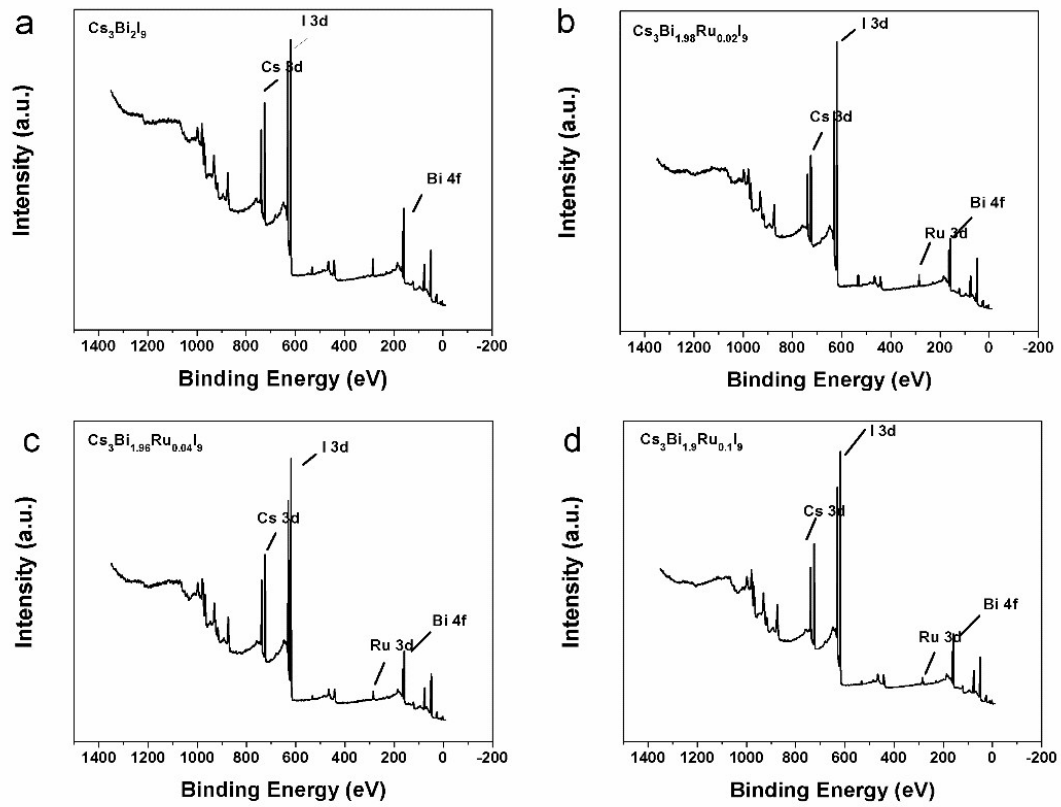


Figure S4. XPS Survey Spectra of Cs₃Bi₂I₉ and Cs₃Bi_{2-x}Ru_xI₉.
 (a) Cs₃Bi₂I₉; (b) Cs₃Bi_{1.98}Ru_{0.02}I₉; (c) Cs₃Bi_{1.96}Ru_{0.04}I₉; (d) Cs₃Bi_{1.9}Ru_{0.1}I₉.

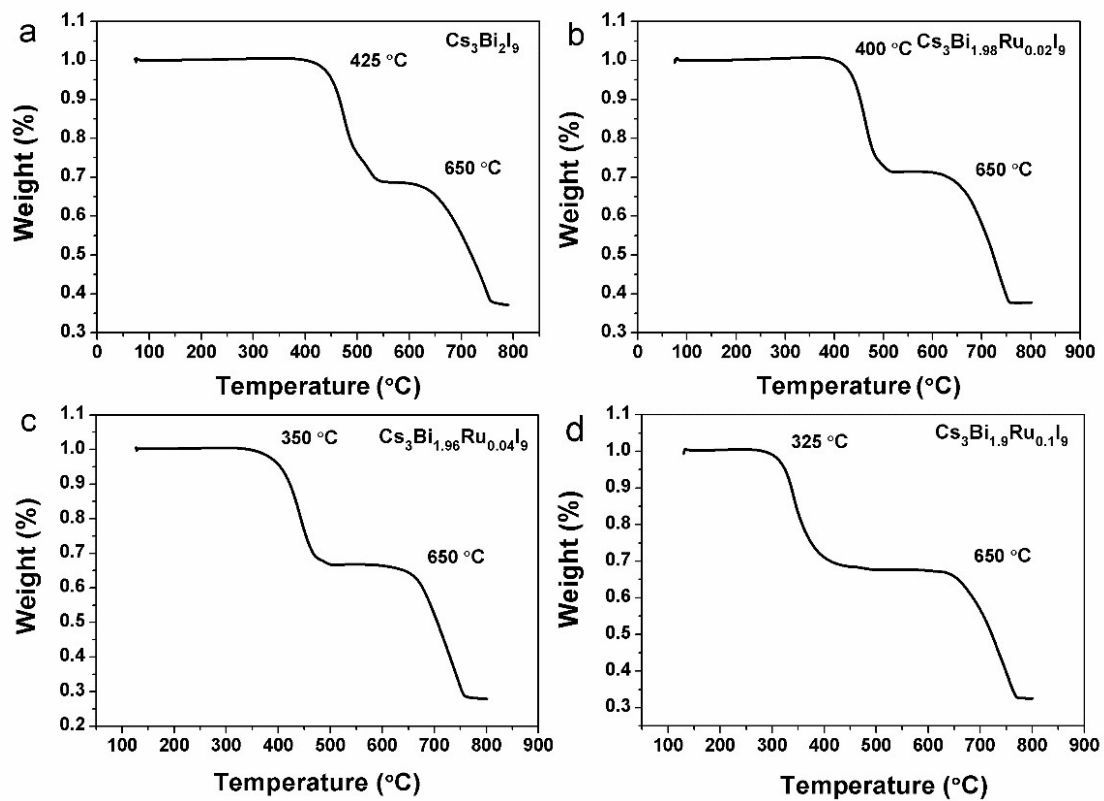


Figure S5. TG curves of $\text{Cs}_3\text{Bi}_2\text{I}_9$ and $\text{Cs}_3\text{Bi}_{2-x}\text{Ru}_x\text{I}_9$.
 (a) $\text{Cs}_3\text{Bi}_2\text{I}_9$; (b) $\text{Cs}_3\text{Bi}_{1.98}\text{Ru}_{0.02}\text{I}_9$; (c) $\text{Cs}_3\text{Bi}_{1.96}\text{Ru}_{0.04}\text{I}_9$; (d) $\text{Cs}_3\text{Bi}_{1.9}\text{Ru}_{0.1}\text{I}_9$.

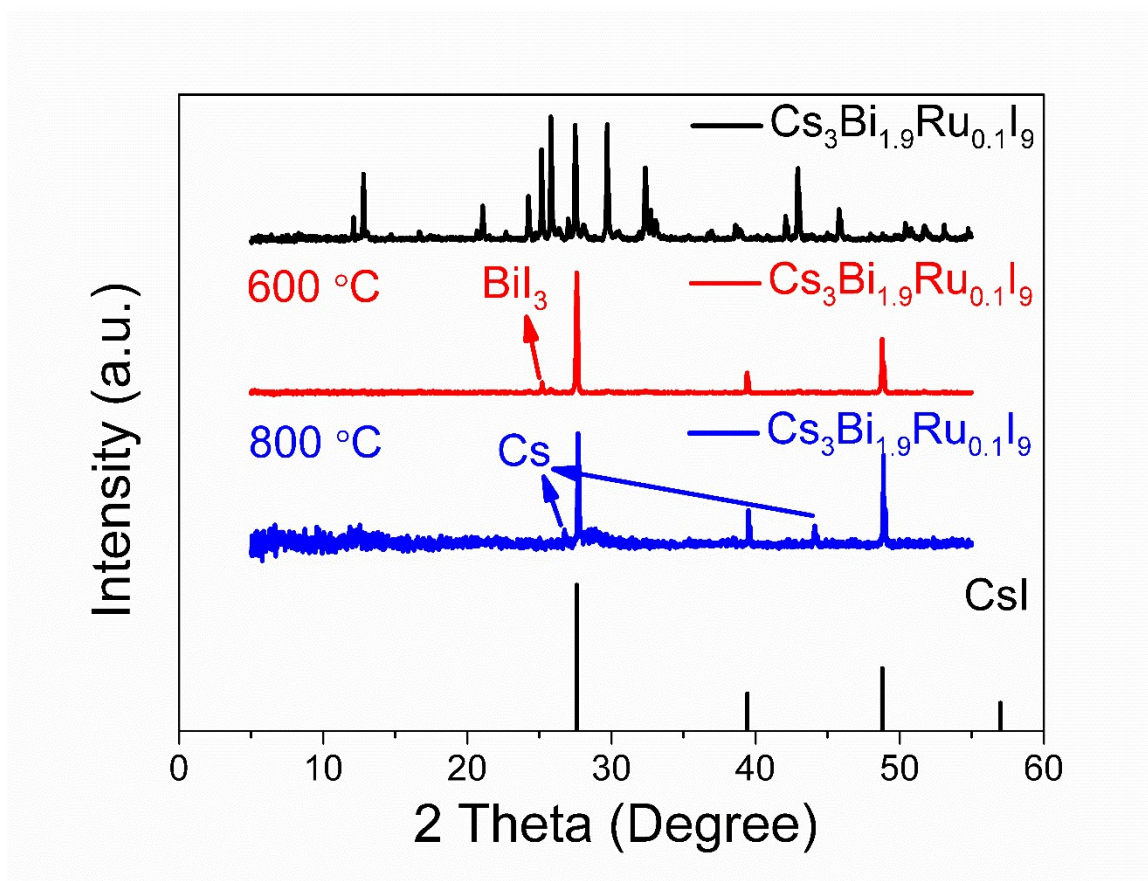


Figure S6. XRD of $\text{Cs}_3\text{Bi}_{1.9}\text{Ru}_{0.1}\text{I}_9$ after heating at 600 °C and 800 °C.

Table 1. Elemental analysis by ICP-AES for $\text{Cs}_3\text{Bi}_{2-x}\text{Ru}_x\text{I}_9$

Samples of $\text{Cs}_3\text{Bi}_{2-x}\text{Ru}_x\text{I}_9$	X = 0	X = 0.02	X = 0.04	X = 0.1
Theoretical doping level	0	1%	2%	5%
Actual doping level by ICP-AES (%)	0	0.9%	1.9%	4.3%