

Facile melting-crystallization synthesis of $\text{Cs}_2\text{Na}_x\text{Ag}_{1-x}\text{InCl}_6$: Bi double perovskites for WLEDs

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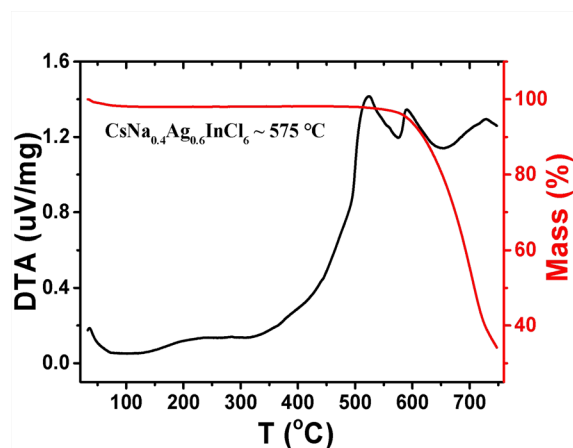


Figure S1. Differential thermal analysis (DTA) and thermogravimetric analysis (TGA) of $\text{Cs}_2\text{Na}_{0.4}\text{Ag}_{0.6}\text{InCl}_6$: Bi DP-MCs.

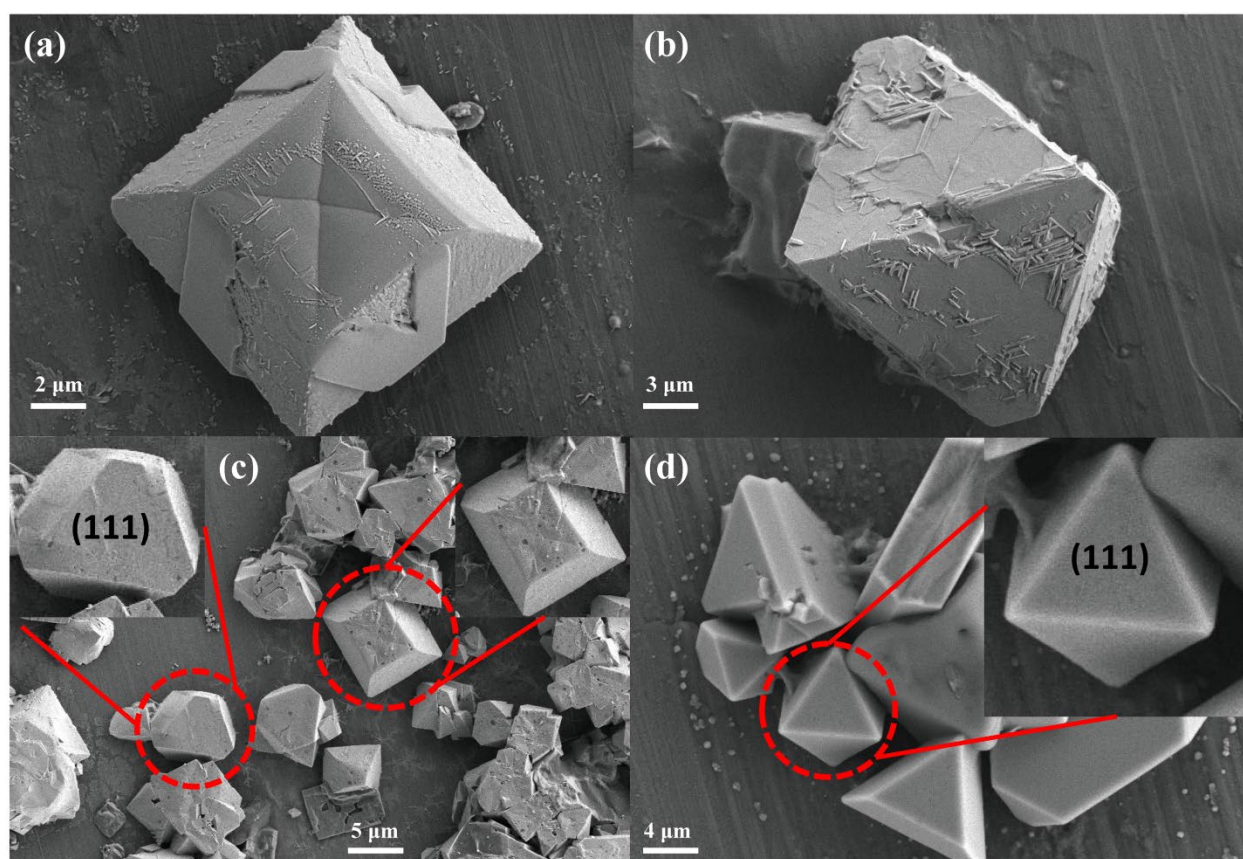


Figure S2. SEM images of the $\text{Cs}_2\text{Na}_{0.4}\text{Ag}_{0.6}\text{InCl}_6$: Bi microcrystal particles with different surface morphology.

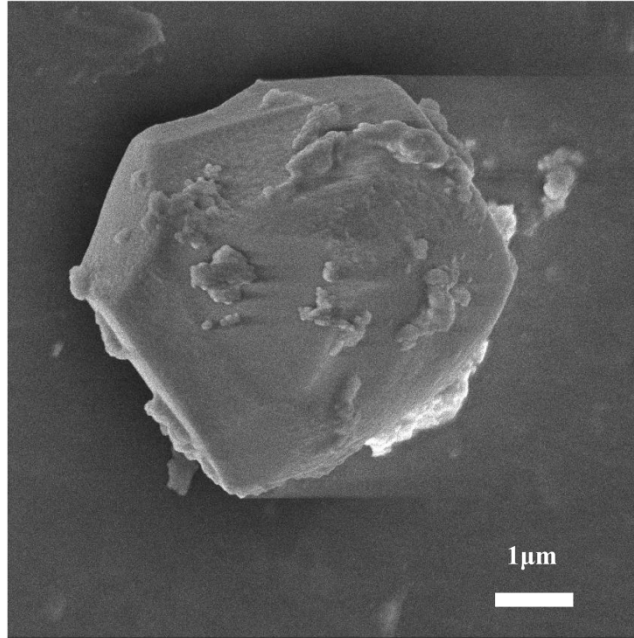


Figure S3. SEM images of selected EDS elemental mapping particles.

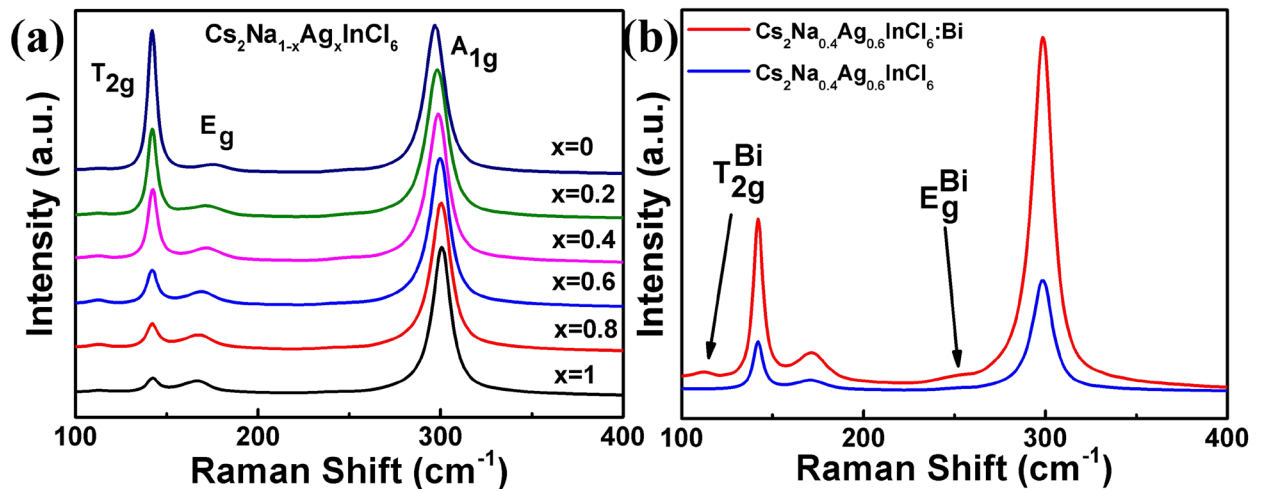


Figure S4. (a) Raman spectra of $\text{Cs}_2\text{Na}_{1-x}\text{Ag}_x\text{InCl}_6$. (b) Raman spectra of $\text{Cs}_2\text{Na}_{0.4}\text{Ag}_{0.6}\text{InCl}_6$ sample with and without Bi doping.

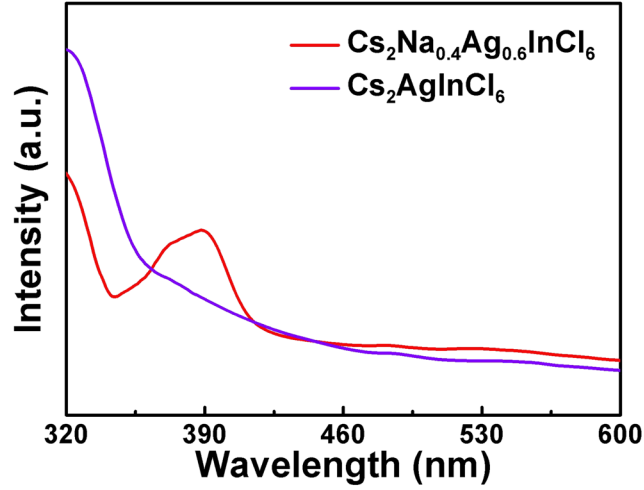


Figure S5. Normalized absorption spectra of $\text{Cs}_2\text{AgInCl}_6$:Bi sample with and without Na alloying.

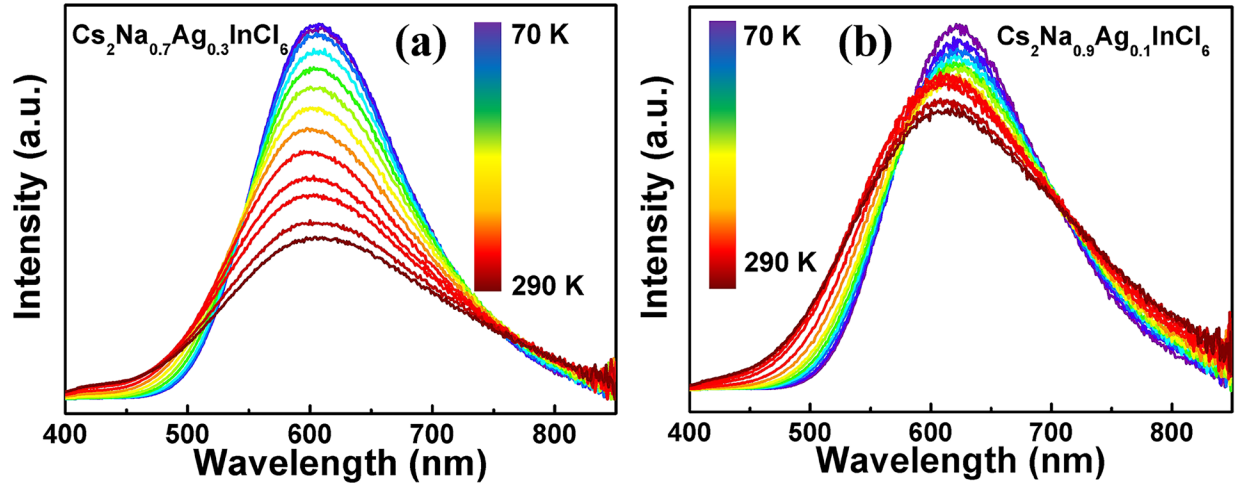


Figure S6. Temperature-dependent emission spectra in the range of 70-290 K ($\lambda=365$ nm) of (a) $\text{Cs}_2\text{Na}_{0.7}\text{Ag}_{0.3}\text{InCl}_6$:Bi and (b) $\text{Cs}_2\text{Na}_{0.9}\text{Ag}_{0.1}\text{InCl}_6$:Bi DP-MCs, respectively.

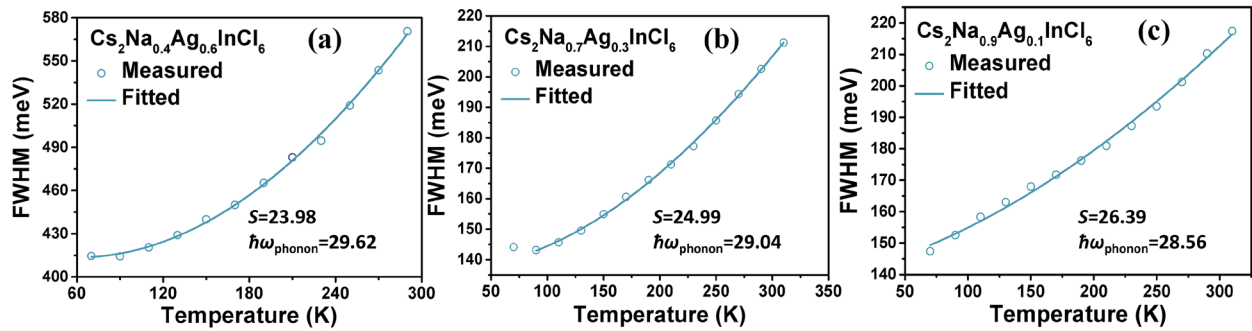


Figure S7. FWHM fitting result as a function of temperature of (a) $\text{Cs}_2\text{Na}_{0.4}\text{Ag}_{0.6}\text{InCl}_6$: Bi, (b) $\text{Cs}_2\text{Na}_{0.7}\text{Ag}_{0.3}\text{InCl}_6$: Bi, and (c) $\text{Cs}_2\text{Na}_{0.9}\text{Ag}_{0.1}\text{InCl}_6$: Bi DP-MCs, respectively.

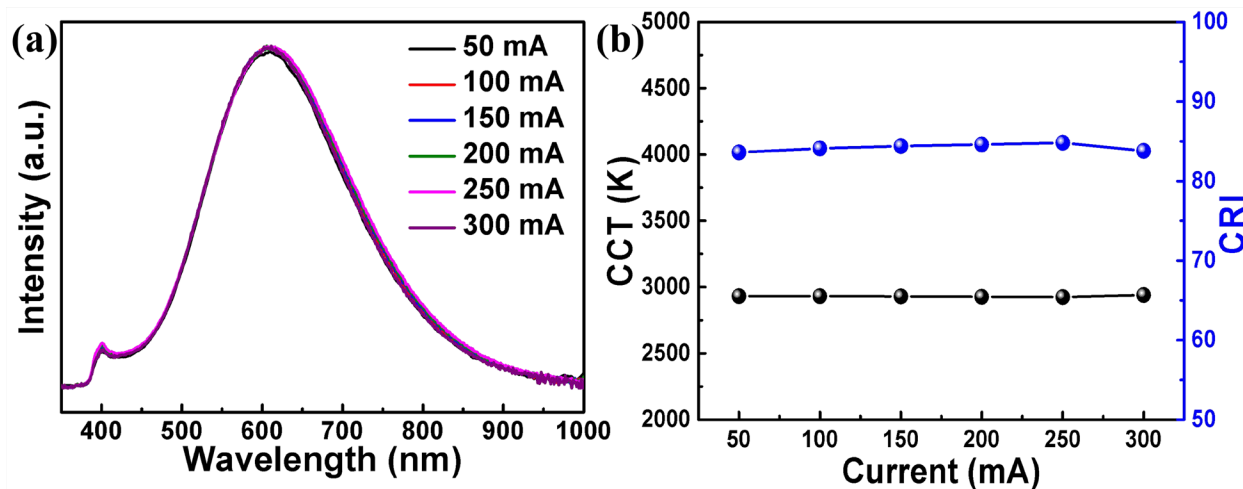


Figure S8. (a) PL spectra and (b) CCT and CRI of corresponding WLED under different driving currents.

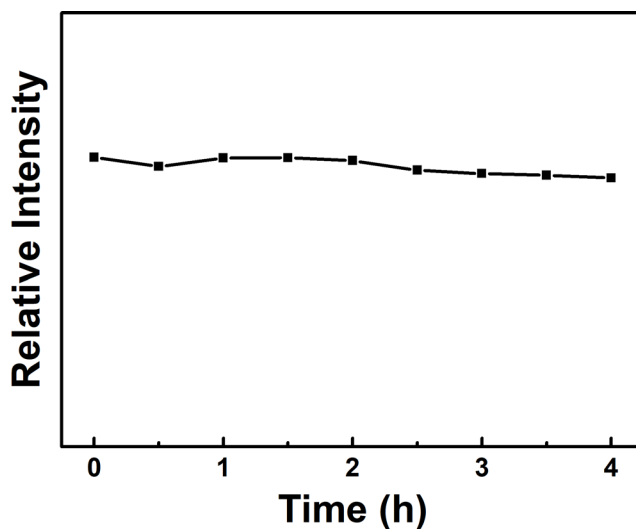


Figure S9. Photostability of $\text{Cs}_2\text{Na}_{0.4}\text{Ag}_{0.6}\text{InCl}_6$: Bi sample under continuous illumination with an UV (380 nm) lamp for 4 h.

Table S1. Calculated formation energies for Cs₂Na_xAg_{1-x}InCl₆: Bi ($x=0, 0.2, 0.4, 0.6, 0.8,$ and 1) samples.

Chemical formula	Atom number	Total energy (E_{total} , meV)	Formation energy (meV/atom)
Cs ₂ AgInCl ₆	Cs ₄₀ Ag ₂₀ In ₂₀ Cl ₁₂₀	-197091.905	-985.46
Cs ₂ Ag _{0.8} Na _{0.2} InCl ₆	Cs ₄₀ Ag ₁₆ Na ₄ In ₂₀ Cl ₁₂₀	-183624.931	-918.12
Cs ₂ Ag _{0.6} Na _{0.4} InCl ₆	Cs ₄₀ Ag ₁₂ Na ₈ In ₂₀ Cl ₁₂₀	-176888.343	-884.44
Cs ₂ Ag _{0.4} Na _{0.6} InCl ₆	Cs ₄₀ Ag ₈ Na ₁₂ In ₂₀ Cl ₁₂₀	-163415.183	-817.08
Cs ₂ Ag _{0.2} Na _{0.8} InCl ₆	Cs ₄₀ Ag ₄ Na ₁₆ In ₂₀ Cl ₁₂₀	-156678.584	-783.39
Cs ₂ NaInCl ₆	Cs ₄₀ Na ₂₀ In ₂₀ Cl ₁₂₀	-143205.361	-716.03

Table S2. Compositional result of Cs₂Na_{0.4}Ag_{0.6}InCl₆: Bi DP-MCs from SEM-EDS analysis (mol%).

	Cs	Na	Ag	In	Cl	Bi	Total
Cs ₂ Na _{0.4} Ag _{0.6} InCl ₆	20.25	3.86	5.7	10.23	59.96	00	100

Table S3. Photoluminescence quantum yield and average lifetime of Cs₂Na_xAg_{1-x}InCl₆: Bi ($x=0, 0.2, 0.4, 0.6, 0.8,$ and 1) samples.

Cs ₂ Na _x Ag _{1-x} InCl ₆ : Bi	PLQY (%)	Average lifetime (μs)
$x=0$	2.28%	4.26
$x=0.2$	31.59%	5.43
$x=0.4$	73.30%	4.89
$x=0.6$	46.04%	2.87
$x=0.8$	67.73%	2.81
$x=1$	5.07%	3.86

Table S4. Mass ratio of three phosphors, CIE color coordinates (x, y), CRI, and CCT of WLEDs.

WLEDs	Mass ratio of blue, green and DP-MCs phosphor	CIE (x, y)	CRI	CCT/K
1	0 : 0 : 1	(0.461, 0.443)	84.8	2930

2	0.8 : 0.65 : 1	(0.363, 0.382)	92.7	4539
3	1.6 : 0.7 : 1	(0.331, 0.340)	97.1	5548
4	2.2 : 0.7 : 1	(0.313, 0.287)	86.5	6957
