

Supporting Information

Towards Promoting Plant Growth and Fruit Maturation: Highly Efficient and Thermally Stable Cr³⁺ Doped Far-Red Phosphor

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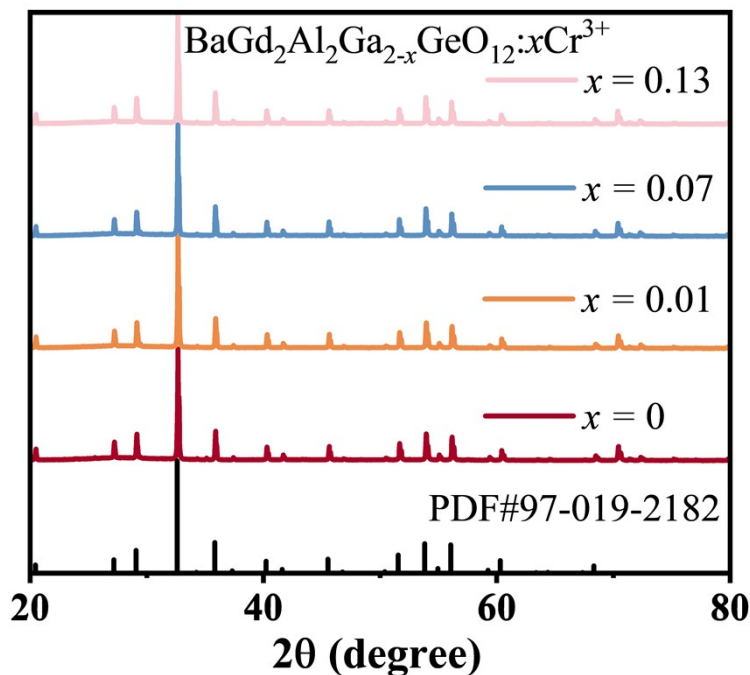


Fig. S1 XRD patterns of the BaGd₂Al₂Ga_{2-x}GeO₁₂:xCr³⁺ (x = 0.01, 0.07, 0.13).

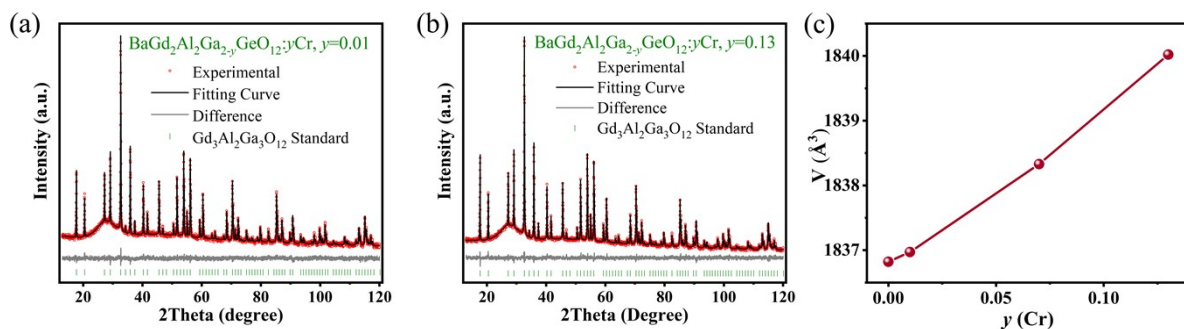


Fig. S2 Difference Rietveld plot of $\text{BaGd}_2\text{Al}_2\text{Ga}_{2-x}\text{GeO}_{12}:x\text{Cr}^{3+}$ (a) $x = 0.01$, (b) $x = 0.13$; (c) Volume V with the increase of the Cr^{3+} concentration.

Table S1 Crystallographic data of $\text{BaGd}_2\text{Al}_2\text{Ga}_{2-x}\text{GeO}_{12}:x\text{Cr}^{3+}$ with different x values.

Formula	$y = 0$	$y = 0.01$	$y = 0.07$	$y = 0.13$
Space Group	Ia-3d			
Cell parameters $a/b/c$ (Å)	12.2468(12)	12.2471(16)	12.2502(14)	12.2539(15)
Cell Volume V (Å ³)	1836.82(6)	1836.97(7)	1838.33(6)	1840.02(7)
2θ -interval, °	5-120			
R_{wp} , %	6.5	7.06	6.61	6.68
R_{p} , %	5.08	5.54	5.14	5.19
χ^2	2.4	2.55	2.35	1.93
R_{B} , %	1.18	1.21	1.26	1.23

Table S2 Fractional atomic coordinates and isotropic displacement parameters (\AA^2) of $\text{BaGd}_2\text{Al}_2\text{Ga}_{2-x}\text{GeO}_{12}:x\text{Cr}^{3+}$ ($0 \leq x \leq 0.13$).

Atom	x	y	z	B_{iso}	$Occ.$
$\text{BaGd}_2\text{Al}_2\text{Ga}_2\text{GeO}_{12}$					
Ba	0.25	0.125	0	1.54(7)	0.33333
Gd	0.25	0.125	0	1.54(7)	0.66667
Ge1	0	0	0	2.79(11)	0.5
Ga1	0	0	0	2.79(11)	0.001(10)
Al1	0	0	0	2.79(11)	0.500(10)
Ga2	0.25	0.375	0	1.00(9)	0.576(8)
Al2	0.25	0.375	0	1.00(9)	0.424(8)
O1	0.0326(4)	0.0491(4)	0.6503(4)	1.21(15)	1
$\text{BaGd}_2\text{Al}_2\text{Ga}_{1.99}\text{GeO}_{12}:0.01\text{Cr}^{3+}$					
Ba	0.25	0.125	0	1.26(7)	0.3333333
Gd	0.25	0.125	0	1.26(7)	0.6666667
Ge1	0	0	0	2.64(12)	0.5
Ga1	0	0	0	2.64(12)	0.001(11)
Al1	0	0	0	2.64(12)	0.500(11)
Ga2	0.25	0.375	0	1.00(9)	0.595(9)
Al2	0.25	0.375	0	1.00(9)	0.405(9)
O	0.0340(5)	0.0475(5)	0.6493(4)	1.26(16)	1
$\text{BaGd}_2\text{Al}_2\text{Ga}_{1.93}\text{GeO}_{12}:0.07\text{Cr}^{3+}$					
Ba	0.25	0.125	0	1.45(7)	0.3333333
Gd	0.25	0.125	0	1.45(7)	0.6666667
Ge1	0	0	0	2.66(11)	0.5
Ga1	0	0	0	2.66(11)	0.001(10)
Al1	0	0	0	2.66(11)	0.500(10)
Ga2	0.25	0.375	0	1.00(9)	0.560(8)
Al2	0.25	0.375	0	1.00(9)	0.440(8)
O	0.0322(4)	0.0480(5)	0.6512(4)	1.14(15)	1
$\text{BaGd}_2\text{Al}_2\text{Ga}_{1.87}\text{GeO}_{12}:0.013\text{Cr}^{3+}$					
Ba	0.25	0.125	0	1.51(7)	0.3333333
Gd	0.25	0.125	0	1.51(7)	0.6666667
Ge1	0	0	0	2.49(11)	0.5
Ga1	0	0	0	2.49(11)	0.001(10)
Al1	0	0	0	2.49(11)	0.500(10)
Ga2	0.25	0.375	0	1.00(9)	0.561(8)

Atom	<i>x</i>	<i>y</i>	<i>z</i>	<i>B</i> _{iso}	<i>Occ.</i>
Al2	0.25	0.375	0	1.00(9)	0.439(8)
O	0.0332(5)	0.0491(5)	0.6506(4)	1.44(15)	1

Table S3 Main bond lengths (Å) of BaGd₂Al₂Ga_{2-x}GeO₁₂:xCr³⁺.

BaGd ₂ Al ₂ Ga _{2-x} GeO ₁₂ :xCr ³⁺			
$x = 0$			
Ba—O ⁱ	2.5117(48)	Ba—O ⁱⁱ	2.3617(48)
Y—O ⁱ	2.5117(48)	Y—O ⁱⁱ	2.3617(48)
Ge1—O ⁱⁱⁱ	1.9771(48)	Ga1—O ⁱⁱⁱ	1.9771(48)
Al1—O ⁱⁱⁱ	1.9771(48)	Ga2—O ^{iv}	1.7700(48)
Ga2—O ^v	3.3676(48)	Al2—O ^{iv}	1.7700(48)
$x = 0.01$			
Ba—O ⁱ	2.5323(49)	Ba—O ⁱⁱ	2.3772(60)
Y—O ⁱ	2.5323(49)	Y—O ⁱⁱ	2.3772(60)
Ge1—O ⁱⁱⁱ	1.9634(50)	Ga1—O ⁱⁱⁱ	1.9634(50)
Al1—O ⁱⁱⁱ	1.9634(50)	Ga2—O ^{iv}	1.7611(60)
Ga2—O ^v	3.3529(53)	Al2—O ^{iv}	1.7611(60)
$x = 0.07$			
Ba—O ⁱ	2.5262(49)	Ba—O ⁱⁱ	2.3492(57)
Y—O ⁱ	2.5262(49)	Y—O ⁱⁱ	2.3492(57)
Ge1—O ⁱⁱⁱ	1.9829(50)	Ga1—O ⁱⁱⁱ	1.9829(50)
Al1—O ⁱⁱⁱ	1.9829(50)	Ga2—O ^{iv}	1.7615(54)
Ga2—O ^v	3.3821(50)	Al2—O ^{iv}	1.7615(54)
$x = 0.13$			
Ba—O ⁱ	2.5148(49)	Ba—O ⁱⁱ	2.3672(60)
Y—O ⁱ	2.5148(49)	Y—O ⁱⁱ	2.3672(60)
Ge1—O ⁱⁱⁱ	1.9832(50)	Ga1—O ⁱⁱⁱ	1.9832(50)
Al1—O ⁱⁱⁱ	1.9832(50)	Ga2—O ^{iv}	1.7638(59)
Ga2—O ^v	3.3657(53)	Al2—O ^{iv}	1.7638(59)

Symmetry codes: Symmetry codes: (i) -x+1/4, -z-3/4, y+1/4; (ii) -z+1, -x, -y; (iii) -x, y, z+1/2; (iv) z+1/2, -x+1/2, -y; (v) z+1/4, y+1/4, -x+1/4

Table S4 Detailed measured data of the FR pc-LED output power and efficiency under different current drive.

Current (mA)	Voltage (V)	Input electrical power (mW)	FR output power (mW)	photoelectric efficiency
50	2.76	138	19.46	14.10%
100	2.87	287	36.78	12.82%
150	2.96	444	51.61	11.62%
200	3.04	608	66.25	10.90%
250	3.10	775	77.33	9.98%
300	3.15	945	89.96	9.52%
350	3.19	1117	98.67	8.84%
400	3.26	1304	107.36	8.23%