Luminescence properties and warm white LED application of ternary-alkaline fluoride red phosphor $K_2\text{NaAlF}_6:\text{Mn}^{4+}$

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Fig. S1. XRD patterns of $\text{Na}_3\text{AlF}_6:\text{Mn}^{4+}$ and $\text{K}_3\text{AlF}_6:\text{Mn}^{4+}$ phosphors synthesized according to references [a-b].
Fig. S2. XRD patterns of $\text{K}_2\text{NaAlF}_6:\text{Mn}^{4+}$ phosphors with different molar ratio of $\text{AlF}_3$ to $\text{K}_2\text{MnF}_6$.

Fig. S3. Excitation spectra of $\text{BaSO}_4$, reflectance and emission spectra of $\text{K}_2\text{NaAlF}_6:\text{Mn}^{4+}$ (2.03 mol.%).
The quantum efficiency (QE) was calculated as follows:

\[
QE = \frac{\int \lambda \cdot P(\lambda) d\lambda}{\int \lambda (E(\lambda) - R(\lambda)) d\lambda}
\]  

(1)

where \(E(\lambda)/h\nu\), \(R(\lambda)/h\nu\) and \(P(\lambda)/h\nu\) 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 Photolal Electronics at room temperature.

Fig. S4. XRD pattern of \(\text{K}_2\text{LiAlF}_6:\text{Mn}^{4+}\) red phosphor synthesized according to reference [c].

References


Eq. S1

\[
\Delta E = \sqrt{(u'_i - u'_0)^2 + (v'_i - v'_0)^2 + (w'_i - w'_0)^2}
\]

where \(u'_i = 4x/(3 - 2x + 12y), \nu'_i = 9y/(3 - 2x + 12y),\) and \(w'_i = 1- u'_i - \nu'_i\). \(x\) 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 \(\nu'\) are the chromaticity coordinates in \(u' \nu'\) uniform color space.