Supporting Information

Highly efficient lead-free (Bi,Ce)-codoped $Cs_2Ag_{0.4}Na_{0.6}InCl_6$ double perovskites for white LEDs

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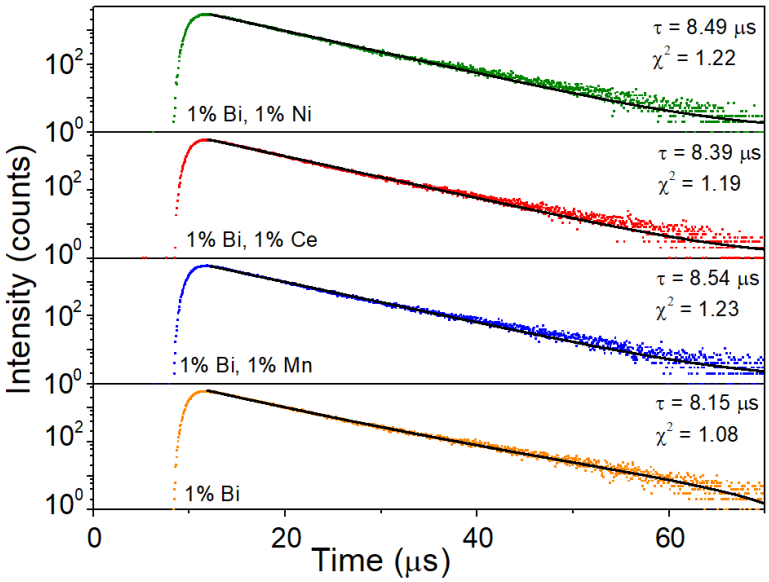

Figure S1. Time resolved photoluminescence spectra of $Cs_2Ag_{0.4}Na_{0.6}InCl_6$:X (X = Bi; Bi, Mn; Bi, Ce; Bi, Ni) perovskite phosphors (λ_{ex} = 350 nm).

Table S1. Comparison of designed composition and measured composition by XPS for each sample.

Sample	Designed composition	Measured composition by XPS	Ag/In molar ratio measured by ICP-MS
Bi doped	$Cs_2Ag_{0.4}Na_{0.6}In_{0.99}Cl_6Bi_{0.01}$	$Cs_{1.92}Ag_{0.22}Na_{0.53}In_{0.99}Cl_{5.68}Bi_{0.016}$	0.32
(Bi,Mn)-codoped	$Cs_2Ag_{0.4}Na_{0.61}In_{0.98}Cl_6Bi_{0.01}Mn_{0.01}$	$Cs_{1.79}Ag_{0.21}Na_{0.63}In_{0.98}Cl_{5.62}Bi_{0.015}Mn_{<0.01}$	0.47
(Bi,Ce)-codoped	$Cs_2Ag_{0.4}Na_{0.6}In_{0.98}Cl_6Bi_{0.01}Ce_{0.01}$	$Cs_{1.81}Ag_{0.22}Na_{0.71}In_{0.98}Cl_{5.80}Bi_{0.018}Ce_{0.018}$	0.40
(Bi,Ni)-codoped	$Cs_2Ag_{0.4}Na_{0.61}In_{0.98}Cl_6Bi_{0.01}Ni_{0.01}$	$Cs_{1.92}Ag_{0.20}Na_{0.65}In_{0.98}Cl_{5.82}Bi_{0.015}Ni_{0.031}$	0.38

Table S2. Summary of calculation details for the total formation energies.

Chemical Formula	Atom Number	Total Energy (E_{total}, eV)	Formation Energy Equations [a]
$Cs_2Ag_{0.4}Na_{0.6}InCl_6$	$Cs_{40}Ag_8Na_{12}In_{20}Cl_{120}$	144897.513	Referenced energy
$Cs_2Ag_{0.4}Na_{0.6}Bi_{0.05}In_{0.95}Cl_6$	$Cs_{40}Ag_8Na_{12}BiIn_{19}Cl_{120}$	145339.653	$E_{total} - E_{ref} - \mu_{Bi} + \mu_{In}$
$Cs_2Mn_{0.05}Ag_{0.4}Na_{0.55}Bi_{0.05}In_{0.95}Cl_6$	$Cs_{40}MnAg_8Na_{11}BiIn_{19}Cl_{120}$	146883.112	$E_{total} - E_{ref} - \mu_{Mn} + \mu_{Na} - \mu_{Bi} + \mu_{In}$
$Cs_2Ce_{0.05}Ag_{0.4}Na_{0.55}Bi_{0.05}In_{0.95}Cl_6$	$Cs_{40}CeAg_8Na_{11}BiIn_{19}Cl_{120}$	145466.068	$E_{total} - E_{ref} - \mu_{Ce} + \mu_{Na} - \mu_{Bi} + \mu_{In}$
$Cs_2Ni_{0.05}Ag_{0.4}Na_{0.55}Bi_{0.05}In_{0.95}Cl_6$	$Cs_{40}NiAg_8Na_{11}BiIn_{19}Cl_{120}$	148358.726	$E_{total} - E_{ref} - \mu_{Ni} + \mu_{Na} - \mu_{Bi} + \mu_{In}$

[a] E_{ref} = -144897.513 eV; μ is chemical potential of an element, μ_{Bi} = -1865.037 eV; μ_{In}= -1423.122 eV; μ_{Na}= -1159.212 eV; μ_{Ce}= -1283.719 eV; μ_{Mn}= -2707.688 eV; μ_{Ni}= -4182.087 eV.

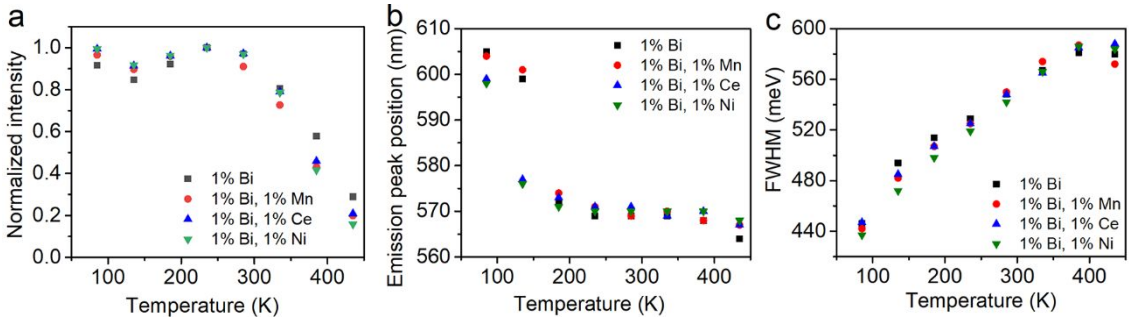

Figure S2. Temperature dependency of normalized PL integral intensity (a), emission peak position (b) and FWHM (c) in the temperature range of 85 - 435 K for $Cs_2Ag_{0.4}Na_{0.6}InCl_6$ phosphors doped with 1% Bi; 1% Bi, 1% Mn; 1% Bi, 1% Ce and 1% Bi, 1% Ni.