Electronic Supplementary Information (ESI)

A new red phosphor $BaGeF_6:Mn^{4+}$: hydrothermal synthesis, photo-luminescent properties, and its application in warm white LED devices

Qiang Zhou,[a] Yayun Zhou,[a] Yong Liu,[a] Lijun Luo,[a] Zhengliang Wang,*[a] Jinhui Peng,[a] Jing Yan,[b] and Mingmei Wu*[b]

a) Key Laboratory of Comprehensive Utilization of Mineral Resources in Ethnic Regions, Key Laboratory of Resource Clean Conversion in Ethnic Regions, Education Department of Yunnan, School of Chemistry and Biotechnology, Yunnan Minzu University, Kunming, Yunnan 650031, P. R. China

b) MOE Key Laboratory of Bioinorganic and Synthetic Chemistry, School of Chemistry and Chemical Engineering, Sun Yat-Sen (Zhongshan) University, Guangzhou, 510275, P. R. China, E-mail: ceswmm@mail.sysu.edu.cn

Email: wangzhengliang@foxmail.com

ceswmm@mail.sysu.edu.cn

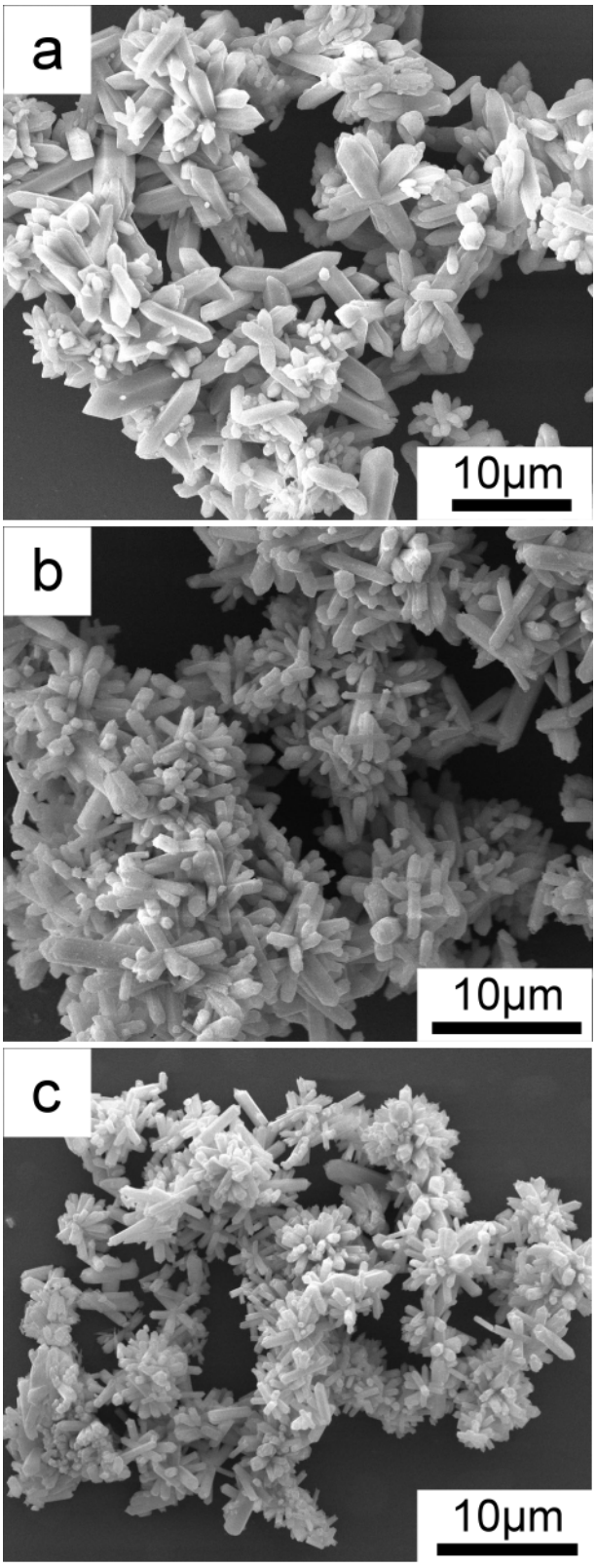

Fig. S1: SEM images of $BaGeF_6:Mn^{4+}$ products obtained with 10.0 mmol·L^{-1} $KMnO_4$ and (a) 10 %, (b) 20 % and (c) 30 % HF solution at 180 °C for 8.0 h.

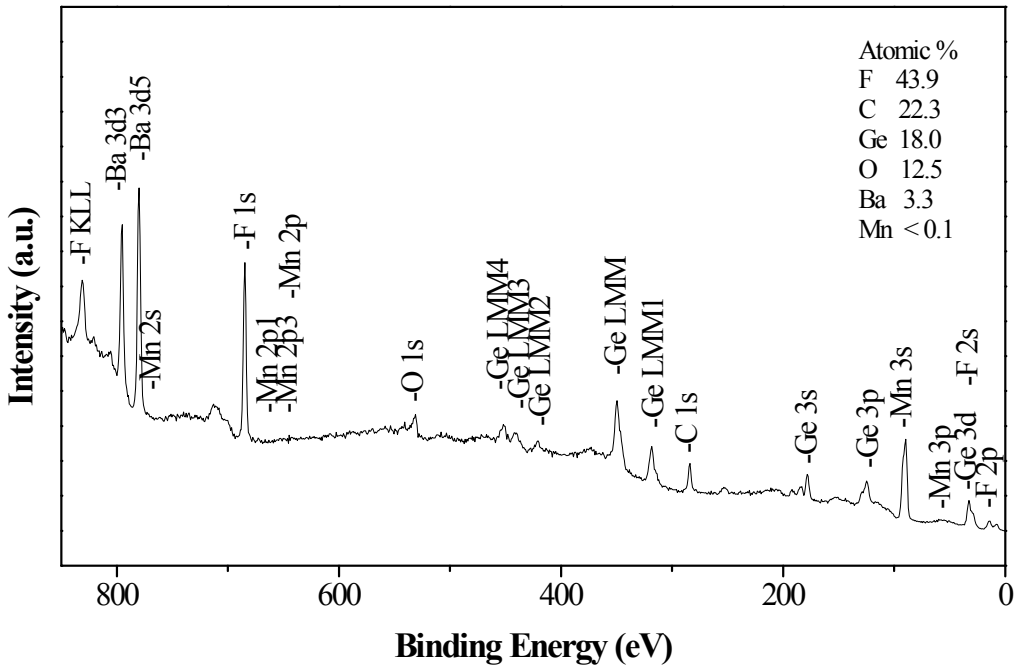

Fig. S2 XPS spectrum of red phosphor $BaGeF_6:Mn^{4+}$.

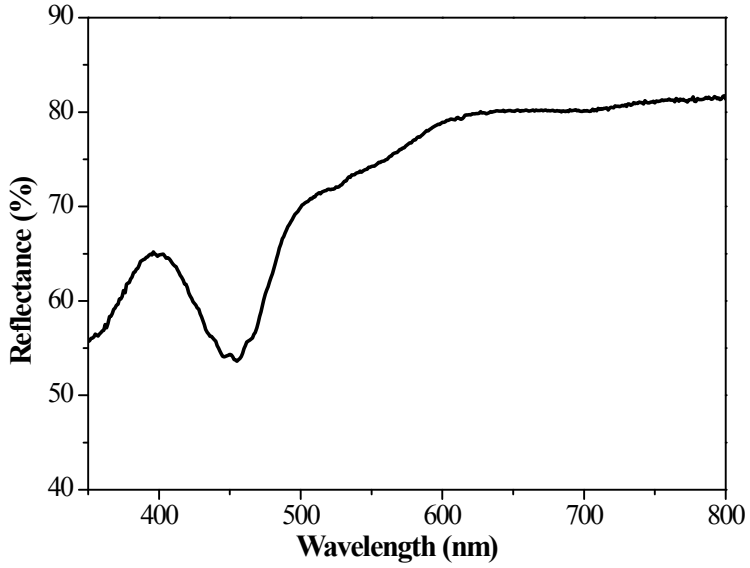

Fig. S3 Diffuse reflection spectrum of red phosphor $BaGeF_6:Mn^{4+}$.

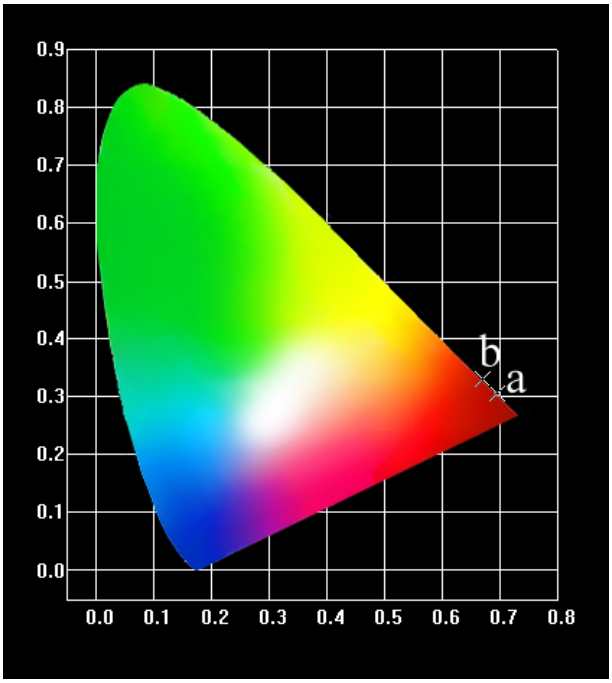

Fig. S4 CIE chromaticity diagram for (a) $BaGeF_6:Mn^{4+}$ and (b) NTSC "ideal red".

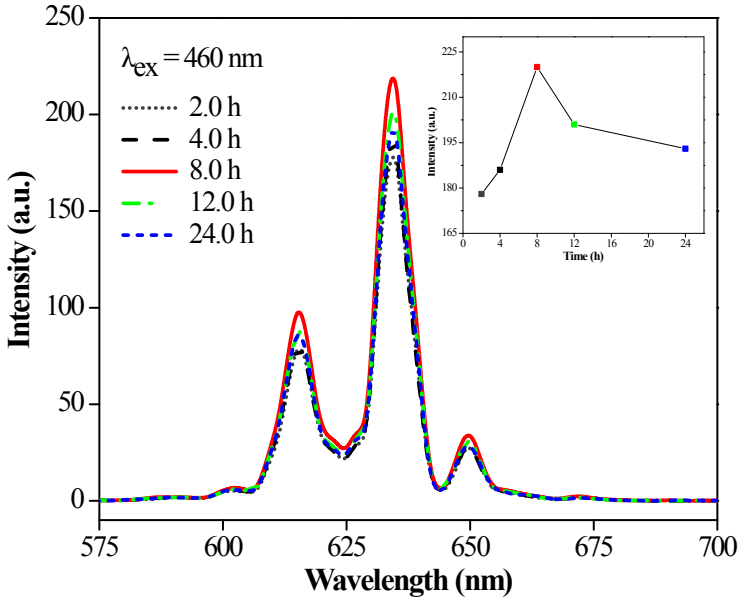

Fig. S5 Emission spectra of $BaGeF_6:Mn^{4+}$ red phosphors obtained from 40% HF and 10.0 mmol·L^{-1} $KMnO_4$ at 180 °C for (a) 2.0 h, (b) 4.0 h, (c) 8.0 h, (d) 12.0 h and (e) 24.0 h. The inserted curve is the effect of reaction time on the relative emission intensity of BGFM.

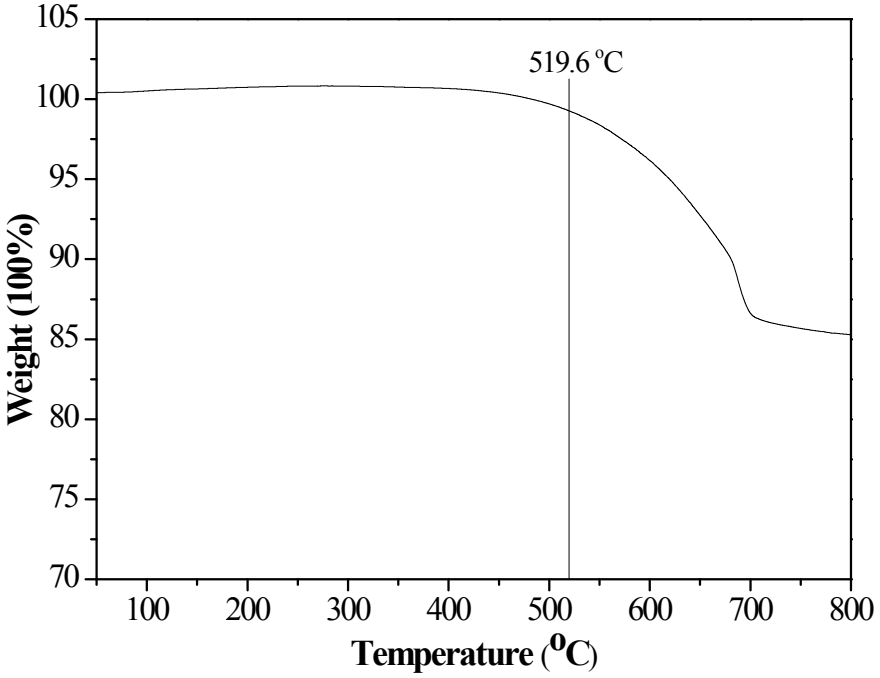

Fig. S6 Thermogravimetrics (TG) as synthesized $BaGeF_6:Mn^{4+}$ under N_2 atmosphere. The thermal stability the red phosphor behavior of $BaGeF_6:Mn^{4+}$ is investigated by thermogravimetrics analysis (TG: PerkinElmer STA 8000, at a heating rate of 10 K/min).

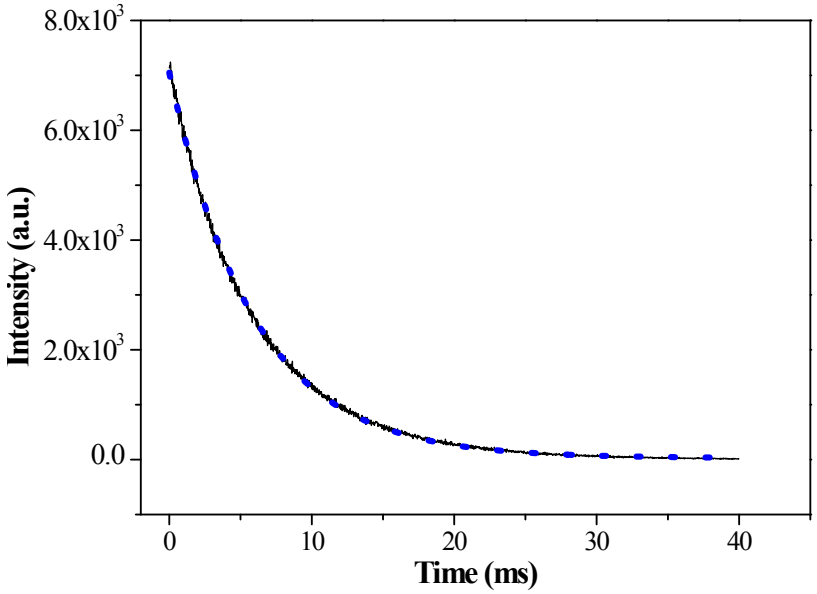

Fig. S7 Decay curve of the BGFM red phosphors examined at room temperature. The monitoring wavelength is at 634 nm with a 460 nm light excitation.

Tab. S1: Performance of the GaN-based WLEDs coated with: (1) YAG:Ce, (2) YAG:Ce and BGFM mixture at 20 mA forward current and 5 V reverse voltage.

No. of LEDs Samples	CT(K)	CRI	Luminous Efficiency (lm/W)	CIE (*x*, *y*)
1	6283	76.0	45.21	(0.3129, 0.3660)
2	4210	84	52.21	(0.3693,0.3608)

Note: The luminous efficiency has also been enhanced with the use of BGFM.