Electronic Supplementary Information

Design, preparation, and optimized luminescence of a dodec-fluoride phosphor $Li_3Na_3Al_2F_{12}:Mn^{4+}$ for warm WLEDs application

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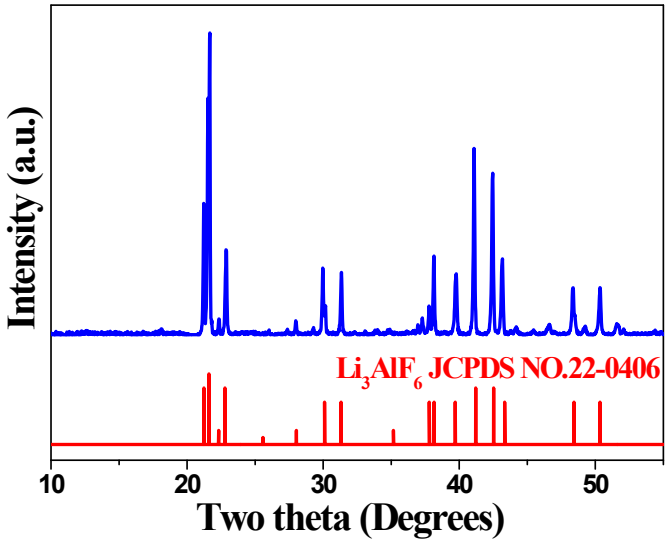

Figure S1. X-ray diffraction pattern of the sample obtained in the reaction with molecular ratio of LiF/AlF_3 at 3:1 absent of NaF as compared with the standard data of Li_3AlF_6 in JCPDS no. 22-0406.

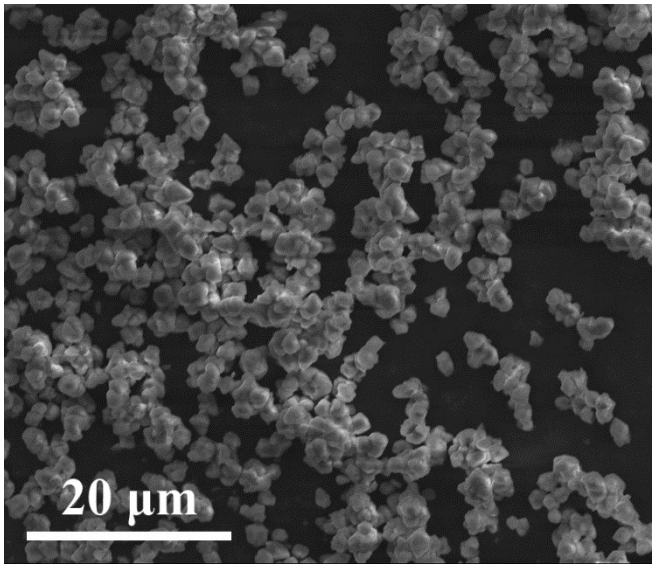

Figure S2. SEM images of $LiNa_2AlF_6:Mn^{4+}$ phosphor obtained at room temperature.

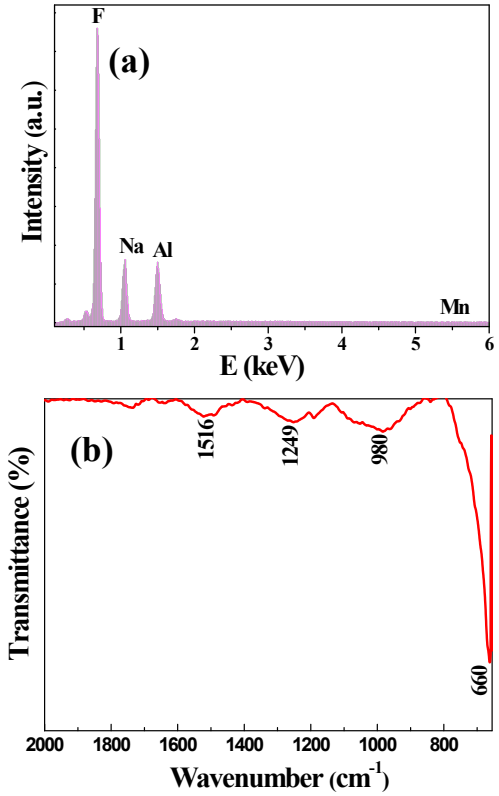

Figure S3. (a) EDS and (d) IR spectrum of red phosphor $Li_3Na_3Al_2F_{12}:Mn^{4+}$.

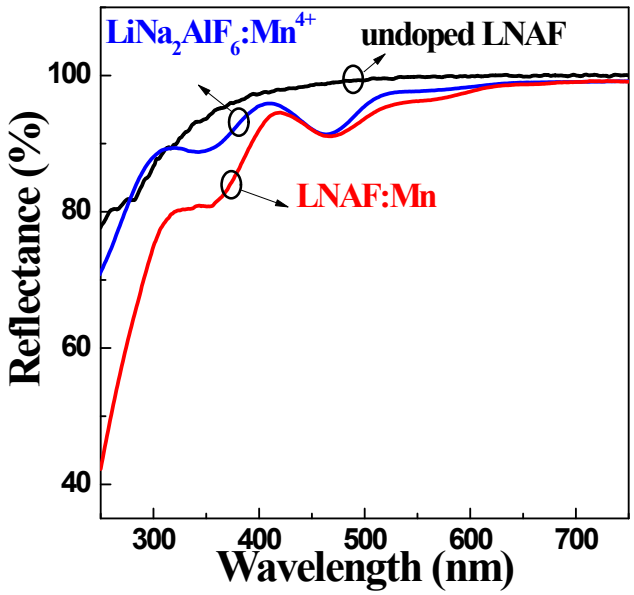

Figure S4. The powder diffuse reflectance spectra of undoped $Li_3Na_3Al_2F_{12}$ and two red phosphors $Li_3Na_3Al_2F_{12}:Mn^{4+}$ and $LiNa_2AlF_6:Mn^{4+}$.

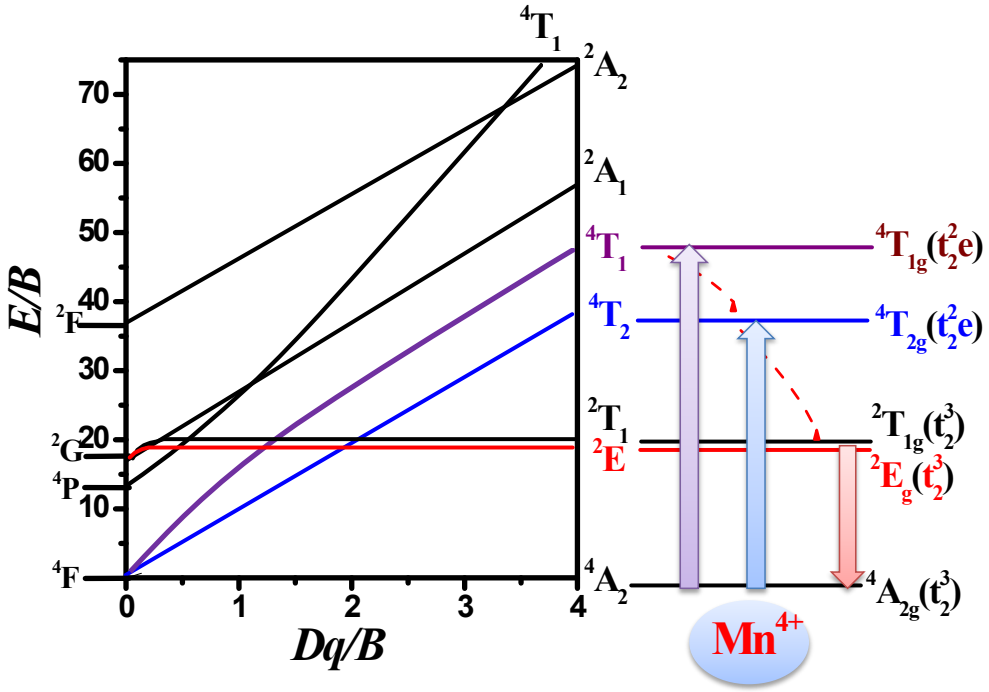

Figure S5. Tanabe-Sugano energy level diagram for $5d^3$ electron configuration of Mn^{4+} in the center of octahedron.

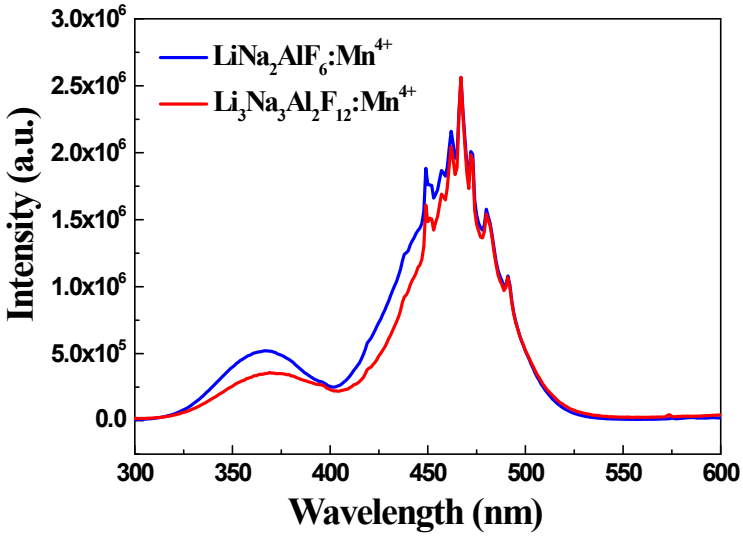

Figure S6. The excitation spectra of LNAF:Mn and $LiNa_2AlF_6:Mn^{4+}$ with modified intensity.

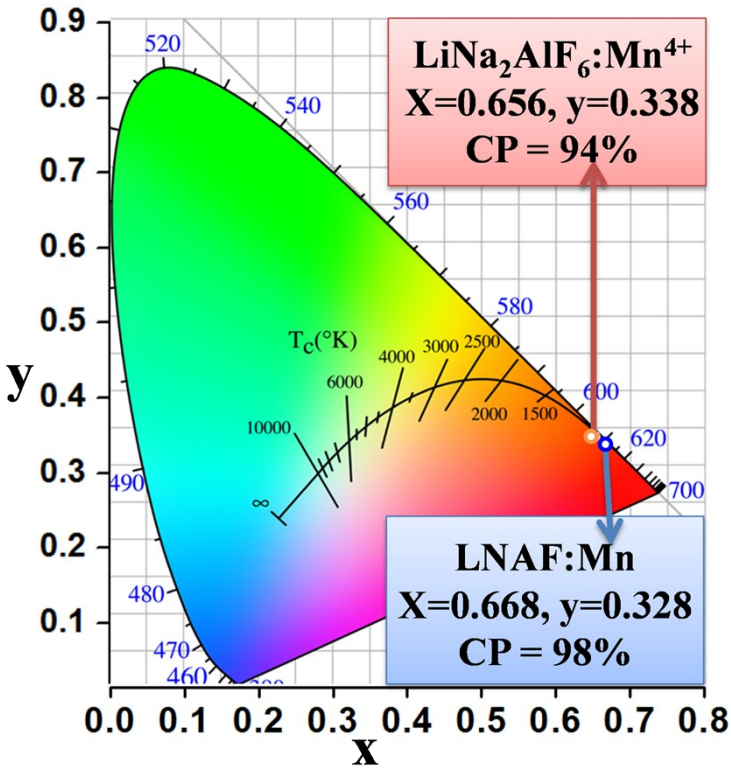

Figure S7. CIE chromaticity coordinates and color purity of the as-obtained red phosphors $Li_3Na_3Al_2F_{12}:Mn^{4+}$ and $LiNa_2AlF_6:Mn^{4+}$.

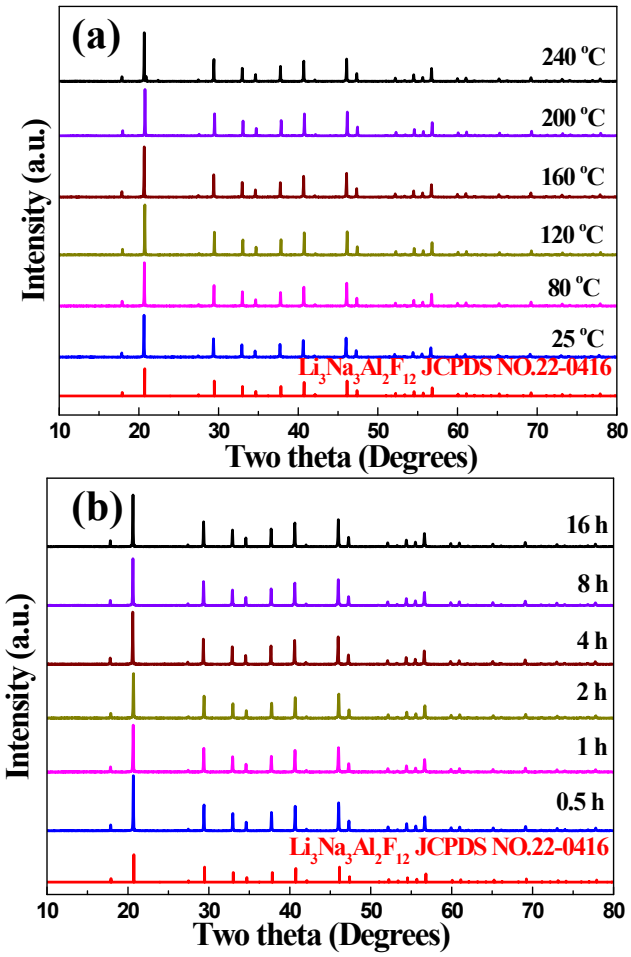

Figure S8. X-ray diffraction patterns of the red phosphor $Li_3Na_3Al_2F_{12}:Mn^{4+}$ obtained (a) at various temperatures and (b) for different reaction times compared with the standard data of $Li_3Na_3Al_2F_{12}$ in JCPDS no. 22-0416.

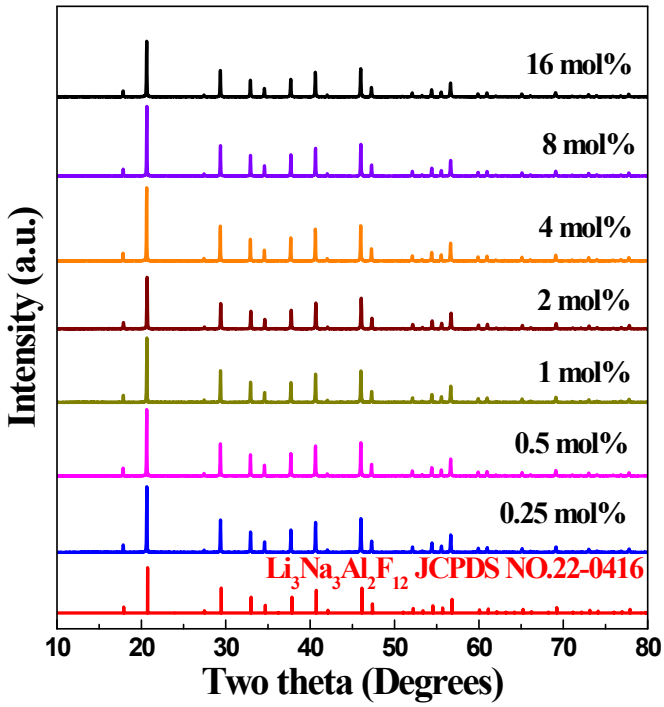

Figure S9. Dependence of x-ray diffraction patterns of the red phosphor $Li_3Na_3Al_2F_{12}:Mn^{4+}$ on ratio of K_2MnF_6/ $Li_3Na_3Al_2F_{12}$.

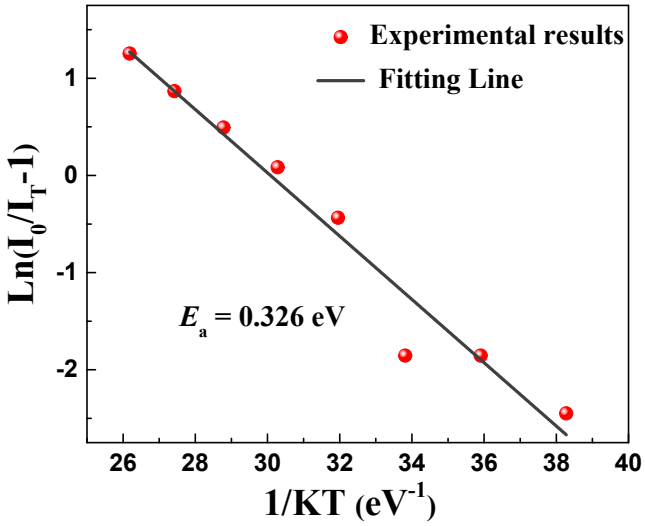

Figure S10. Arrhenius fitting of the emission intensity of the phosphor $Li_3Na_3Al_2F_{12}:Mn^{4+}$ decreased with temperature increasing.

Table S1. Details of Rietveld Refinement of $Li_3Na_3Al_2F_{12}:Mn^{4+}$ and $LiNa_2AlF_6:Mn^{4+}$.

Formula	**$Li_3Na_3Al_2F_{12}$**	**$LiNa_2AlF_6$**
CSD number	9923	96477
Formula weight	371.73	193.89
Crystal system	Cubic	monoclinic
Space group	Ia-3d	P121/n1
D (calc)	2.77	3.02
a (Å)	12.122(2)	5.2842(1)
b (Å)	12.122(2)	5.3698(1)
c (Å)	12.122(2)	7.5063(2)
V ($Å^3$)	1781.24	212.99
Z	8	2
Space group number	230	14
a	90^o	90^o
β	90^o	$89.98(1)^o$
γ	90^o	90^o