# Supporting Information

# High-concentration $Mn^{4+}$ doping in boron-modified $Ca_{14}Zn_6Al_{10}O_{35}$–based phosphors: Decoding superior luminescence performances

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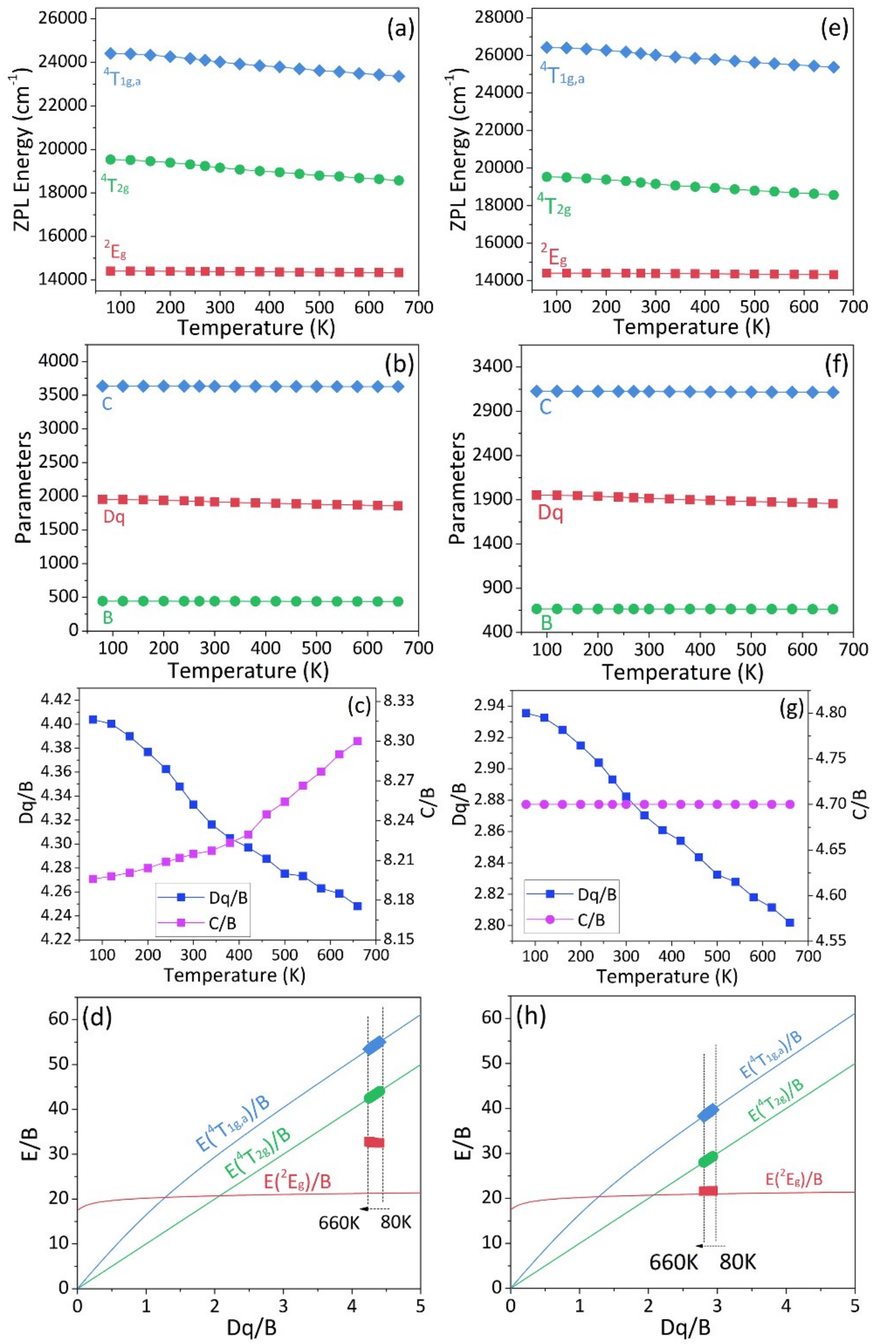


**Fig. S1** Temperature-dependence of the corrected (a, e) $E(^2E_g)_{ZPL}$, $E(^4T_{2g})_{ZPL}$, and $E(^4T_{1g,a})_{ZPL}$, (b, f) parameters Dq, B, and C, (c, g) Dq/B and C/B, and (d, h) Excitation/emission energies (divided by B) vs. Dq/B on the Tanabe-Sugano energy diagram. For (a)-(d), the values of $E(^4T_{2g})_{ZPL}$ and $E(^4T_{1g,a})_{ZPL}$ were corrected based on the redshift of the peak position of the corresponding transition bands, and then the values of Dq, B, and C were calculated by Eqs.(3)-(6). For (e)-(h), the values of $E(^4T_{2g})_{ZPL}$ were corrected based on the redshift of the peak position of the $^4T_{2g}$ transition band, and then the values of $E(^4T_{1g,a})_{ZPL}$, Dq, B, and C were calculated from $E(^2E_g)_{ZPL}$ and $E(^4T_{2g})_{ZPL}$ by assuming the Racah parameter ratio of C/B = 4.7, proposed by Adachi (S. Adachi, *ECS J. Solid State Sci. Technol.,* 2020, **9**, 046004).

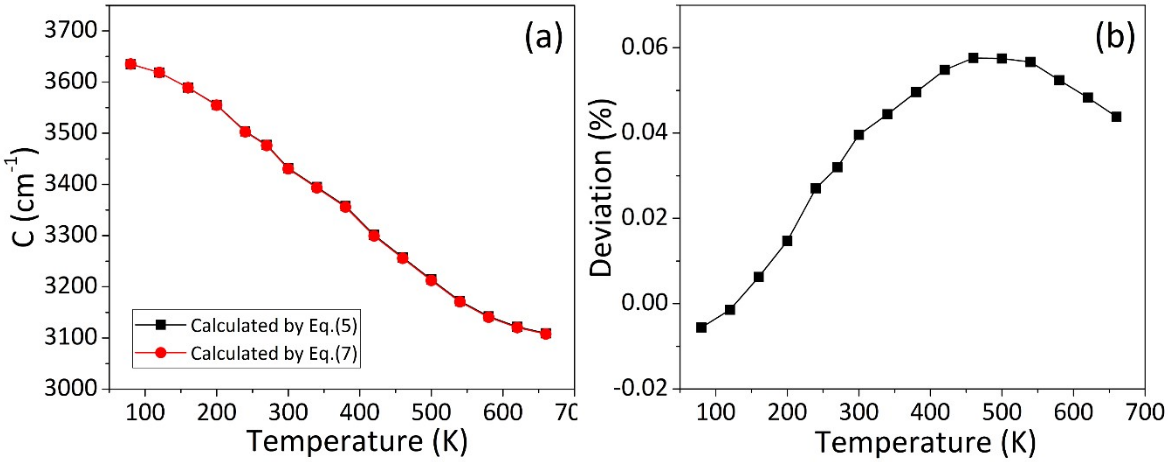


**Fig. S2** (a) Temperature-dependent Racah parameter C calculated by formulas (5) and (7), and (b) their divergence [(C5-C7)/C5*100%, where C5 and C7 are the C values calculated by formulas (5) and (7), respectively].

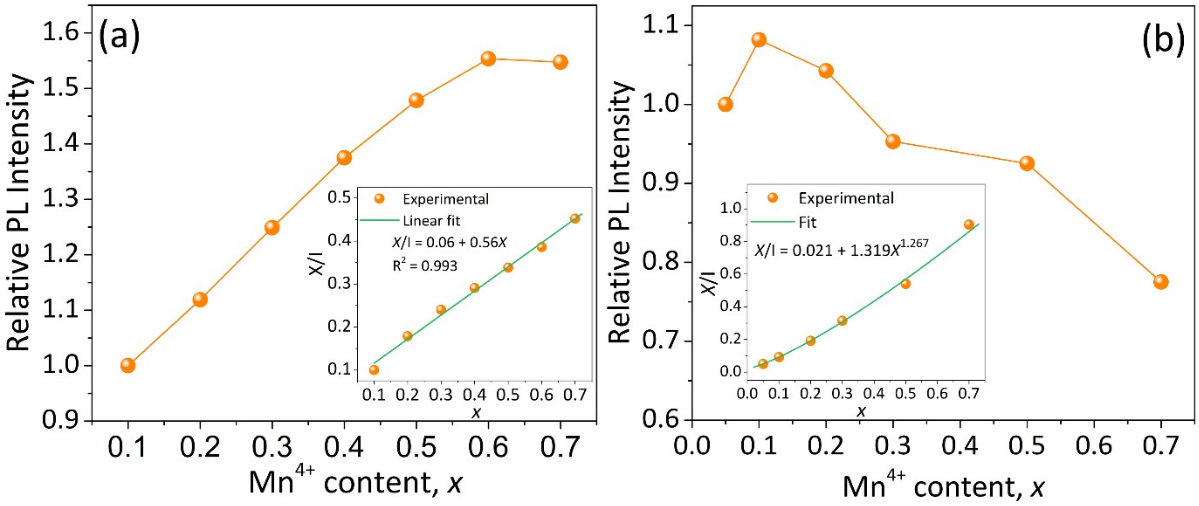


**Fig. S3** Dependence of the integrated PL intensity on the Mn-doping concentration for (a) the $Ca_{14}Zn_6Al_{9.85-2x}B_{0.15}Mn_xMg_xO_{35}$ – 0.42% $B_2O_3$ phosphors and (b) $Ca_{14}Zn_6Al_{10-2x}Mn_xMg_xO_{35}$ phosphors.

For $Ca_{14}Zn_6Al_{10-2x}Mn_xMg_xO_{35}$ phosphors, the optimal doping concentration of $Mn^{4+}$ is 1%. Beyond this concentration, the PL intensity decreases as the doping concentration increases. However, by introducing B doping and using $B_2O_3$ as a flux, the PL intensity of the $Ca_{14}Zn_6Al_{9.85-2x}B_{0.15}Mn_xMg_xO_{35}$ – 0.42% $B_2O_3$ phosphors increases with $Mn^{4+}$ concentration ($x$), up to $x = 0.6$. This observation confirms that B-modification can effectively reduce the crystal defects, thereby suppressing the concentration quenching.