Supporting Information

Co-precipitation synthesis and photoluminescence properties of $BaTiF_6:Mn^{4+}$: an efficient red phosphor for warm white LEDs

Yong Liu,[a] Guojun Gao,[b] Lin Huang,[a] Yiwen Zhu,[a] Xuejie Zhang,[a] Jinbo Yu,[a] Bryce S. Richards,[b,c] Tongtong Xuan,[a] Zhengliang Wang*[d] and Jing Wang*[a]

[a] *Ministry of Education Key Laboratory of Bioinorganic and Synthetic Chemistry, State Key Laboratory of Optoelectronic Materials and Technologies, School of Chemistry, School of Materials Science and Engineering, Sun Yat-Sen University, Guangzhou, 510275, P. R. China. *E-mail: ceswj@mail.sysu.edu.cn*

[b] *Institute of Microstructure Technology, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344Eggenstein-Leopoldshafen, Germany*

[c] *Light Technology Institute, Karlsruhe Institute of Technology, Engesserstrasse 13, 76131 Karlsruhe, Germany*

[d] *Key Laboratory of Comprehensive Utilization of Mineral Resources in Ethnic Regions, Joint Research Centre for International Cross-border Ethnic Regions Biomass Clean Utilization in Yunnan, School of Chemistry & Environment, Yunnan Minzu University, Kunming, 650500, P. R. China, *E-mail: wangzhengliang@foxmail.com*

Synthesis of $BaTiF_6$: Mn^{4+}

The red phosphor $BaTi_{0.97}F_6$: $0.03Mn^{4+}$ samples were synthesized through a hydrothermal route. The specific process is as follows： firstly, 2.5 mmol of TiO_2, 2.5 mmol of BaF_2 and 0.075 mmol of K_2MnF_6 were added into a solution containing 5 mL of HF (40% wt). secondly, the mixed solution was stirred for 10 min and then transferred into an 10 mL of Teflon lined autoclave. The autoclave was maintained at 120 °C for 15 h. As the autoclave was cooled to room temperature naturally, the final products were washed three times with ethanol. At last, the product was dried at 80 °C for 2 h.

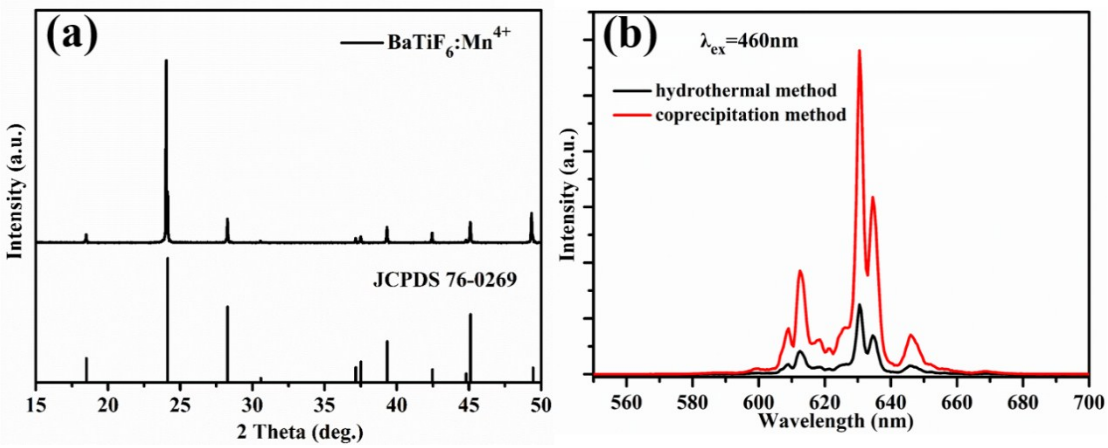

Fig. S1. (a) XRD pattern of the red phosphors $BaTi_{0.97}F_6$:$0.03Mn^{4+}$ by hydrothermal method at 150 °C for 12 h and (b) PL (λ_{ex} = 460 nm) spectra of the red phosphors $BaTi_{0.97}F_6$:$0.03Mn^{4+}$ by hydrothermal method (black line) and coprecipitation method (red line).

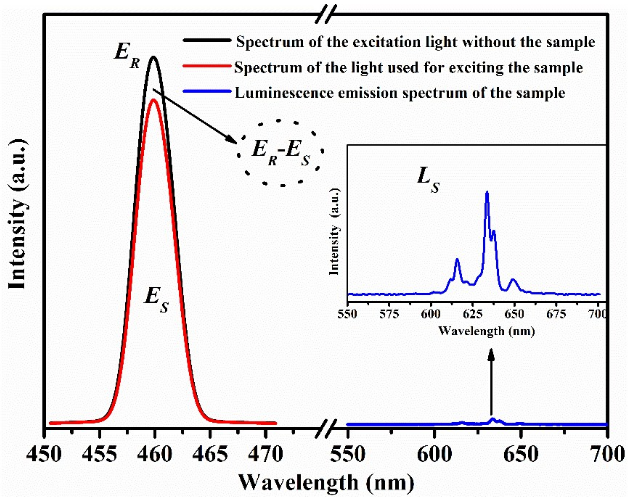

Fig. S2 Spectrum of the excitation light without the $BaTi_{0.97}F_6$:0.03Mn^{4+} sample (E_R), spectrum of the light used for exciting the $BaTi_{0.97}F_6$:0.03Mn^{4+} sample(E_S), luminescence emission spectrum of the $BaTi_{0.97}F_6$:0.03Mn^{4+} sample(L_S), and the inset shows a magnification of the emission spectrum.

Note: QE is defined as the ratio of the number of emitted photons (I_{em}) to the number of absorbed photons (I_{abs}), and can be calculated by the following equation:

$$IQE = \frac{I_{em}}{I_{abs}} = \frac{\int Ls}{\int E_R - \int Es}$$

where E_R is the spectrum of the excitation light without the sample in the sphere, E_S is the spectrum of the light used for exciting the sample,and L_S is the luminescence emission spectrum of the sample.

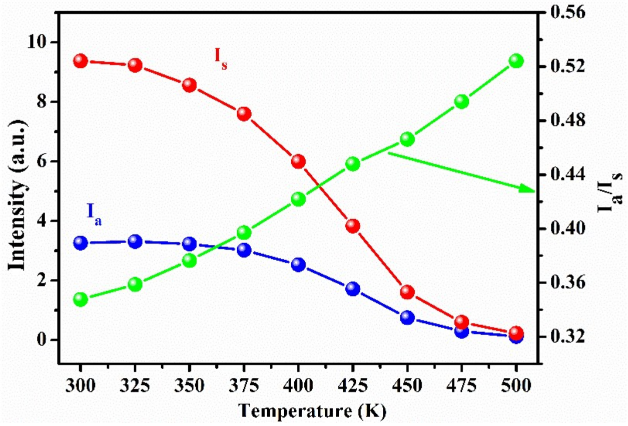

Fig. S3 The temperature-dependent PL intensity of the as-synthesized $BaTi_{0.97}F_6$:0.03Mn^{4+} in the wavelength ranges of 605–623 nm (I_a), and 623–655 nm (I_s).