Beyond Single-Ion Doping: K^+-Bi^{3+} Synergy Enables Crop-Tailored Blue Luminescence through Crystal Field Engineering

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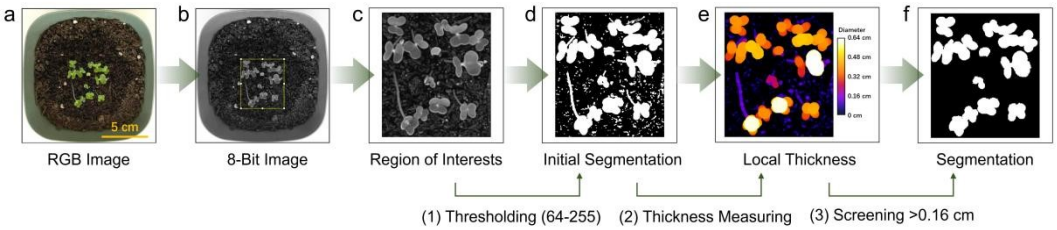

Fig. S1 The process of calculating leaf area using image segmentation methods.

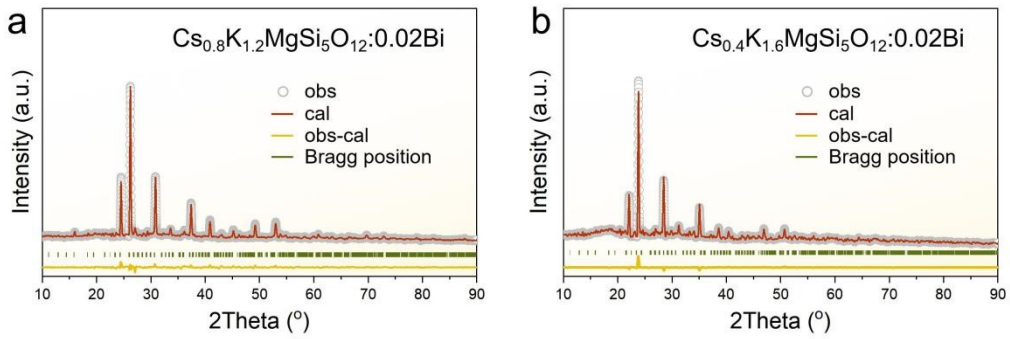

Fig. S2 Rietveld refinement results of $Cs_{0.8}K_{1.2}MgSi_5O_{12}$:0.02$Bi^{3+}$ (a) and $Cs_{0.4}K_{1.6}MgSi_5O_{12}$:0.02$Bi^{3+}$ (b).

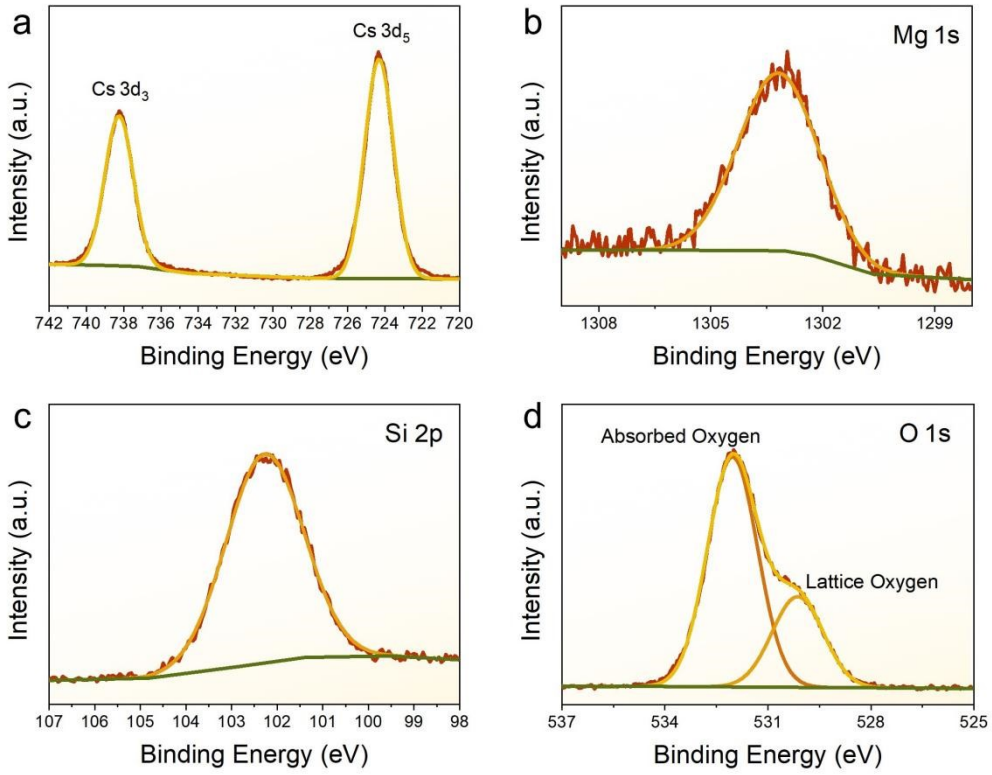

Fig. S3 The high-resolution XPS spectra of the Cs 3d core levels ($3d_3$ and $3d_5$) (a), Mg 1s core levels (b), Si 2p core levels (c), and O 1s core levels (d) in $Cs_2MgSi_5O_{12}$:0.02Bi^{3+}.

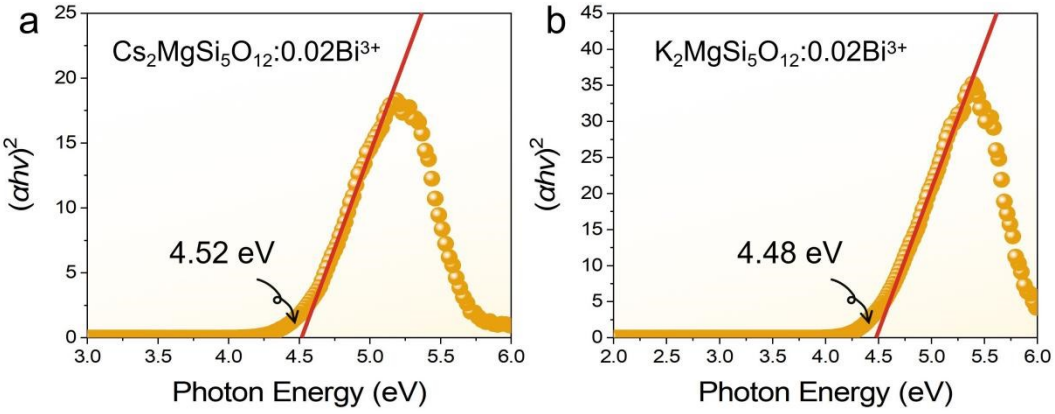

Fig. S4 Relationship curve between the absorption coefficient and photon energy for $Cs_2MgSi_5O_{12}$:0.02Bi^{3+} (a) and $K_2MgSi_5O_{12}$:0.02Bi^{3+} (b).

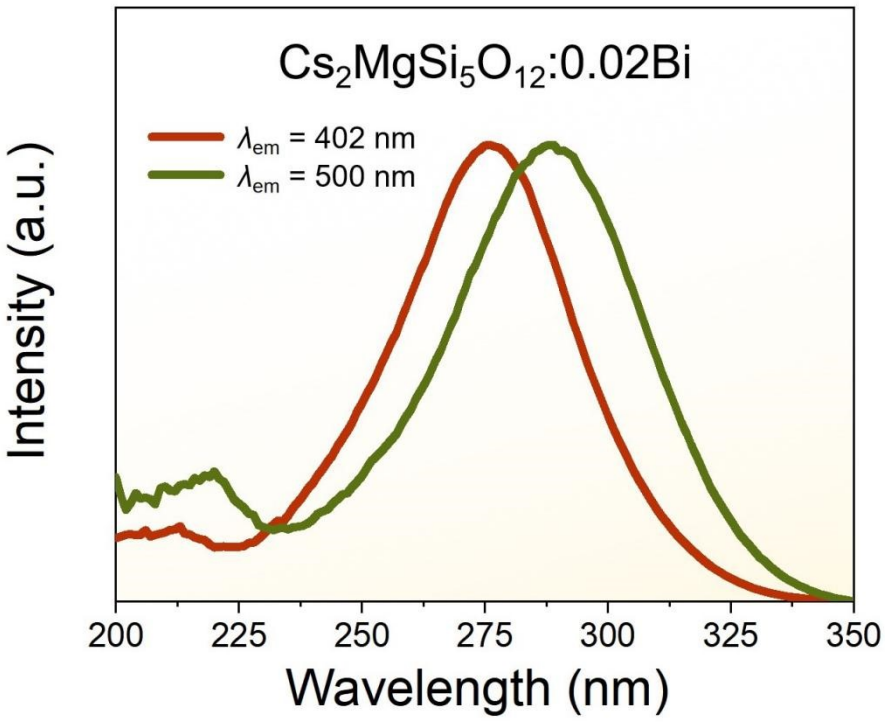

Fig. S5 The PLE spectrum of $Cs_2MgSi_5O_{12}$:0.02Bi^{3+}.

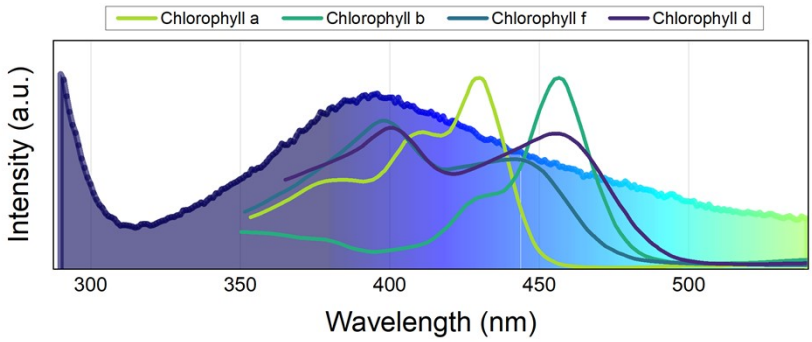

Fig. S6 EL spectrum of packaged LEDs, and absorption spectra of chlorophylls a, b, d, f.

Fig. S7 Top-view images of both groups at 5, 7, 10, and 14 days post-planting.

Table S1 The space group, lattice parameters and refinement parameters for $Cs_{1.6}K_{0.4}MgSi_5O_{12}$:0.02$Bi^{3+}$, $Cs_{1.2}K_{0.8}MgSi_5O_{12}$:0.02$Bi^{3+}$, $Cs_{1.8}K_{1.2}MgSi_5O_{12}$:0.02$Bi^{3+}$, and $Cs_{0.4}K_{1.6}MgSi_5O_{12}$:0.02$Bi^{3+}$.

Chemical formula	$Cs_{1.6}K_{0.4}MgSi_5O_{12}$: 0.02Bi	$Cs_{1.2}K_{0.8}MgSi_5O_{12}$: 0.02Bi	$Cs_{1.8}K_{1.2}MgSi_5O_{12}$: 0.02Bi	$Cs_{0.4}K_{1.6}MgSi_5O_{12}$: 0.02Bi
Space Group	*Pbca*	*Pbca*	*Pbca*	*Pbca*
a (Å)	13.6373	13.6112	13.5934	13.5732
b (Å)	13.6636	13.6332	13.6034	13.5832
c (Å)	13.7278	13.7023	13.6925	13.6725
V (Å^3)	2557.9643	2542.6565	2531.9686	2520.7645
R_p	6.35%	6.67%	6.28%	5.54%
R_{wp}	7.93%	8.54%	8.78%	8.28%
R_{exp}	6.74%	7.05%	6.64%	6.01%
χ^2	1.382	1.464	1.747	1.895

Table S2 The CIE coordinates under different K^+ ion concentration doping.

Concentration (*y*)	CIE X	CIE Y
0	0.1538	0.0538
0.1	0.1552	0.0478
0.2	0.1555	0.0454
0.3	0.1560	0.0435
0.4	0.1564	0.0421
0.5	0.1556	0.0453
0.6	0.1552	0.0469
0.7	0.1553	0.0459
0.8	0.1544	0.0504
0.9	0.1539	0.0524
1.0	0.1531	0.0595

Table S3 Comparison of ΔE values for phosphors with different Bi^{3+} doping concentrations.

Materials	ΔE (eV)	$I_{(423K)}/I_{(273K)}$	Ref.
$Ca_{12}Al_{44}O_{33}$-$Ca_3Al_2O_6$:0.02Bi^{3+}	0.136 eV	3.26%	1
$Ca_4Sn_{0.5}Zr_{0.5}Ge_3O_{12}$:$Bi^{3+}$	0.274 eV	24.3%	2
$Ca_4SnGe_3O_{12}$:Bi^{3+}	0.262 eV	10.6%	2
$Ba_3Ga_2O_5Cl_2$:0.015Bi3+	/	17.3%	3
$CaLaMgSb_{0.5}Ta_{0.5}O_6$:0.01$Bi^{3+}$	0.274 eV	22.4%	4
$CaLaMgTaO_6$:0.01Bi^{3+}	0.266 eV	20.9%	4
$CaLaMgSb_{0.25}Ta_{0.75}O_6$:0.01$Bi^{3+}$	0.265 eV	25.2%	4
$Cs_{1.2}K_{0.8}MgSi_5O_{12}$:0.02$Bi^{3+}$	0.277 eV	35.4%	This work

References

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