

## **Supporting Information**

### **Synthesis of $\text{Na}_2\text{SiF}_6:\text{Mn}^{4+}$ red phosphors for white LED applications by co-precipitation**

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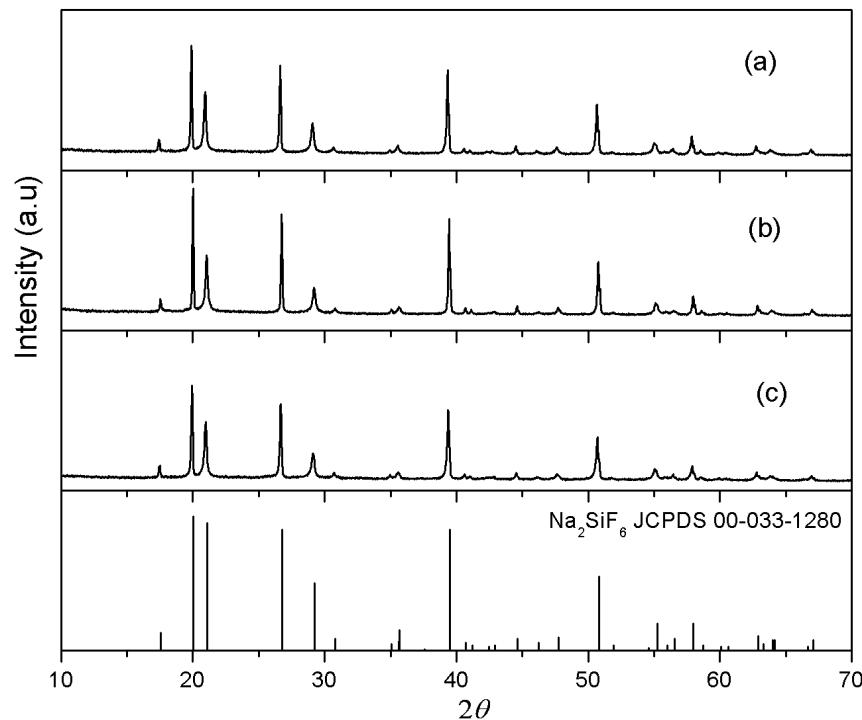
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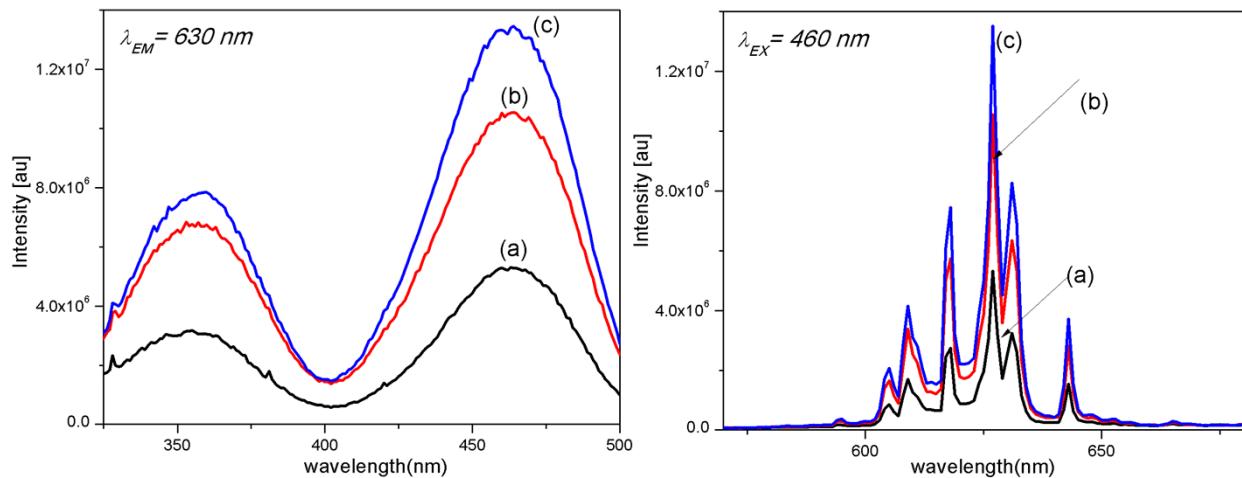
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#### **1. Preparation of $\text{Na}_2\text{SiF}_6:\text{Mn}^{4+}$ (NSFM-1S) via the one-step method**



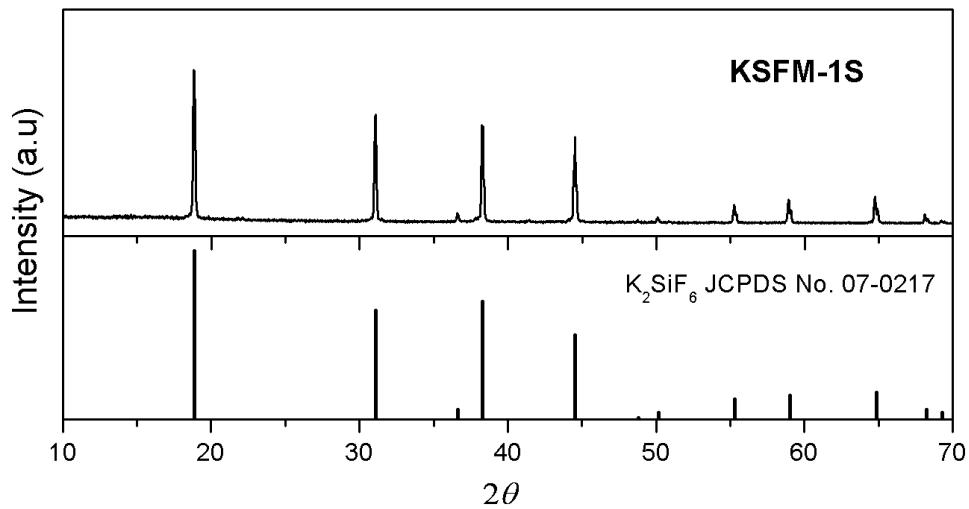
**Figure S1.** XRD patterns of NSFM-1S prepared using saturated solution of (a)  $\text{Na}_2\text{CO}_3$ , (b)  $\text{Na}_2\text{SO}_4$  and (c)  $\text{NaOH}$ .



**Figure S2.** PLE and PL spectra of NSFM-1S prepared using saturated solution of (a)  $\text{Na}_2\text{CO}_3$ , (b)  $\text{Na}_2\text{SO}_4$  and (c)  $\text{NaOH}$ .

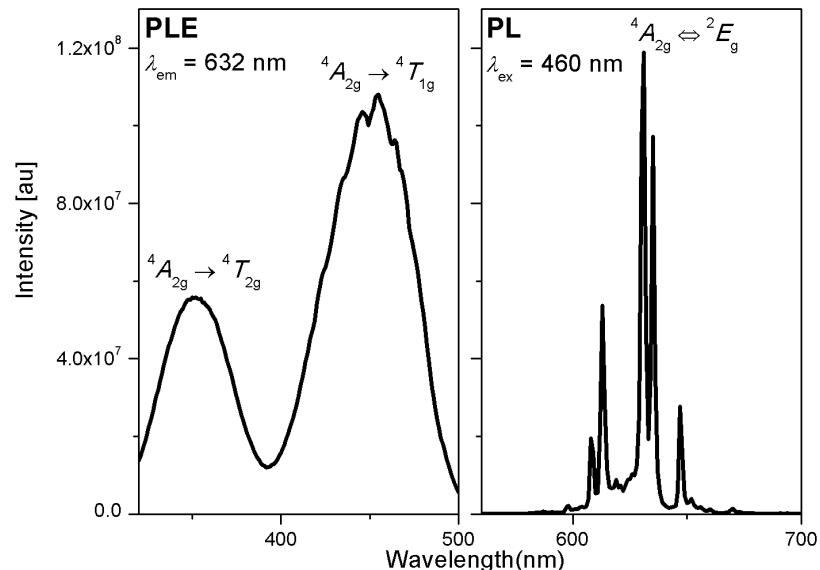
## 2. Preparation of $\text{K}_2\text{SiF}_6:\text{Mn}^{4+}$ (KSFM-1S) via the one-step method

The  $\text{SiO}_2$  powders (1.2 g) were dissolved in 25 mL solution of HF 48% at 60 °C for 2 h to form silicon fluoride solution. The solution was cooled to room temperature and separated from residual powder by using filter paper. 0.23 g  $\text{KMnO}_4$  was added to the filtered solution to obtain solution A. Thereafter, another mixture of 3.4 g KF dissolved in solution of 15 ml HF 48% and 0.15 ml  $\text{H}_2\text{O}_2$  (35–40%) was added to the solution A under vigorous stirring. The deep purple solution turned to yellow rapidly. The yellow powder was obtained as 100 ml acetone (99.9%) was pour into the resulting solution. The powder was dried at 70 °C after washing with solution HF 20% for removing undesired products and residual chemicals, and then with ethanol (99.9%) for several times.

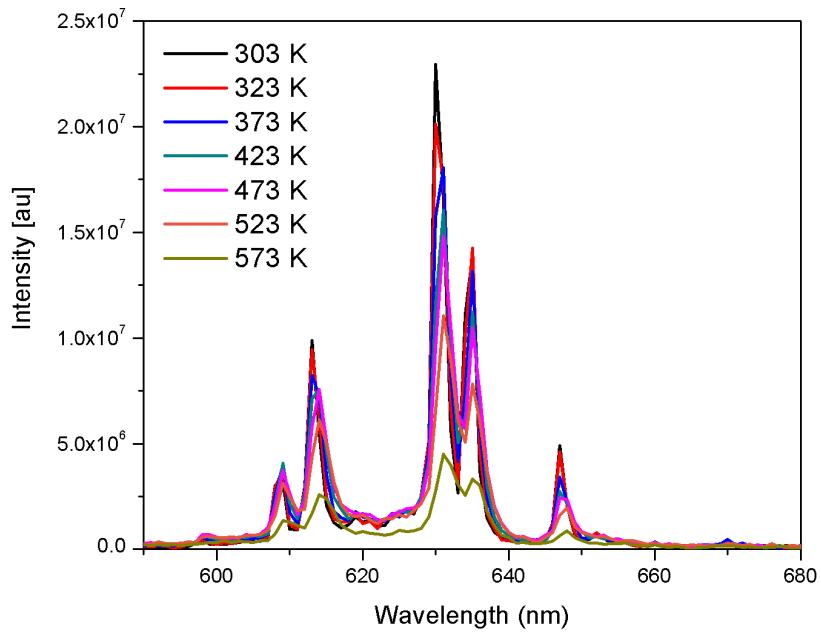


**Figure S3.** XRD diffraction pattern of KSFM-1S.

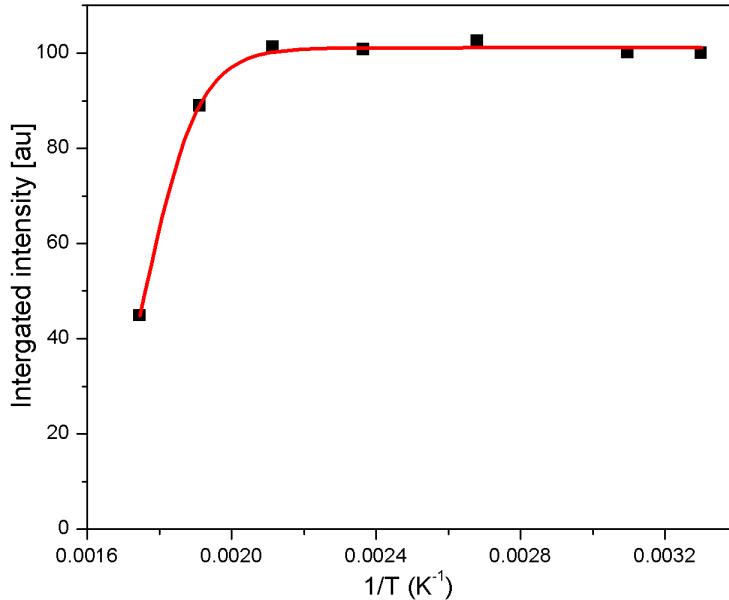
In Figure S3, the X-ray diffraction pattern of prepared KSFM-1S shows all diffracted peaks corresponding to space group *Fm-3m* of cubic  $\text{K}_2\text{SiF}_6$  (JCPDS No. 07–0217).



**Figure S4.** PLE and PL spectra of KSFM-1S.



**Figure S5.** Temperature-dependent emission spectra of KSFM-1S.



**Figure S6.** Integrated red PL intensity for the KSFM-1S.

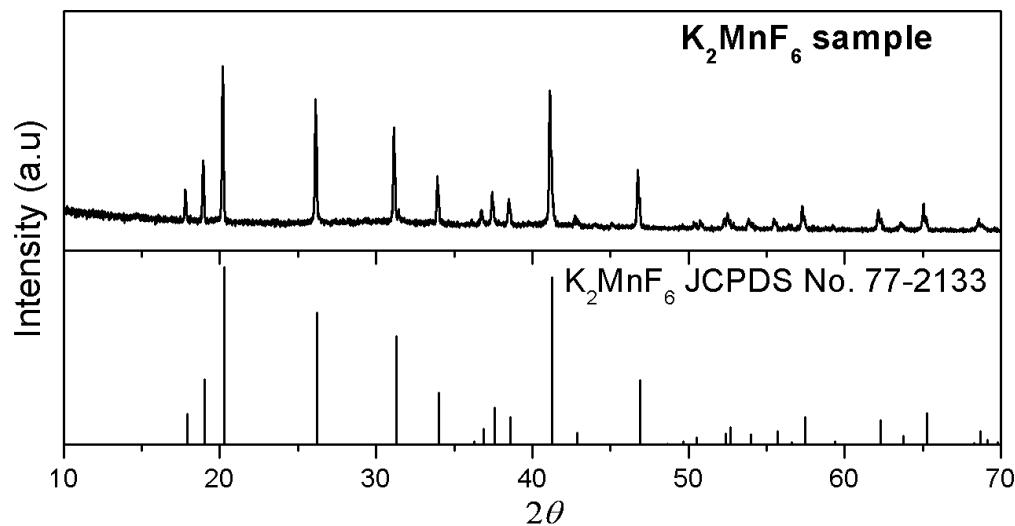
The temperature-dependent behavior of integrated PL intensity ( $I_{PL}/I_{PL303}$ ) (Fig. S6) shows considerable stability for KSFM-1S red phosphor in the temperature range of 303–423 K. At 432 K, the relative PL intensity remains 100% of that at 303 K, showing clearly an excellent thermal stability of KSFM-1S phosphor. The integrated PL intensity for KSFM-1S can be fitted by  $I_T/I_0$

$= [1 + D \exp(-E_a/kT)]^{-1}$ , where  $I_0$  is intensity at  $T = 0$  K,  $D$  and activation energy  $E_a$  are refined variables. The activation energies obtained for KSFM-1S red phosphor is 1.09 eV.

### 3. Preparation of $\text{K}_2\text{MnF}_6$

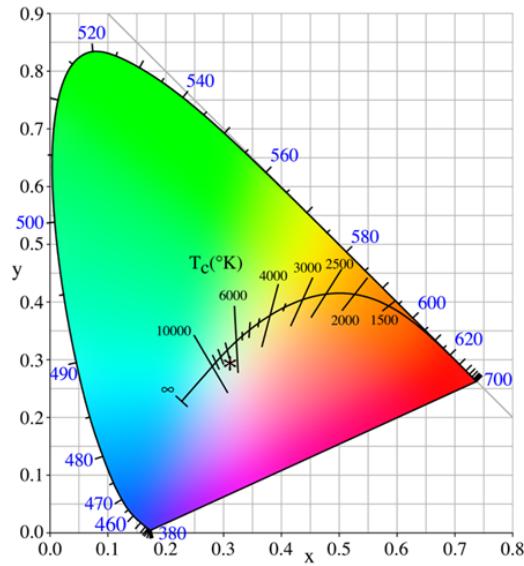
The yellow powder  $\text{K}_2\text{MnF}_6$  was precipitated by slowly dropping  $\text{H}_2\text{O}_2$  into mixture of  $\text{KMnO}_4$  and  $\text{KHF}_2$  (weight ratio of 1:20) dissolved in 48% HF solution.

All x-ray diffracted peaks of prepared  $\text{K}_2\text{MnF}_6$  can be indexed to space group  $P63mc$  of hexagonal  $\text{K}_2\text{MnF}_6$  (JCPDS No. 77-2133), as shown Figure S7.



**Figure S7.** XRD diffraction pattern of  $\text{K}_2\text{MnF}_6$ .

#### 4. The chromaticity coordinate of the fabricated WLED



**Figure S8.** The chromaticity coordinate (\*) of the WLED (fabricated by combining commercial YAG:Ce yellow phosphor, NSFM-2S red phosphor and blue-LED chip) with correlated color temperature of 6875 K in Commission Internationale de l'Éclairage (CIE) 1931 color spaces.