A novel efficient single phase dual-emission phosphor with high resemblance to photosynthesis spectrum

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Supporting information

Table S1 Crystallographic data variation by the Rietveld refinement

Parameter	$Lu_3Al_5O_{12}$ standard data	$Lu_3Al_5O_{12}$:10%Ca^{2+},0.6%Bi^{3+},0.4%Mn^{4+} refined data
Space group	Ia-3d, Cubic	Ia-3d, Cubic
a=b=c	11.906 Å	11.917 Å
α=β=γ	90°	90°
V	1687.7 $Å^3$	1692.4 $Å^3$
Distance between Lu and Al1	3.328 Å	3.342 Å

Table S2 The elements composition of $Lu_3Al_5O_{12}$:10%Ca^{2+},0.6%Bi^{3+},0.4%Mn^{4+} by EDS measurement

Elements	Wt%	At%
O	22.86	59.66
Al	15.85	24.52
Lu	59.30	14.15
Ca	1.45	1.51
Bi	0.45	0.09
Mn	0.09	0.07

The main influence factor on the luminescence performance is Mn^{4+} doping concentration. In order to optimize the doping concentration of Mn^{4+} ions, $Lu_3Al_5O_{12}$:xMn^{4+} (x=0.03%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0%) were synthesized. In Fig. S1 and S2, with increasing of Mn^{4+} ions, the intensity gradually increases and reaches the maximum at x=0.4%, and then decreases due to ion-ion interaction which causes cross-relaxation energy transfer and nonradiative relaxation when the activator ions are close in the lattice. According to the Dexter energy resonance theory, the interaction type between Mn^{4+} ions can be calculated by the following equation:

$$\log\left(I/x\right) = C - \left(m/3\right)\log x$$

Where I represents the emission intensity, x is the quenching concentration of activator, C is a constant. m values are 6, 8, and 10, corresponding to dipole-dipole (d-d), dipole-quadrupole (d-q), and quadrupole-quadrupole (q-q) interactions, respectively. Fig. S3 shows the relationship between log (I/x) and log (x). A relative red linear fitting can be achieved based on the four experimental points after the quenching concentration. The slope of the straight line is fitting to 1.78. Thus, the value of m is determined to approximately 6, illustrating that the interaction type in

$Lu_3Al_5O_{12}:xMn^{4+}$ is belong to d-d interaction for the Mn^{4+} center.

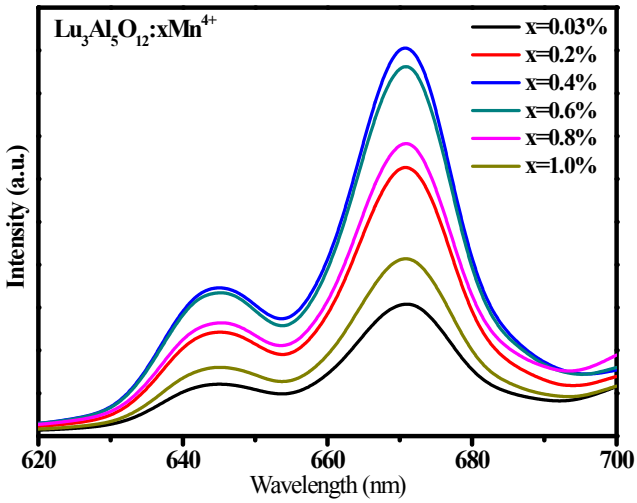

Fig. S1 PL spectra of $Lu_3Al_5O_{12}:xMn^{4+}$ phosphors with x=0.03%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0%.

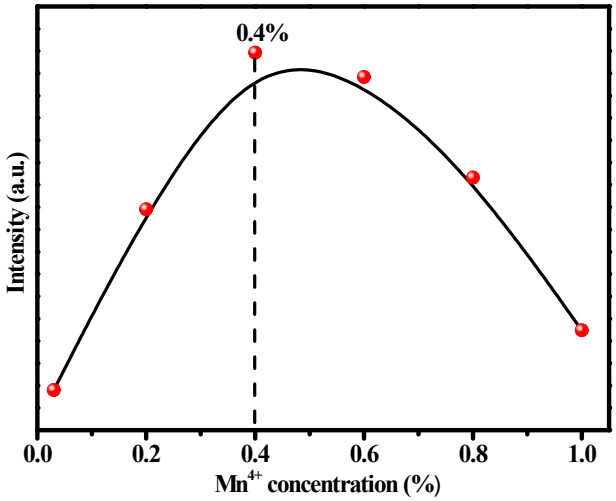

Fig. S2 Concentration-dependent intensity curve.

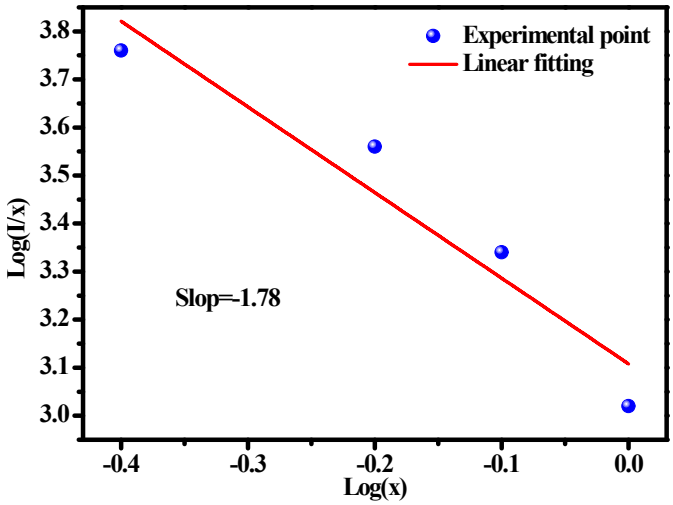

Fig. S3 Fitting curve of interaction type between Mn^{4+} ions.

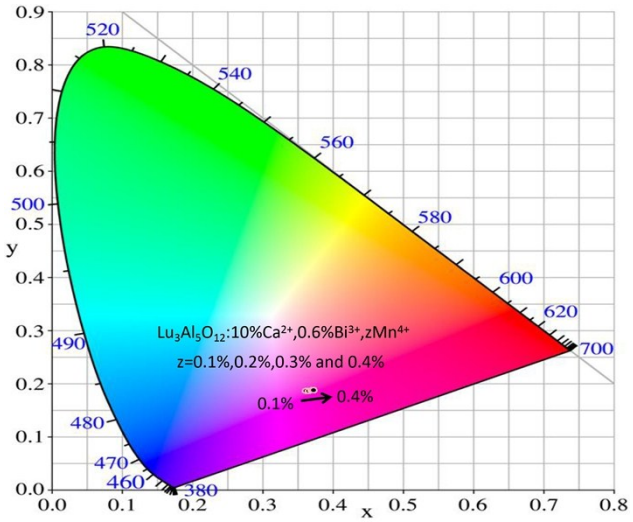

Fig. S4 The changing trend of blue-violet and deep red light in CIE diagram for co-doped samples with different ratios of Bi^{3+} and Mn^{4+}.

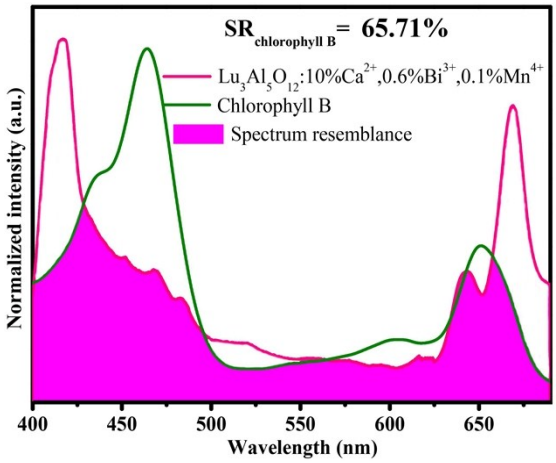

Fig. S5 The diagram of spectrum resemblance between $Lu_3Al_5O_{12}$:10%Ca^{2+},0.6%Bi^{3+},0.1%Mn^{4+} and chlorophyll B