Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.
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Designed synthesis, morphology evolution, and enhanced photoluminescence of a highly efficient red dodec-fluoride phosphor $Li_3Na_3Ga_2F_{12}:Mn^{4+}$ for warm WLEDs

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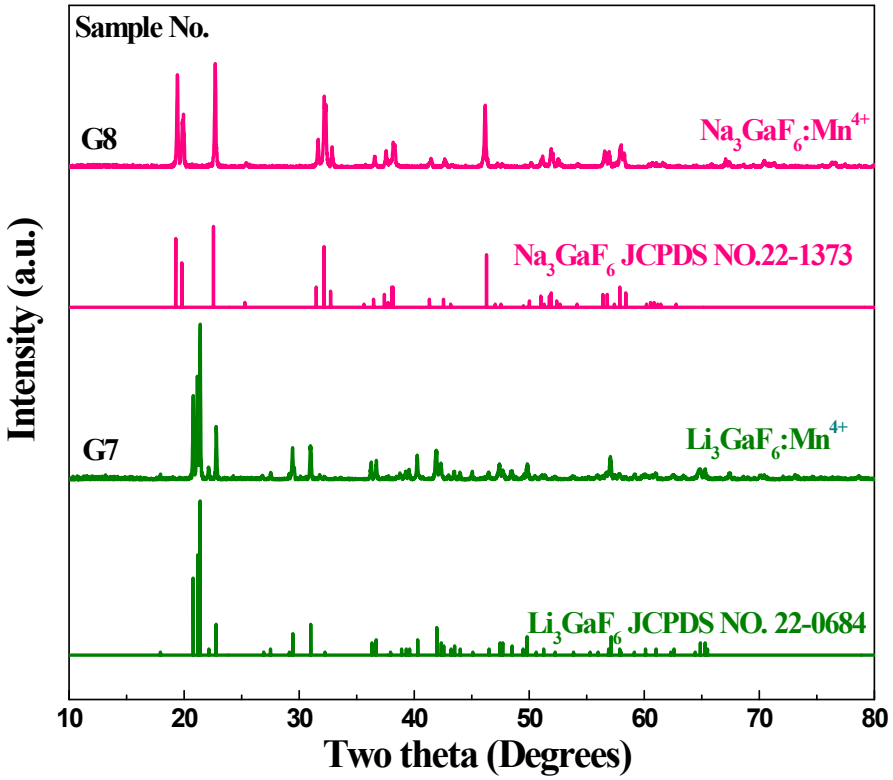

Figure S1 XRD patterns of samples prepared from LiF, NaF, and Ga_2O_3 in HF solution according to the molecular ratios list in Table S1.

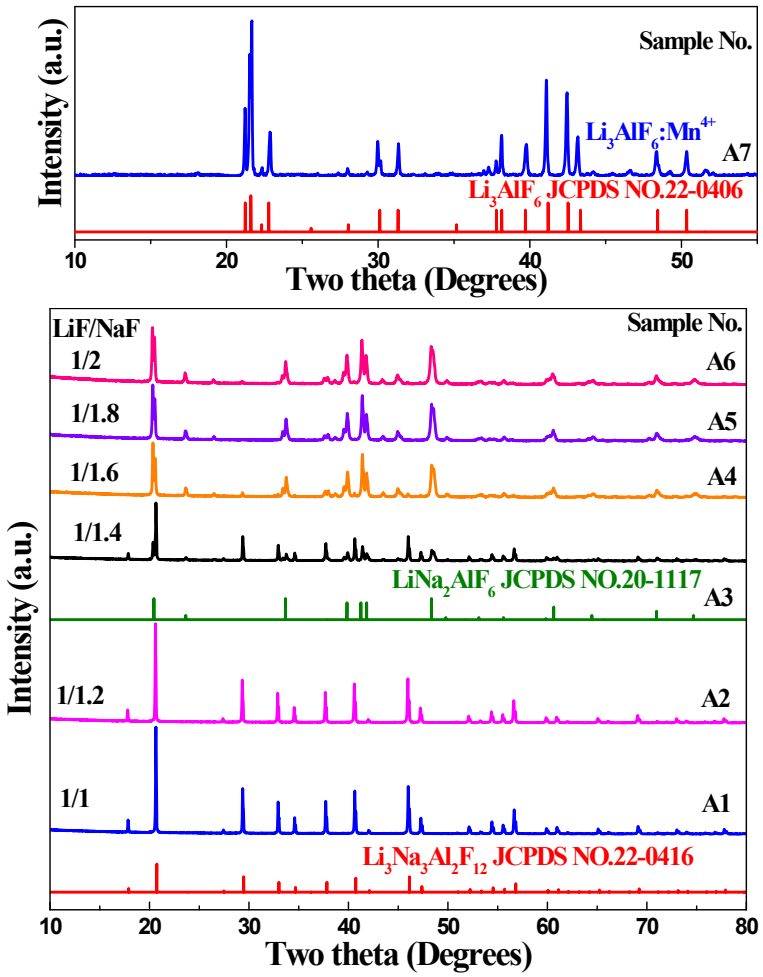

Figure S2 XRD patterns of samples prepared from LiF, NaF, and $AlF_3 \cdot 3H_2O$ according to the molecular ratios list in Table S2.

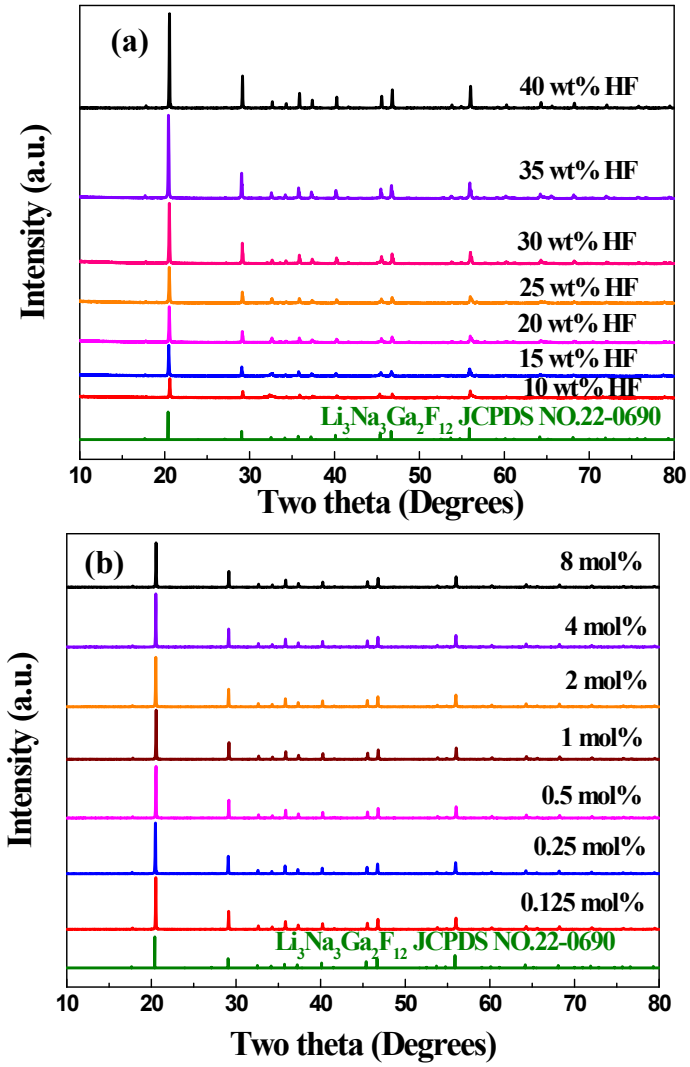

Figure S3 XRD patterns of samples $Li_3Na_3Ga_2F_{12}:Mn^{4+}$ prepared with various concentrations of (a) HF and (b) K_2MnF_6 (mol % of $Li_3Na_3Ga_2F_{12}$).

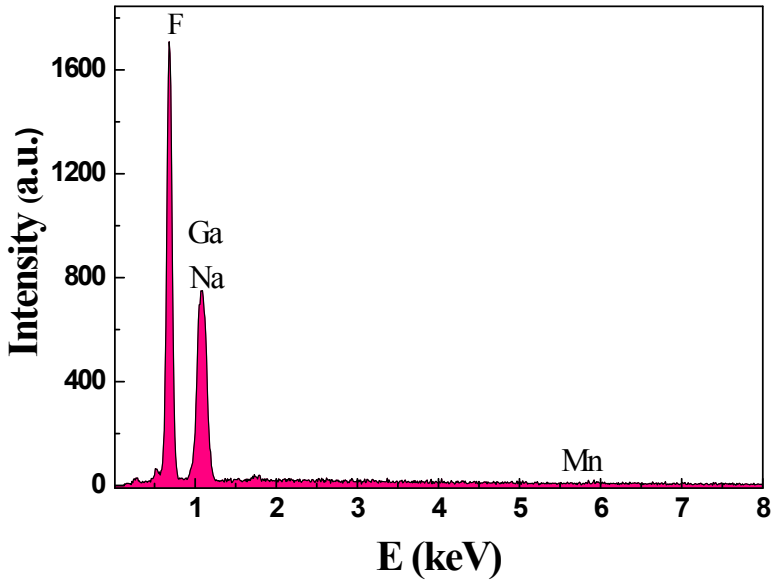

Figure S4 Energy dispersive spectrum (EDS) of red phosphor $Li_3Na_3Ga_2F_{12}:Mn^{4+}$.

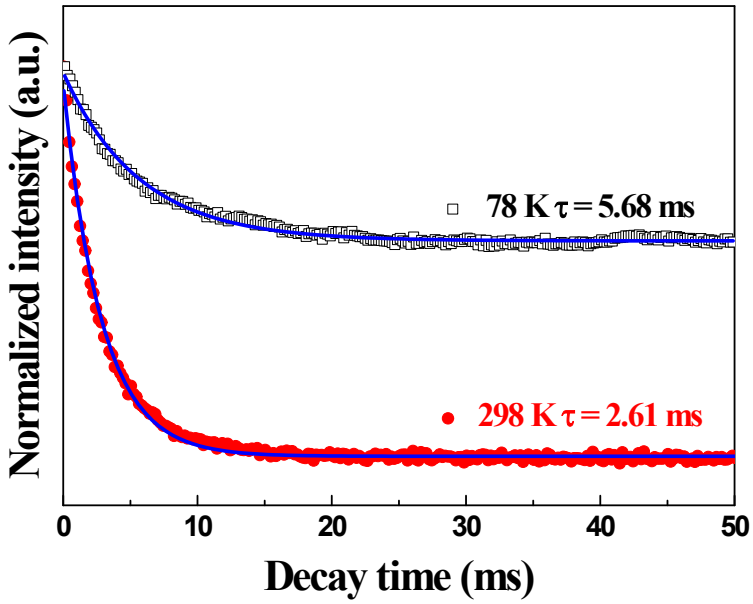

Figure S5 Decay curves of 629 nm emission of red phosphor $Li_3Na_3Ga_2F_{12}:Mn^{4+}$ excited at 467 nm measured at 78 and 298 K.

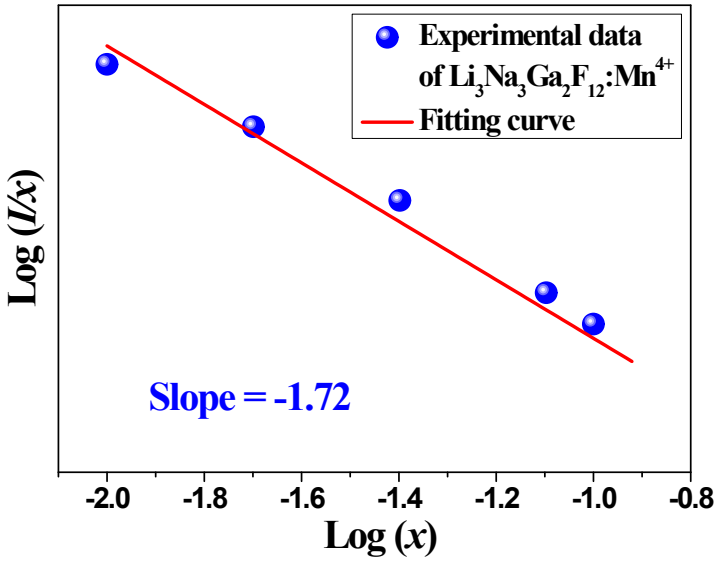

Figure S6 The relationship between log (x) versus log (I/x) in the phosphor $Li_3Na_3Ga_2F_{12}:Mn^{4+}$. (Note: x is the concentration of Mn^{4+}.)

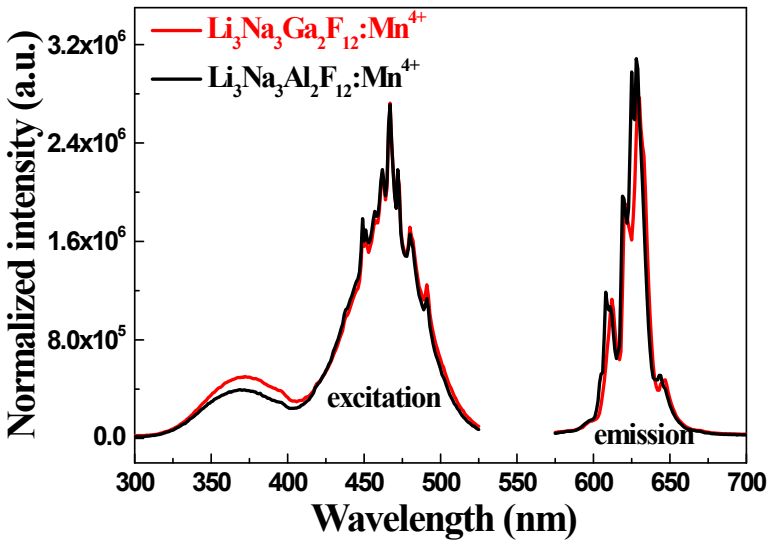

Figure S7 Excitation (monitored at 629 nm) and emission spectra (excited at 467 nm) of red phosphors $Li_3Na_3Ga_2F_{12}:Mn^{4+}$ and $Li_3Na_3Al_2F_{12}:Mn^{4+}$ with normalized intensities.

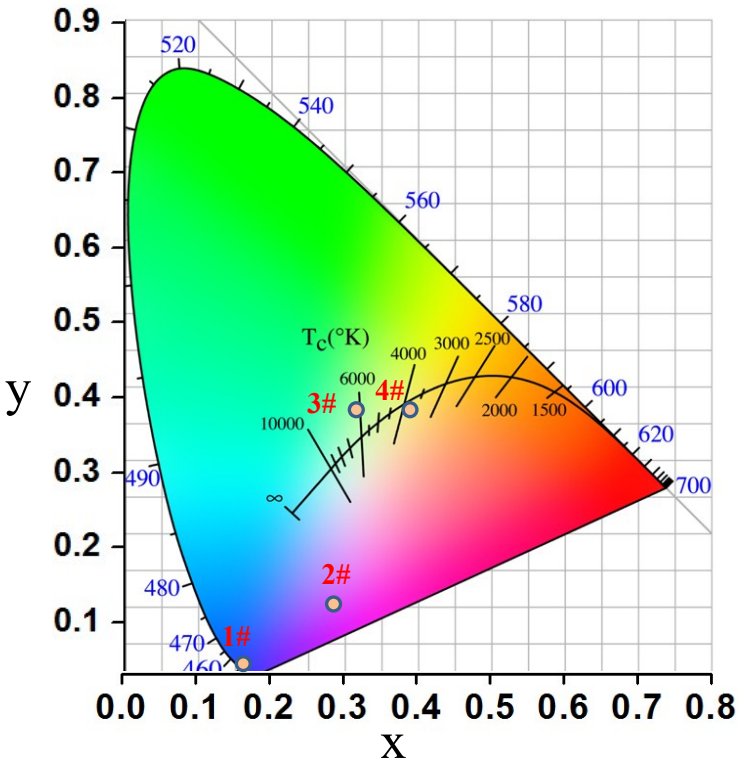

Figure S8. CIE chromaticity coordinates, correlated color temperature (CCT) and color rendering index (CRI) of the as- fabricated LEDs as shown in Fig. 7.

Table S1 The phases of samples prepared from LiF, NaF, and Ga_2O_3 with various

molecular ratios in HF solution analyzed by XRD technology.

Sample No.	LiF	NaF	Ga_2O_3	Phases
G1	2	2	0.1	LNGF + Ga_2O_3 + LiF
G2	1.5	2	0.15	LNGF + Ga_2O_3 + LiF
G3	1	2	0.15	LNGF + Ga_2O_3
G4	1.5	2	0.1	LNGF + Ga_2O_3 + LiF
G5	1	2	0.1	LNGF + Ga_2O_3
G6	**1**	**2**	**0.05**	**Pure LNGF**
G7	1	0	0.67	Pure Li_3GaF_6
G8	0	2	0.67	Pure Na_3GaF_6

Table S2 The phases of samples prepared from LiF, NaF, and $AlF_3 \cdot 3H_2O$ with various molecular ratios in HF solution analyzed by XRD technology.

Sample No.	LiF	NaF	$AlF_3 \cdot 3H_2O$	Phases
A1	**1**	**1**	**0.67**	**Pure LNAF**
A2	**1**	**1.2**	**0.67**	**Pure LNAF**
A3	1	1.4	0.67	LNAF + $LiNa_2AlF_6$
A4	1	1.6	0.67	Pure $LiNa_2AlF_6$
A5	1	1.8	0.67	Pure $LiNa_2AlF_6$
A6	1	2	0.67	Pure $LiNa_2AlF_6$
A7	1	0	0.67	Pure Li_3AlF_3