Electronic Supplementary Material (ESI) for Dalton Transactions.

Luminescence properties and warm white LED application of ternary-alkaline fluoride red phosphor $K_2NaAlF_6:Mn^{4+}$

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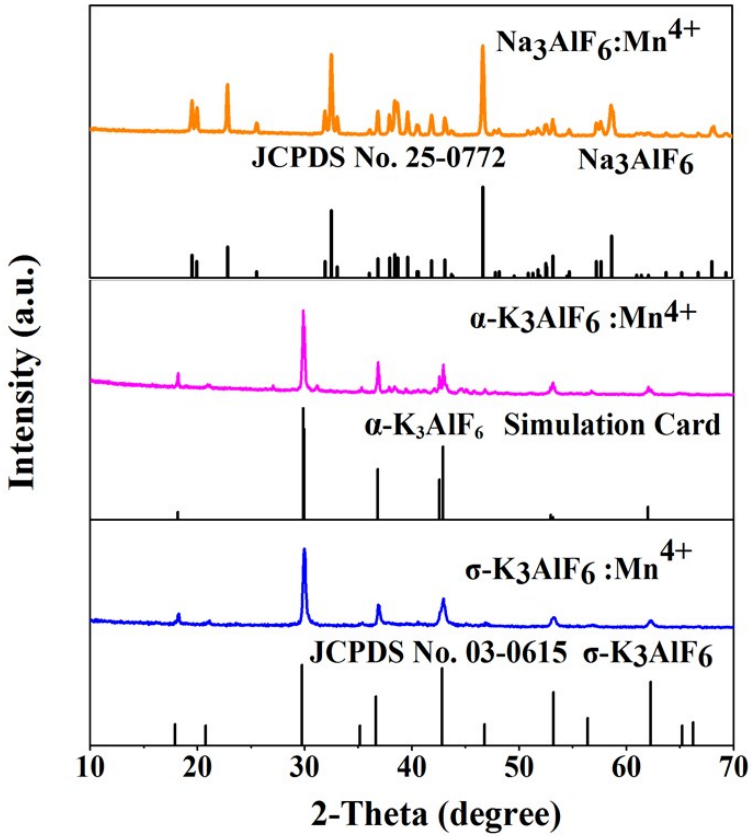

Fig. S1. XRD patterns of $Na_3AlF_6:Mn^{4+}$ and $K_3AlF_6:Mn^{4+}$ phosphors synthesized according to references [a-b].

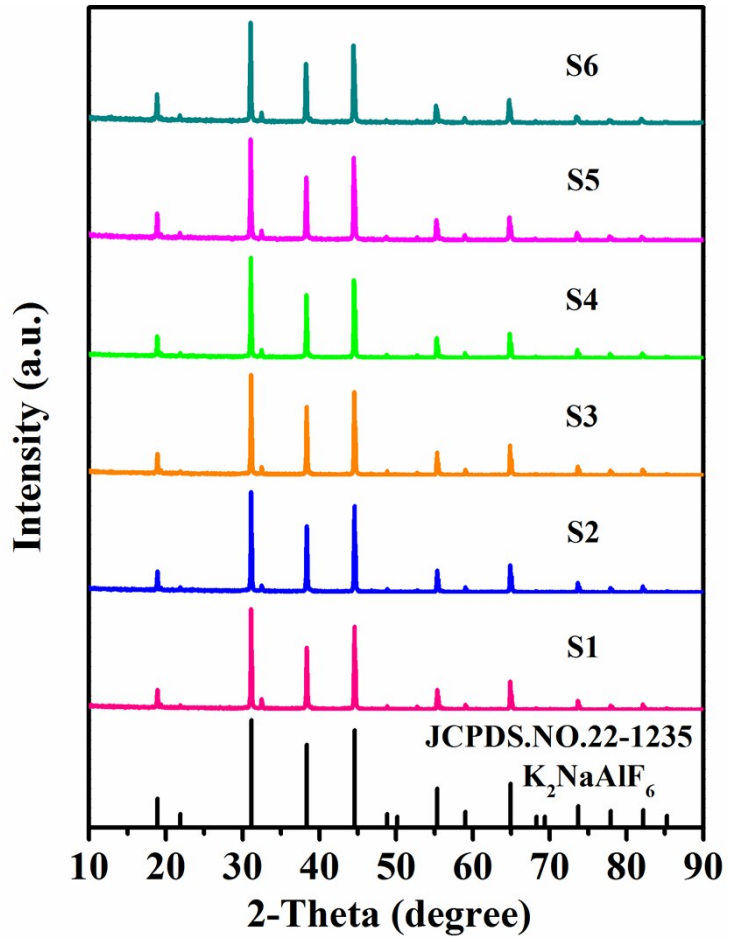

Fig. S2. XRD patterns of $K_2NaAlF_6:Mn^{4+}$ phosphors with different molar ratio of AlF_3 to K_2MnF_6.

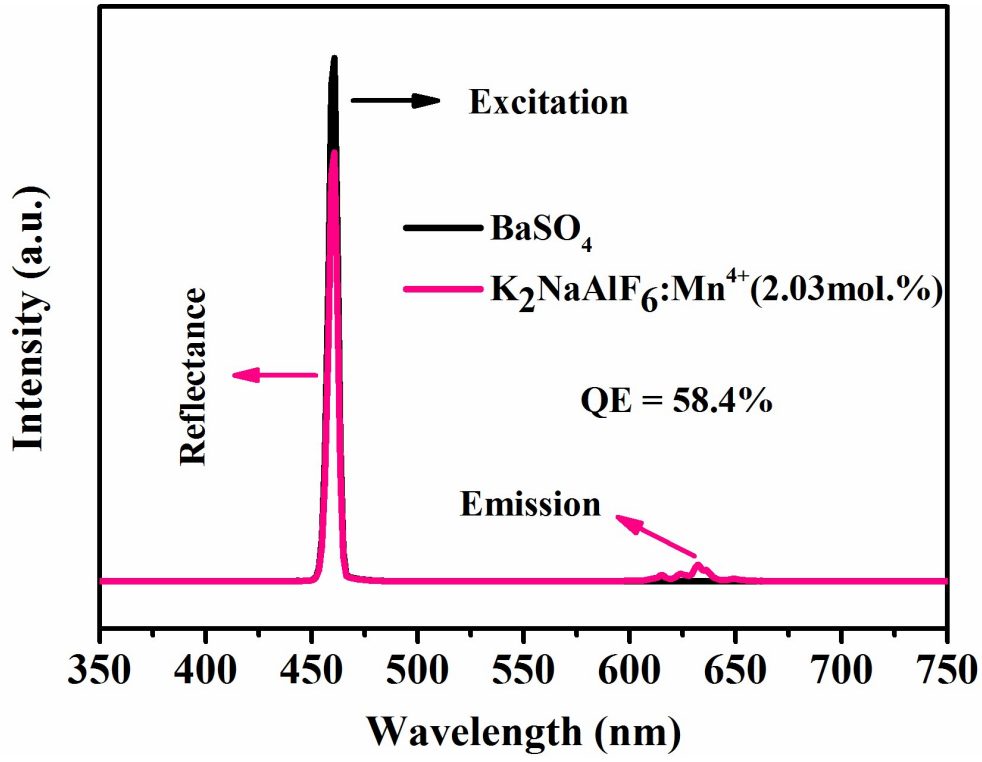

Fig. S3. Excitation spectra of $BaSO_4$, reflectance and emission spectra of $K_2NaAlF_6:Mn^{4+}$ (2.03 mol.%).

The quantum efficiency (QE) was calculated as follows:

$$QE = \frac{\int \lambda \cdot P(\lambda) d\lambda}{\int \lambda \{E(\lambda) - R(\lambda)\} d\lambda} \quad (1)$$

where E(λ)/hυ, R(λ)/hυ and P(λ)/hυ are the number of photons in the spectrum of excitation, reflectance and emission of the phosphor, respectively. All of spectra were recorded by an optical integrating sphere coupled to the QE-2100 spectrophotometer from Otsuka Photal Electronics at room temperature.

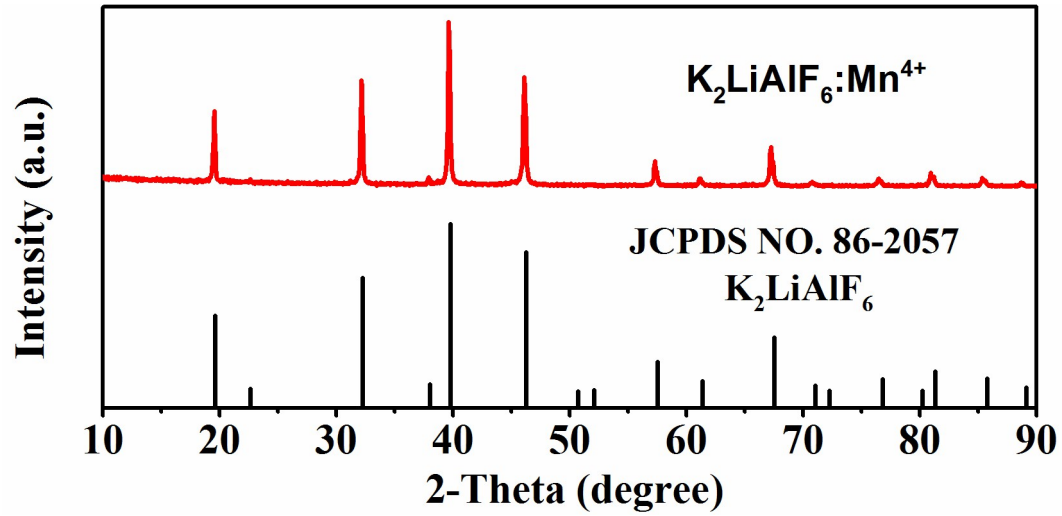

Fig. S4. XRD pattern of $K_2LiAlF_6:Mn^{4+}$ red phosphor synthesized according to reference [c].

References

[a] E. H. Song, J. Q. Wang, S. Ye, X. F. Jiang, M. Y. Peng and Q. Y. Zhang, *J. Mater. Chem. C*, 2016, **4**, 2480-2487.
[b] E. Song, J. Wang, J. Shi, T. Deng, S. Ye, M. Peng, J. Wang, L. Wondraczek and Q. Zhang, *ACS Appl. Mater. Interfaces*, 2017, **9(10)**, 8805-8812.
[c] Y. Zhu, L. Huang, R. Zou, J. Zhang, J. Yu, M. Wu, J. Wang and Q. Su, *J. Mater. Chem. C*, 2016, **4**, 5690–5695.

Eq. S1

$$\Delta E = \sqrt{(u_t' - u_0')^2 + (v_t' - v_0')^2 + (w_t' - w_0')^2}$$

where u' = 4x/(3 - 2x + 12y), v'= 9y/(3 -2x + 12y), and w'= 1- u'- v'. x and y are the chromaticity coordinates in CIE 1931, 0 and t are the chromaticity shift at 20 °C and a given temperature, respectively. u' and v' are the chromaticity coordinates in u' v ' uniform color space.