# Electronic Supplementary Information (ESI)

## Local structure modulation of $Mn^{4+}$-doped $Na_2Si_{1-y}Ge_yF_6$ red phosphor for enhancement of emission intensity, moisture resistant, thermal stability and application in warm pc-WLEDs

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**Table 1** Cell parameters of $Na_2Si_{1-y}Ge_yF_6$:0.06$Mn^{4+}$ (y = 0, 0.3, 0.5, 0.7 and 1) red phosphors

| Samples | Crystalline phase | Space group | Lattice parameters | | |
|---|---|---|---|---|---|
| | | | a = b (Å) | c (Å) | *V* (Å$^3$) |
| $NaSiF_6$ (standard) | Hexagonal | P321(150) | 8.8659 | 5.0433 | 343.3 |
| $Na_2SiF_6$:0.06$Mn^{4+}$ | Hexagonal | P321(150) | 8.8520 | 5.0374 | 341.84 |
| $Na_2Si_{0.3}Ge_{0.7}F_6$:0.06$Mn^{4+}$ | Hexagonal | P321(150) | 8.8801 | 5.0412 | 344.27 |
| $Na_2Si_{0.5}Ge_{0.5}F_6$:0.06$Mn^{4+}$ | Hexagonal | P321(150) | 8.9593 | 5.1451 | 357.67 |
| $Na_2Si_{0.7}Ge_{0.3}F_6$:0.06$Mn^{4+}$ | Hexagonal | P321(150) | 9.0274 | 5.0767 | 361.40 |
| $Na_2GeF_6$:0.06$Mn^{4+}$ | Hexagonal | P321(150) | 9.0392 | 5.10637 | 362.33 |
| $Na_2GeF_6$ (standard) | Hexagonal | P321(150) | 9.0576 | 5.1071 | 362.9 |

**Table 2** Spectroscopic parameters and $\beta_1$ values of $Mn^{4+}$ ions for as-reported $Mn^{4+}$-activated fluorides and oxides phosphor.

| Host | *Dq*/cm$^{-1}$ | B/cm$^{-1}$ | C/cm$^{-1}$ | $\beta_1$ | E($^2E_g$)/cm$^{-1}$ | Ref. |
|---|---|---|---|---|---|---|
| $Mg_2Al_4Si_5O_{18}$ | 2141 | 927 | 2560 | 0.996 | 14409 | 1 |
| $La_3GaGe_5O_{16}$ | 2141 | 900 | 2858 | 1.020 | 15174 | 2 |
| $LaTiSbO_6$ | 2062 | 876 | 2752 | 0.989 | 14641 | 3 |
| $La_{0.98}Lu_{0.02}AlO_3$ | 2018 | 820 | 2659 | 0.940 | 13991 | 4 |
| $Li_2Ge_4O_9$ | 2252 | 608 | 3423 | 0.953 | 14948 | 5 |
| $SrMg_2La_2W_2O_{12}$ | 2088 | 746 | 2856 | 0.924 | 14124 | 6 |
| $KZnF_3$ | 2105 | 607 | 3785 | 1.024 | 15797 | 7 |
| $NaHF_2$ | 2141 | 665 | 4016 | 1.095 | 15923 | 8 |
| $CsPF_6$ | 2127 | 617 | 3787 | 1.028 | 16103 | 9 |
| $K_{0.007}Ba_{0.965}TiF_6$ | 2096 | 610 | 3677 | 1.002 | 15713 | 10 |
| $Na_2Si_{0.5}Ge_{0.5}F_6$ | 2137 | 556 | 3858 | 1.017 | 15898 | This work |

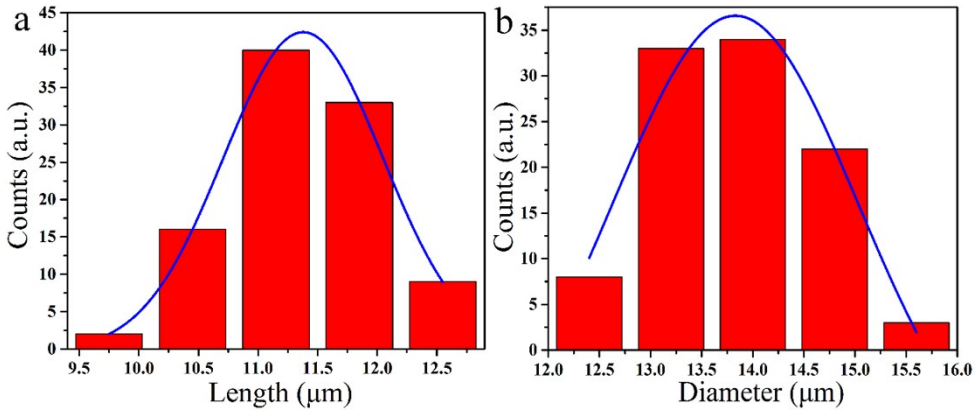


**Fig. S1** Histogram of length (a) and diameter (b) of as-prepared $Na_2SiF_6$:0.06$Mn^{4+}$ red phosphor

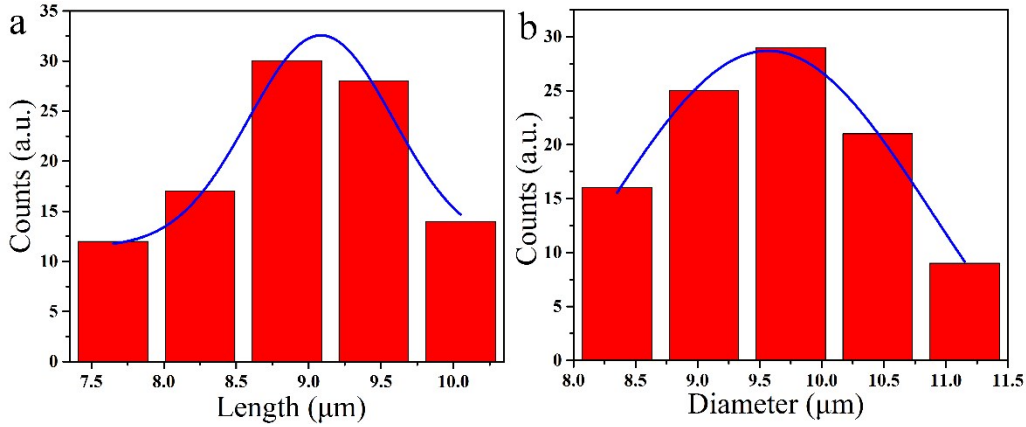


**Fig. S2** Histogram of length (a) and diameter (b) of as-prepared $Na_2Si_{0.7}Ge_{0.3}F_6$:0.06$Mn^{4+}$ red phosphor

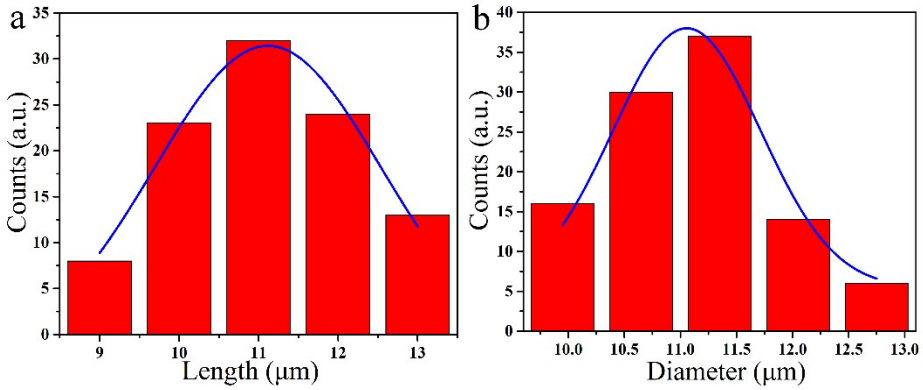


**Fig. S3** Histogram of length (a) and diameter (b) of as-prepared $Na_2Si_{0.5}Ge_{0.5}F_6$:0.06$Mn^{4+}$ red phosphor

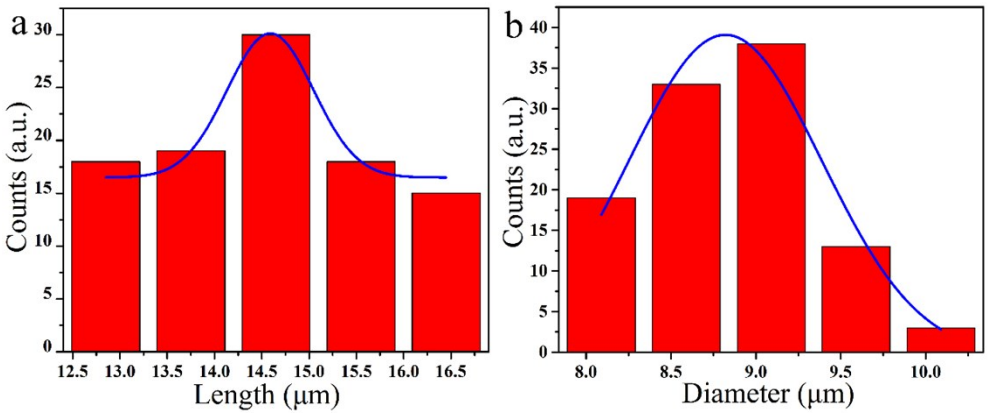


**Fig. S4** Histogram of length (a) and diameter (b) of as-prepared $Na_2Si_{0.3}Ge_{0.7}F_6$:0.06$Mn^{4+}$ red phosphor

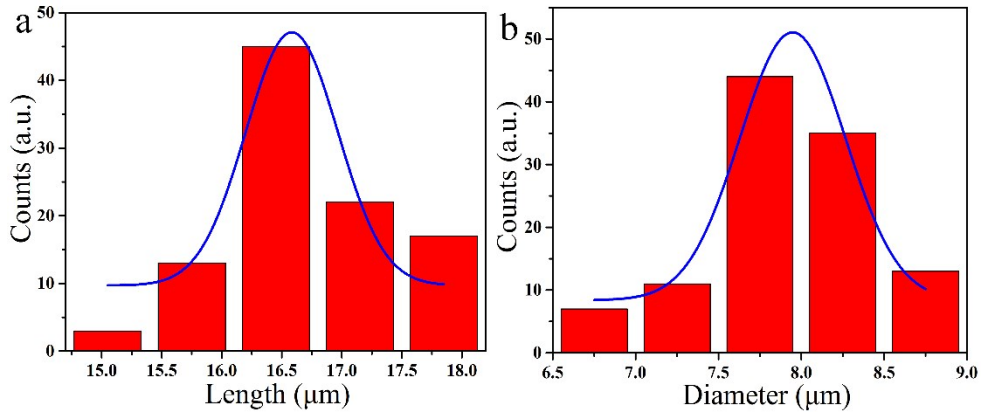


**Fig. S5** Histogram of length (a) and diameter (b) of as-prepared $Na_2GeF_6$:0.06$Mn^{4+}$ red phosphor

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