Modulation of Bi^{3+} luminescence from broadband green to broadband deep red in Lu_2WO_6 by Gd^{3+} doping and its applications in high color rendering index white LED and near-infrared LED

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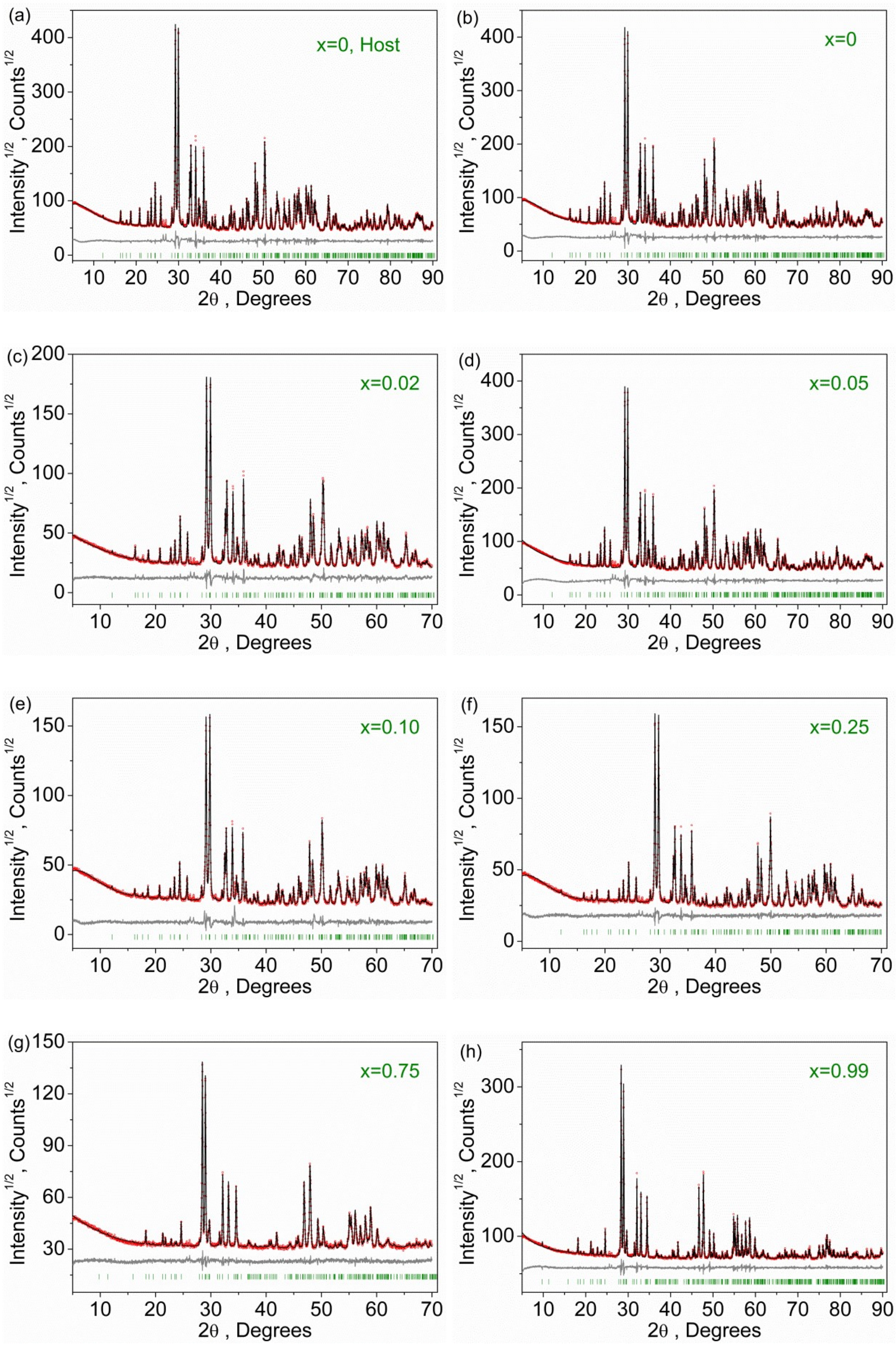

Fig. S1 Difference Rietveld plot for Lu_2WO_6 (a) and $(Lu_{0.99\text{-}x}Gd_xBi_{0.01})_2WO_6$, where x = 0 (b), x = 0.02 (c), x = 0.05 (d), x = 0.10 (e), x = 0.25 (f), x = 0.75 (g) and x = 0.99 (h)

Table S1. Main parameters of processing and refinement of the Lu_2WO_6 and $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$ samples.

x	Space Group	Cell parameters (Å), Cell volume (Å^3)	R_{wp} (%), R_p (%), R_B (%), χ^2
Pure Lu_2WO_6	*P*2/*c*	*a* = 7.52262(10), *b* = 5.26905(8), *c* = 11.22463(16), *β* = 104.6413(7), *V* = 430.463(11)	5.61, 4.04, 1.1, 4.05
x=0	*P*2/*c*	*a* = 7.52432(8), *b* = 5.27010(6), *c* = 11.22511(12), *β* = 104.6428(6), *V* = 430.663(8)	5.36, 3.96, 0.97, 3.78
x=0.02	*P*2/*c*	*a* = 7.52747(14), *b* = 5.27346(11), *c* = 11.2307(2), *β* = 104.6381(11), *V* = 431.341(14)	6.8, 5.19, 2.28, 2.4
x=0.05	*P*2/*c*	*a* = 7.53287(10), *b* = 5.27787(8), *c* = 11.24076(15), *β* = 104.6241(8), *V* = 432.426(10)	5.92, 4.51, 1.09, 4.17

x=0.10	$P2/c$	a = 7.54138(16), b = 5.28624(12), c = 11.2588(3), β = 104.5927(13), V = 434.359(17)	6.57, 4.61, 0.0, 2.18
x=0.25	$P2/c$	a = 7.56643(11), b = 5.30847(9), c = 11.30437(17), β = 104.5274(9), V = 439.536(12)	4.78, 3.76, 0.0, 1.64
x=0.75	$C2/c$	a = 16.3383(4), b = 11.1340(3), c = 5.39850(14), β = 107.7554(11), V = 935.26(4)	4.04, 3.21, 0.66, 1.5
x=0.99	$C2/c$	a = 16.39881(15), b = 11.17398(10), c = 5.43037(5), β = 107.6698(5), V = 948.116(15)	3.12, 2.25, 0.81, 2.52

Table S2. Fractional atomic coordinates (x, y, z), isotropic displacement parameter B_{iso} (Å^2) and atomic occupancy *Occ.* of Lu_2WO_6 and $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$

Atom	x	y	z	B_{iso}	*Occ.*
		Pure Lu_2WO_6			

Lu1	0	0.7372(5)	0.25	0.63(14)	1
Lu2	0.5	0.6840(5)	0.25	0.55(14)	1
Lu3	0.2016(2)	0.1874(4)	0.07864(15)	0.58(14)	1
W1	0.2802(2)	0.2549(4)	0.38720(14)	0.80(14)	1
O1	0.356(3)	0.135(4)	0.5525(19)	1.1(2)	1
O2	0.507(3)	0.374(3)	0.3862(17)	1.1(2)	1
O3	0.151(3)	0.525(4)	0.442(2)	1.1(2)	1
O4	0.276(3)	-0.014(3)	0.2665(18)	1.1(2)	1
O5	0.070(3)	0.034(4)	0.3981(17)	1.1(2)	1
O6	0.197(3)	0.467(3)	0.2220(18)	1.1(2)	1
			$x = 0$		
Lu1	0	0.7378(5)	0.25	0.50(12)	1
Lu2	0.5	0.6841(5)	0.25	0.52(13)	1
Lu3	0.2016(2)	0.1871(3)	0.07876(14)	0.46(12)	1
W1	0.2799(2)	0.2549(4)	0.38712(13)	0.70(12)	1
O1	0.360(2)	0.134(3)	0.5535(19)	1.1(2)	1
O2	0.513(2)	0.366(3)	0.3830(16)	1.1(2)	1
O3	0.156(3)	0.525(4)	0.438(2)	1.1(2)	1
O4	0.275(3)	-0.013(3)	0.2675(17)	1.1(2)	1
O5	0.063(3)	0.040(4)	0.3946(17)	1.1(2)	1
O6	0.198(3)	0.464(3)	0.2232(17)	1.1(2)	1
			x=0.02		
Lu1	0	0.7304(9)	0.25	3.2(3)	0.77(8)
Gd1	0	0.7304(9)	0.25	3.2(3)	0.23(8)

Lu2	0.5	0.6840(9)	0.25	3.4(3)	0.93(9)
Gd2	0.5	0.6840(9)	0.25	3.4(3)	0.07(9)
Lu3	0.2031(3)	0.1892(8)	0.0775(2)	4.2(3)	1.00(10)
W1	0.2819(3)	0.2577(7)	0.3876(2)	3.8(3)	1
O1	0.300(4)	0.108(7)	0.559(3)	4.3(4)	1
O2	0.509(4)	0.372(5)	0.386(2)	4.3(4)	1
O3	0.141(4)	0.582(6)	0.426(3)	4.3(4)	1
O4	0.268(5)	-0.015(4)	0.262(2)	4.3(4)	1
O5	0.102(5)	0.051(6)	0.398(3)	4.3(4)	1
O6	0.257(5)	0.422(5)	0.231(3)	4.3(4)	1
x=0.05					
Lu1	0	0.7375(6)	0.25	0.77(17)	0.98(7)
Gd1	0	0.7375(6)	0.25	0.77(17)	0.02(7)
Lu2	0.5	0.6844(6)	0.25	1.1(2)	1.00(5)
Lu3	0.2009(3)	0.1876(4)	0.07863(17)	0.63(16)	0.92(6)
Gd3	0.2009(3)	0.1876(4)	0.07863(17)	0.63(16)	0.08(6)
W1	0.2796(2)	0.2548(4)	0.38722(16)	1.00(16)	1
O1	0.353(3)	0.130(4)	0.548(2)	1.6(3)	1
O2	0.508(3)	0.370(4)	0.382(2)	1.6(3)	1
O3	0.155(4)	0.521(5)	0.446(3)	1.6(3)	1
O4	0.269(4)	-0.009(4)	0.264(2)	1.6(3)	1
O5	0.075(3)	0.038(5)	0.403(2)	1.6(3)	1
O6	0.199(4)	0.462(4)	0.226(2)	1.6(3)	1
x=0.10					

Lu1	0	0.7361(11)	0.25	1.2(4)	0.92(11)
Gd1	0	0.7361(11)	0.25	1.2(4)	0.08(11)
Lu2	0.5	0.6852(10)	0.25	0.6(4)	0.68(9)
Gd2	0.5	0.6852(10)	0.25	0.6(4)	0.32(9)
Lu3	0.2016(4)	0.1895(8)	0.0777(3)	1.8(4)	1.00(11)
W1	0.2797(4)	0.2547(7)	0.3867(3)	1.4(4)	1
O1	0.325(5)	0.106(8)	0.529(4)	1.7(5)	1
O2	0.516(5)	0.376(6)	0.392(3)	1.7(5)	1
O3	0.125(5)	0.541(8)	0.434(4)	1.7(5)	1
O4	0.273(7)	-0.030(5)	0.268(3)	1.7(5)	1
O5	0.059(5)	0.031(6)	0.382(3)	1.7(5)	1
O6	0.216(6)	0.465(5)	0.221(3)	1.7(5)	1
			x=0.25		
Lu1	0	0.7353(9)	0.25	1.7(3)	0.92(9)
Gd1	0	0.7353(9)	0.25	1.7(3)	0.08(9)
Lu2	0.5	0.6836(9)	0.25	1.3(3)	0.50(7)
Gd2	0.5	0.6836(9)	0.25	1.3(3)	0.50(7)
Lu3	0.2001(3)	0.1910(6)	0.0779(2)	1.5(3)	0.80(8)
Gd3	0.2001(3)	0.1910(6)	0.0779(2)	1.5(3)	0.20(8)
W1	0.2790(3)	0.2538(6)	0.3873(2)	1.6(3)	1
O1	0.342(4)	0.133(6)	0.548(3)	1.9(4)	1
O2	0.506(4)	0.368(5)	0.382(2)	1.9(4)	1
O3	0.150(4)	0.532(6)	0.435(3)	1.9(4)	1
O4	0.273(5)	-0.016(4)	0.272(3)	1.9(4)	1

O5	0.069(4)	0.046(6)	0.399(3)	1.9(4)	1
O6	0.211(5)	0.457(4)	0.222(3)	1.9(4)	1
			x=0.75		
Lu1	0.5	0.1066(8)	0.75	2.0(6)	0.25(10)
Gd1	0.5	0.1066(8)	0.75	2.0(6)	0.75(10)
Gd2	0	0.1329(7)	0.75	2.0(6)	1.00(9)
Lu3	0.3285(4)	0.1136(5)	0.1144(13)	1.9(4)	0.20(9)
Gd3	0.3285(4)	0.1136(5)	0.1144(13)	1.9(4)	0.80(9)
W1	0.1543(3)	0.1451(4)	0.4346(11)	1.9(3)	1
O1	0.246(3)	0.045(5)	0.388(10)	0.6(5)	1
O2	0.066(3)	0.039(3)	0.463(10)	0.6(5)	1
O3	0.227(3)	0.201(4)	0.738(9)	0.6(5)	1
O4	0.100(3)	0.218(4)	0.120(13)	0.6(5)	1
O5	0.094(4)	0.259(3)	0.598(13)	0.6(5)	1
O6	0.604(3)	0.012(3)	0.570(9)	0.6(5)	1
			x=0.99		
Lu1	0.5	0.1084(5)	0.75	1.7(3)	0.07(7)
Gd1	0.5	0.1084(5)	0.75	1.7(3)	0.93(7)
Lu2	0	0.1328(4)	0.75	1.4(3)	0.01(5)
Gd2	0	0.1328(4)	0.75	1.4(3)	0.99(5)
Gd3	0.3275(3)	0.1150(4)	0.1135(9)	1.49(19)	1.00(5)
W1	0.1535(2)	0.1467(3)	0.4367(8)	1.66(17)	1
O1	0.236(2)	0.046(3)	0.402(8)	2.6(3)	1
O2	0.087(2)	0.039(3)	0.472(7)	2.6(3)	1

O3	0.234(2)	0.216(3)	0.730(7)	2.6(3)	1
O4	0.113(2)	0.212(3)	0.167(8)	2.6(3)	1
O5	0.084(3)	0.264(2)	0.598(10)	2.6(3)	1
O6	0.598(2)	0.013(2)	0.604(10)	2.6(3)	1

Table S3. Main bond lengths (Å) of Lu_2WO_6 and $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$

Pure Lu_2WO_6			
Lu1—O3	2.438(21)	Lu1—O4^{i}	2.422(17)
Lu1—O5^{i}	2.245(19)	Lu1—O6	2.134(16)
Lu2—O1^{ii}	2.404(20)	Lu2—O2	2.228(17)
Lu2—O4^{i}	2.358(16)	Lu2—O6	2.497(17)
Lu3—O1^{iii}	2.119(19)	Lu3—O2^{iv}	2.343(17)
Lu3—O3^{v}	3.153(18)	Lu3—O3^{ii}	2.120(21)
Lu3—O4	2.299(18)	Lu3—O5^{v}	2.272(18)
Lu3—O5^{iii}	2.330(19)	Lu3—O6	2.188(17)
W1—O1	1.905(20)	W1—O1^{vi}	3.351(18)
W1—O2	1.820(17)	W1—O2^{vii}	3.285(17)
W1—O3	1.910(19)	W1—O4	1.955(17)
W1—O5	1.991(19)	W1—O6	2.119(18)
$x = 0$			
Lu1—O3	2.415(21)	Lu1—O4^{i}	2.416(17)
Lu1—O5^{i}	2.237(19)	Lu1—O6	2.149(17)
Lu2—O1^{ii}	2.391(19)	Lu2—O2	2.230(16)
Lu2—O4^{i}	2.370(16)	Lu2—O6	2.500(17)

Lu3—O1^{iii}	2.129(14)	Lu3—O2^{iv}	2.284(11)
Lu3—O3^{v}	3.192(18)	Lu3—O3^{ii}	2.154(21)
Lu3—O4	2.305(18)	Lu3—O5^{v}	2.226(18)
Lu3—O5^{iii}	2.388(19)	Lu3—O6	2.186(17)
W1—O1	1.920(20)	W1—O1^{vi}	3.327(12)
W1—O2	1.860(11)	W1—O2^{vii}	3.323(16)
W1—O3	1.868(19)	W1—O4	1.942(17)
W1—O5	2.005(18)	W1—O6	2.099(17)
	x = 0.02		
Lu1—O3	2.141(31)	Lu1—O4^{i}	2.398(29)
Lu1—O5^{i}	2.359(32)	Lu1—O6	2.577(28)
Gd1—O3	2.141(31)	Gd1—O4^{i}	2.398(29)
Gd1—O5^{i}	2.359(32)	Gd1—O6	2.577(28)
Lu2—O1^{ii}	2.537(32)	Lu2—O2	2.234(24)
Lu2—O4^{i}	2.388(27)	Lu2—O6	2.259(28)
Gd2—O1^{ii}	2.537(32)	Gd2—O2	2.234(24)
Gd2—O4^{i}	2.388(27)	Gd2—O6	2.259(28)
Lu3—O1^{iii}	1.762(34)	Lu3—O2^{iv}	2.311(24)
Lu3—O3^{v}	3.309(26)	Lu3—O3^{ii}	2.041(32)
Lu3—O4	2.275(21)	Lu3—O5^{v}	2.490(29)
Lu3—O5^{iii}	2.339(32)	Lu3—O6	2.071(30)
W1—O1	2.052(33)	W1—O2	1.817(24)
W1—O2^{vii}	3.276(23)	W1—O3	2.113(29)
W1—O4	1.998(21)	W1—O5	1.765(30)

W1—O6	1.926(31)		
	$x = 0.05$		
Lu1—O3	2.494(30)	Lu1—O4^{i}	2.399(23)
Lu1—O5^{i}	2.302(24)	Lu1—O6	2.153(23)
Gd1—O3	2.494(30)	Gd1—O4^{i}	2.399(23)
Gd1—O5^{i}	2.302(24)	Gd1—O6	2.153(23)
Lu2—O1^{ii}	2.464(21)	Lu2—O2	2.216(21)
Lu2—O4^{i}	2.410(23)	Lu2—O6	2.506(23)
Lu3—O1^{iii}	2.107(19)	Lu3—O2^{iv}	2.332(17)
Lu3—O3^{v}	3.160(23)	Lu3—O3^{ii}	2.108(29)
Lu3—O4	2.267(21)	Lu3—O5^{v}	2.280(18)
Lu3—O5^{iii}	2.295(23)	Lu3—O6	2.203(21)
Gd3—O1^{iii}	2.107(19)	Gd3—O2^{iv}	2.332(17)
Gd3—O3^{v}	3.160(23)	Gd3—O3^{ii}	2.108(29)
Gd3—O4	2.267(21)	Gd3—O5^{v}	2.280(18)
Gd3—O5^{iii}	2.295(23)	Gd3—O6	2.203(21)
W1—O1	1.871(21)	W1—O1^{vi}	3.361(18)
W1—O2	1.839(17)	W1—O2^{vii}	3.333(21)
W1—O3	1.898(25)	W1—O4	1.951(21)
W1—O5	1.963(20)	W1—O6	2.071(21)
	$x = 0.10$		
Lu1—O3	2.293(42)	Lu1—O4^{i}	2.366(40)
Lu1—O5^{i}	2.122(32)	Lu1—O6	2.254(33)
Gd1—O3	2.293(42)	Gd1—O4^{i}	2.366(40)

Gd1—O5^{i}	2.122(32)	Gd1—O6	2.254(33)
Lu2—O1^{ii}	2.737(42)	Lu2—O2	2.268(32)
Lu2—O4^{i}	2.326(37)	Lu2—O6	2.386(34)
Gd2—O1^{ii}	2.737(42)	Gd2—O2	2.268(32)
Gd2—O4^{i}	2.326(37)	Gd2—O6	2.386(34)
Lu3—O1^{iii}	1.965(38)	Lu3—O2^{iv}	2.292(29)
Lu3—O3^{v}	3.061(33)	Lu3—O3^{ii}	2.123(43)
Lu3—O4	2.376(31)	Lu3—O5^{v}	2.284(29)
Lu3—O5^{iii}	2.485(32)	Lu3—O6	2.155(30)
W1—O1	1.739(43)	W1—O1^{vi}	3.463(33)
W1—O2	1.880(29)	W1—O2^{vii}	3.233(32)
W1—O3	2.061(37)	W1—O4	2.004(29)
W1—O5	2.031(30)	W1—O6	2.120(31)
	x = 0.25		
Lu1—O3	2.373(32)	Lu1—O4^{i}	2.411(27)
Lu1—O5^{i}	2.321(32)	Lu1—O6	2.255(26)
Gd1—O3	2.373(32)	Gd1—O4^{i}	2.411(27)
Gd1—O5^{i}	2.321(32)	Gd1—O6	2.255(26)
Lu2—O1^{ii}	2.494(32)	Lu2—O2	2.236(24)
Lu2—O4^{i}	2.401(26)	Lu2—O6	2.445(27)
Gd2—O1^{ii}	2.494(32)	Gd2—O2	2.236(24)
Gd2—O4^{i}	2.401(26)	Gd2—O6	2.445(27)
Lu3—O1^{iii}	2.099(29)	Lu3—O2^{iv}	2.351(24)
Lu3—O3^{v}	3.181(25)	Lu3—O3^{ii}	2.146(32)

Lu3—O4	2.391(30)	Lu3—O5^{v}	2.252(23)
Lu3—O5^{iii}	2.377(32)	Lu3—O6	2.141(28)
Gd3—O1^{iii}	2.099(29)	Gd3—O2^{iv}	2.351(24)
Gd3—O3^{v}	3.181(25)	Gd3—O3^{ii}	2.146(32)
Gd3—O4	2.391(30)	Gd3—O5^{v}	2.252(23)
Gd3—O5^{iii}	2.377(32)	Gd3—O6	2.141(28)
W1—O1	1.871(32)	W1—O1^{vi}	3.452(26)
W1—O2	1.836(24)	W1—O2^{vii}	3.368(24)
W1—O3	1.920(29)	W1—O4	1.929(27)
W1—O5	1.965(25)	W1—O6	2.106(30)
		x = 0.75	
Lu1—O4^{viii}	2.770(40)	Lu1—O5^{viii}	2.523(54)
Lu1—O6	2.438(36)	Lu1—O6^{ix}	2.413(40)
Gd1—O4^{viii}	2.770(40)	Gd1—O5^{viii}	2.523(54)
Gd1—O6	2.438(36)	Gd1—O6^{ix}	2.413(40)
Gd2—O2	2.382(41)	Gd2—O2^{ix}	2.322(38)
Gd2—O4^{x}	2.359(58)	Gd2—O5	2.402(44)
Lu3—O1	2.407(42)	Lu3—O1^{iii}	2.328(51)
Lu3—O3^{xi}	2.402(44)	Lu3—O3^{xii}	2.481(43)
Lu3—O4^{xiii}	2.717(45)	Lu3—O5^{xii}	2.197(52)
Lu3—O6^{iv}	2.038(37)	Lu3—O6^{vi}	2.220(41)
Gd3—O1	2.407(42)	Gd3—O1^{iii}	2.328(51)
Gd3—O3^{xi}	2.402(44)	Gd3—O3^{xii}	2.481(43)
Gd3—O4^{xiii}	2.717(45)	Gd3—O5^{xii}	2.197(52)

Gd3—O6^{iv}	2.038(37)	Gd3—O6^{vi}	2.220(41)
W1—O1	1.944(42)	W1—O1^{ix}	3.237(52)
W1—O2	1.906(33)	W1—O2^{iii}	3.244(44)
W1—O3	1.815(44)	W1—O3^{xii}	2.944(39)
W1—O4	1.846(62)	W1—O5	1.971(45)
	x =0.99		
Lu1—O4^{viii}	2.858(28)	Lu1—O5^{viii}	2.433(42)
Lu1—O6	2.262(24)	Lu1—O6^{ix}	2.498(40)
Gd1—O4^{viii}	2.858(28)	Gd1—O5^{viii}	2.433(42)
Gd1—O6	2.262(24)	Gd1—O6^{ix}	2.498(40)
Lu2—O2	2.592(28)	Lu2—O2^{ix}	2.475(32)
Lu2—O4^{x}	2.607(37)	Lu2—O5	2.327(32)
Gd2—O2	2.592(28)	Gd2—O2^{ix}	2.475(32)
Gd2—O4^{x}	2.607(37)	Gd2—O5	2.327(32)
Gd3—O1	2.593(30)	Gd3—O1^{iii}	2.400(33)
Gd3—O3^{xi}	2.454(34)	Gd3—O3^{xii}	2.413(31)
Gd3—O4^{xiii}	2.812(33)	Gd3—O5^{xii}	2.237(39)
Gd3—O6^{iv}	2.250(30)	Gd3—O6^{vi}	2.180(38)
W1—O1	1.812(26)	W1—O1^{ix}	3.282(37)
W1—O2	1.673(28)	W1—O2^{iii}	3.192(35)
W1—O3	1.898(33)	W1—O3^{xii}	2.755(27)
W1—O4	1.589(39)	W1—O5	2.095(33)

Symmetry codes: (i) x, y+1, z; (ii) x, -y+1, z+1/2; (iii) x, -y, z+1/2; (iv) -x+1, y, -z+1/2; (v) -x, y, -z+1/2; (vi) -x+1, -y, -z+1; (vii) -x+1, -y+1, -z+1; (viii) x, -y, z+1/2; (ix) x, -y, z+1/2; (x) x, y, z+1; (xi) x, y, z-1; (xii) -x, -y, -z+1; (xiii) -x, -y, -z

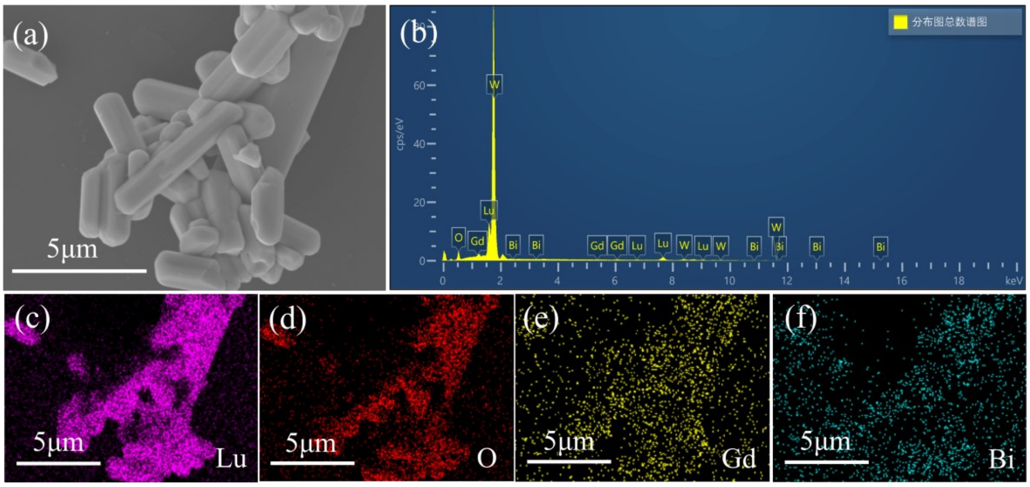

Fig. S2 SEM morphology (a), EDS analysis (b), and the mapping images of Lu, O, Gd, Bi elements for the $(Lu_{0.94}Gd_{0.05}Bi_{0.01})_2WO_6$ sample (c-f).

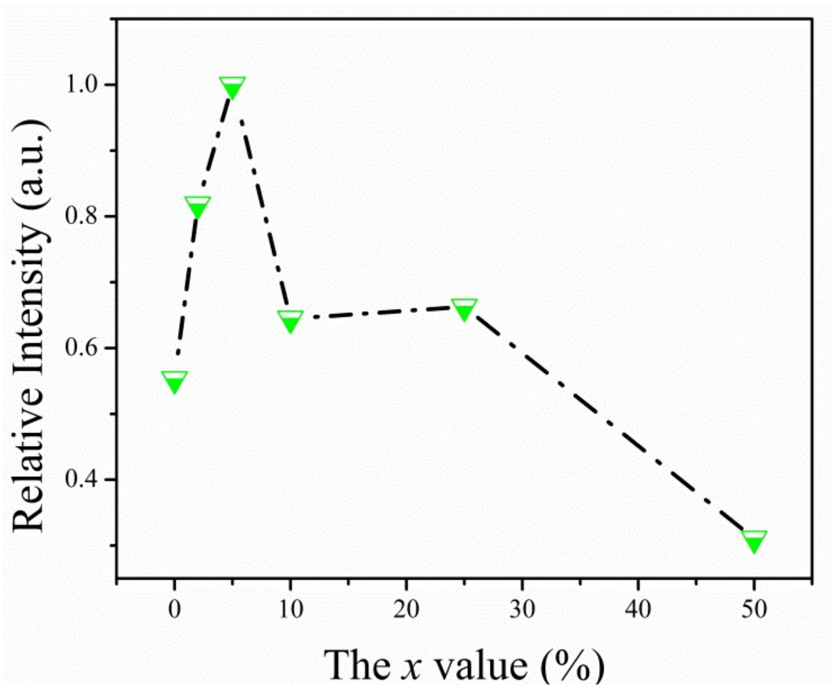

Fig. S3 The relative intensity of the strongest emission as a function of the Gd^{3+} content for $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$ (x = 0-0.50).

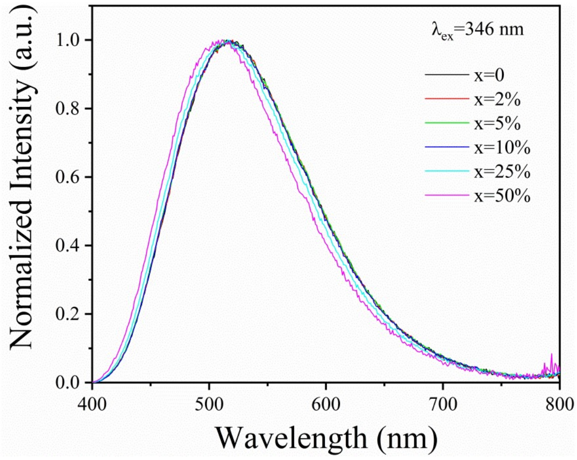

Fig. S4 The normalized PL spectra of $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$ for x=0-0.50.

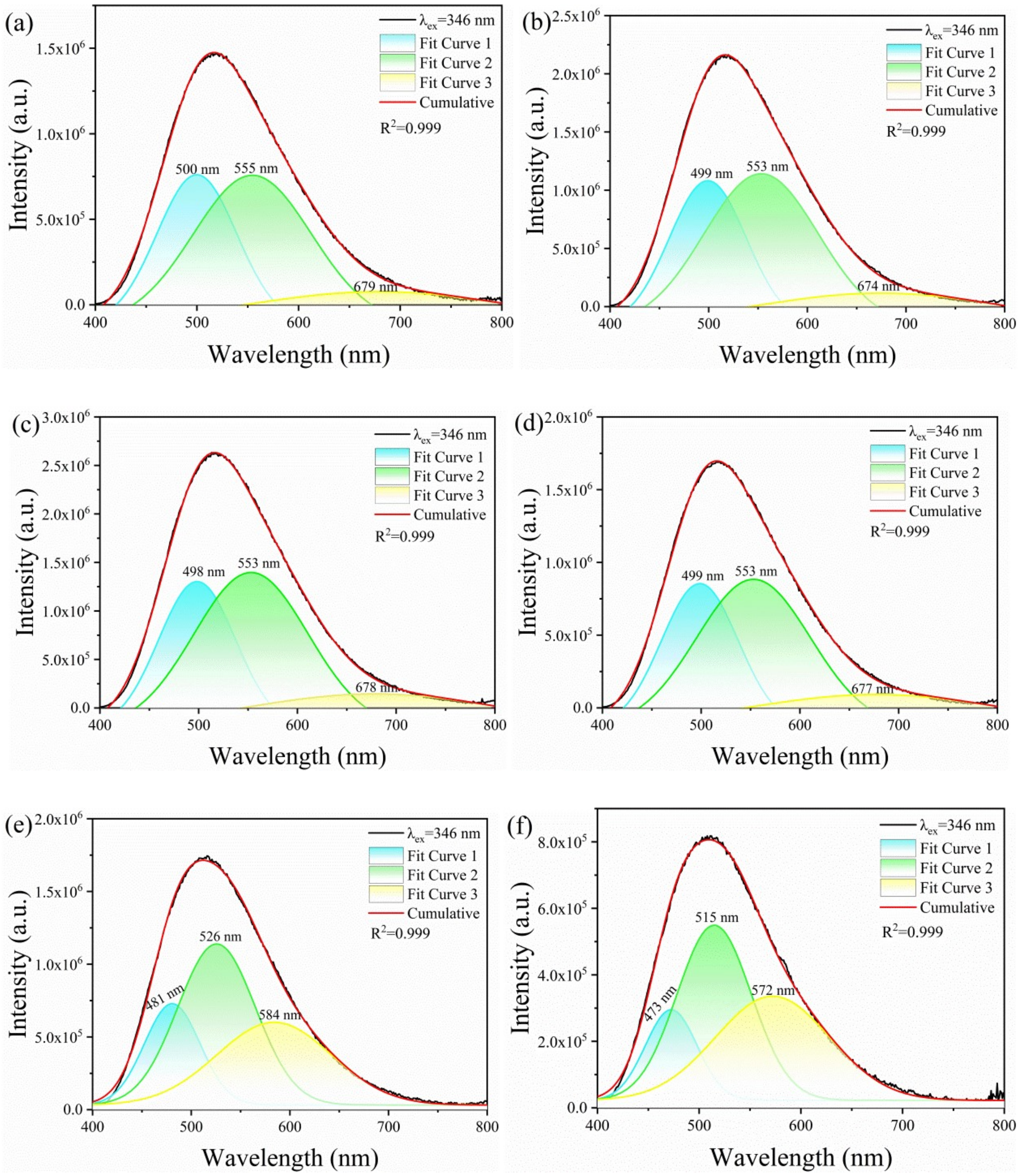

Fig. S5 Gaussian fitting of the emission spectra of $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$, where (a) x=0, (b) x=0.02, (c) x=0.05, (d) x=0.10, (e) x=0.25 and (f) x=0.50.

Table S4. A summary of the Gaussian fitting results for the emission spectra of $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$

x value	Peak 1 (nm)	Peak 2 (nm)	Peak 3 (nm)
x=0	500	555	679
x=0.02	499	553	674
x=0.05	498	553	678
x=0.10	499	553	677
x=0.25	481	526	584
x=0.50	473	515	572

Table S5. A summary of the excitation wavelength, emission wavelength, quantum yield, and FWHM for $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$

x value	Ex (nm)	Em (nm)	Quantum Yield (%)	FWHM (eV)
x=0	347	517	13.97%	0.61
x=0.02	347	520	16.91%	0.62
x=0.05	346	513	18.88%	0.63
x=0.10	347	516	17.18%	0.62
x=0.25	345	516	14.01%	0.61
x=0.50	343	511	6.59%	0.62
x=0.75	335	615	1.57%	0.72
x=0.99	332	609	4.09%	0.70

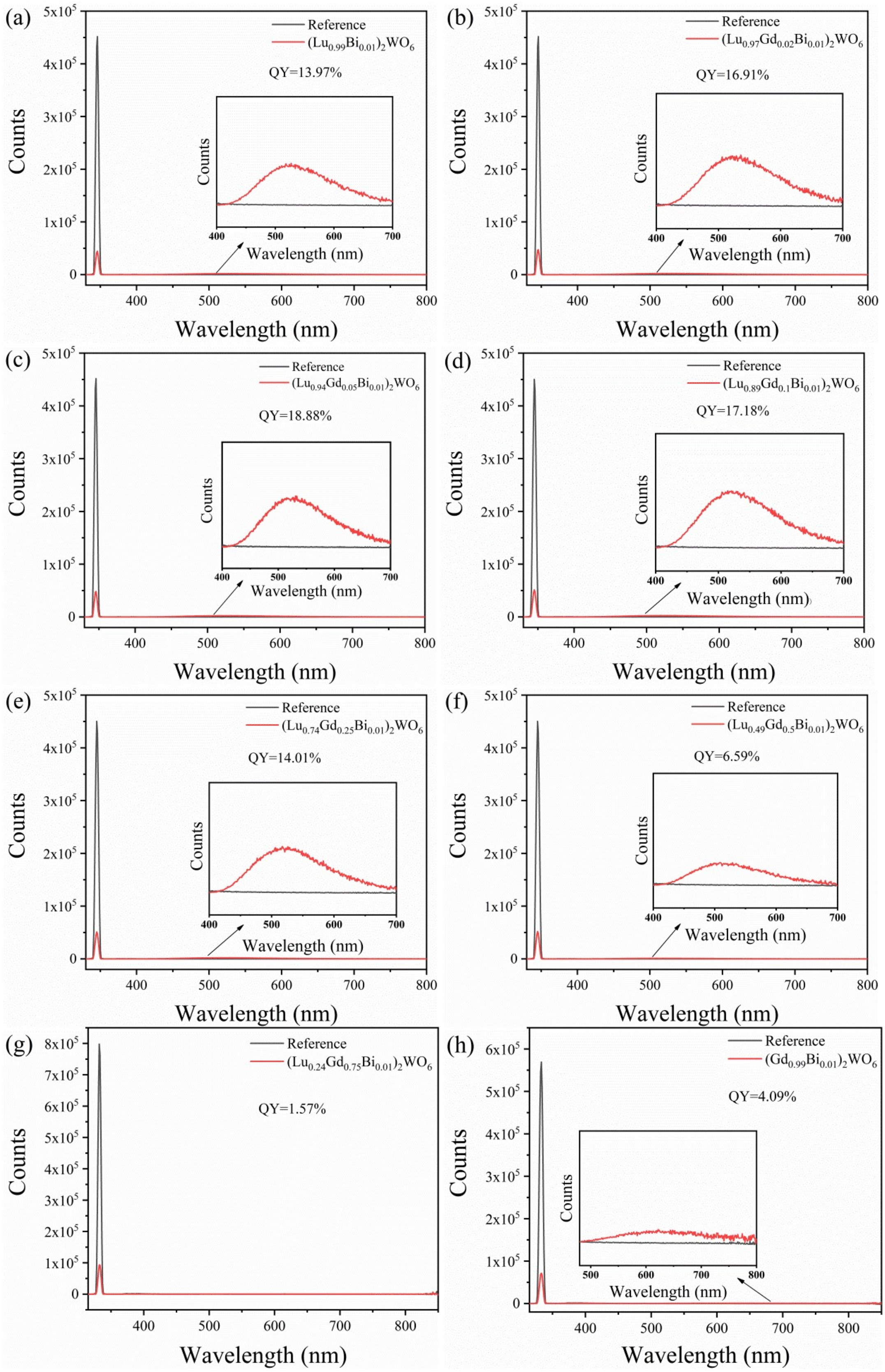

Fig. S6 The results of quantum yield measurement for $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$, with (a) *x*=0; (b) *x*=0.02; (c) *x*=0.05; (d) *x*=0.10; (e) *x*=0.25; (f) *x*=0.50; (g) *x*=0.75; (h) *x*=0.99..

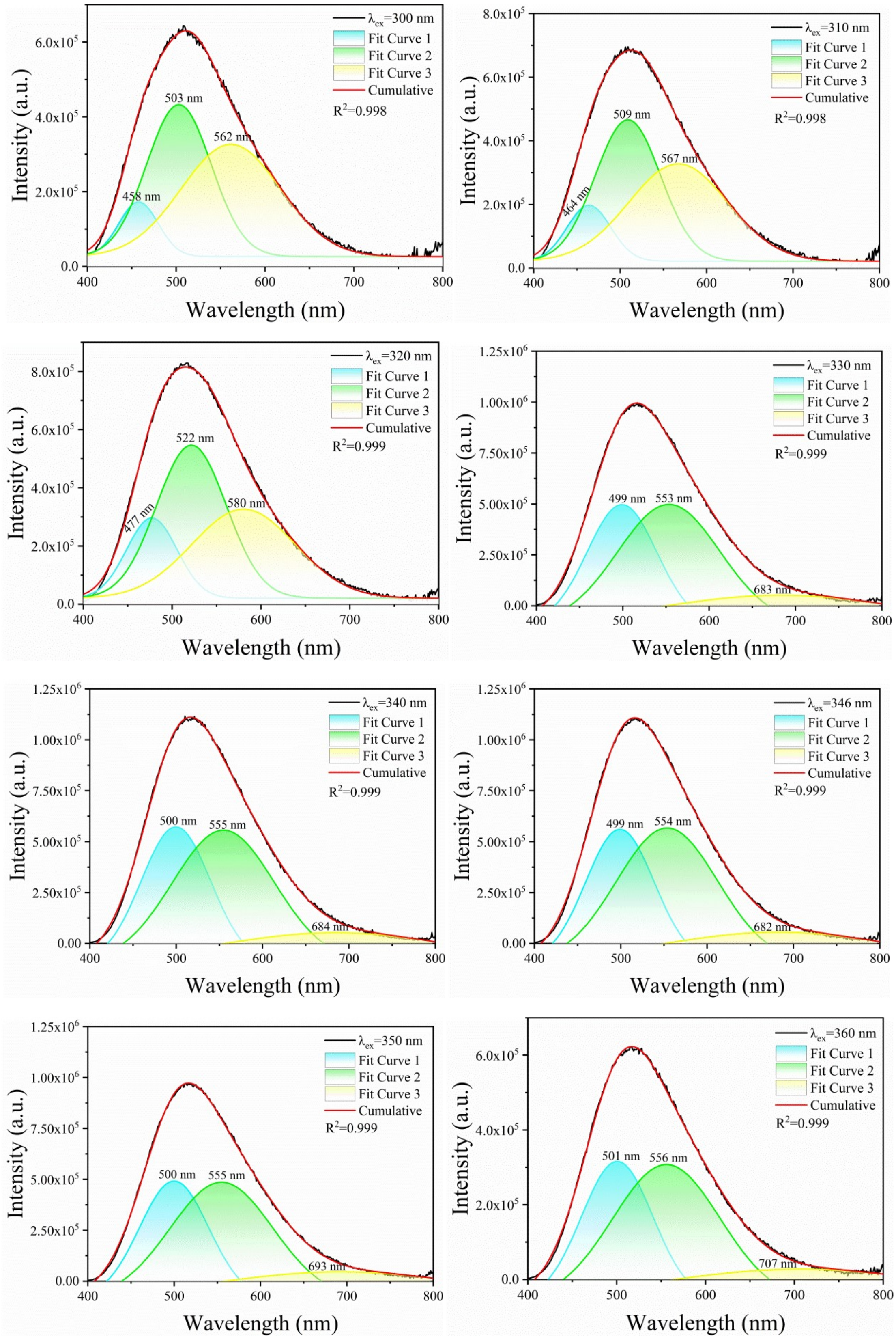

Fig. S7 Gaussian deconvolution of the emission bands of $(Lu_{0.94}Gd_{0.05}Bi_{0.01})_2WO_6$ obtained under the different excitation wavelengths indicated in the figure (300-360 nm).

Table S6. A summary of the peak position for the three sub-peaks of the $(Lu_{0.94}Gd_{0.05}Bi_{0.01})_2WO_6$ phosphor

Ex	Peak 1 (nm)	Peak 2 (nm)	Peak 3 (nm)
300	458	503	562
305	459	504	563
310	464	509	567
315	468	513	570
320	477	522	580
330	499	553	683
335	500	555	689
340	500	555	684
346	499	554	682
350	500	555	693
355	500	554	684
360	501	556	707
365	501	556	720

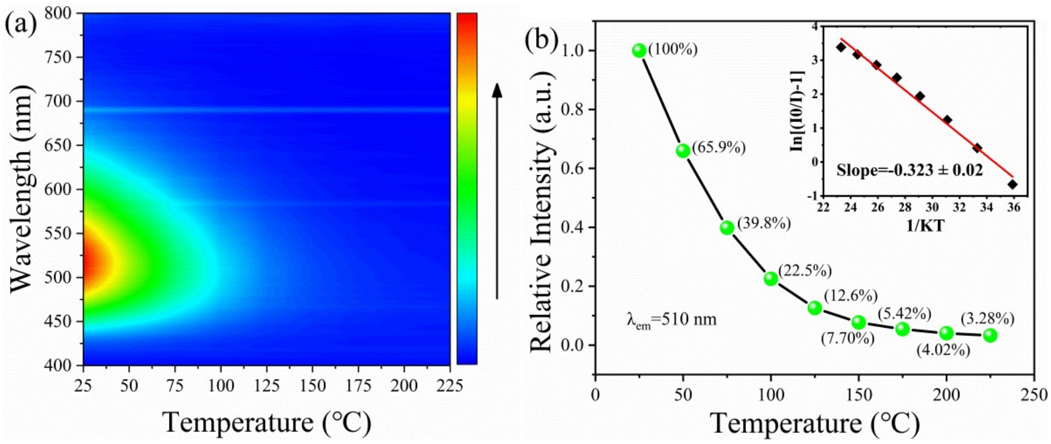

Fig. S8 Temperature-dependent PL spectra of $(Lu_{0.94}Gd_{0.05}Bi_{0.01})_2WO_6$ sample under the excitation of 346 nm UV light (a); the relative intensity of the main emission as function of the measurement temperature (b). The inset in (b) is the In[(I_0/I)-1] *versus* 1/(KT) plot for the determination of activation energy for thermal quenching of luminescence.

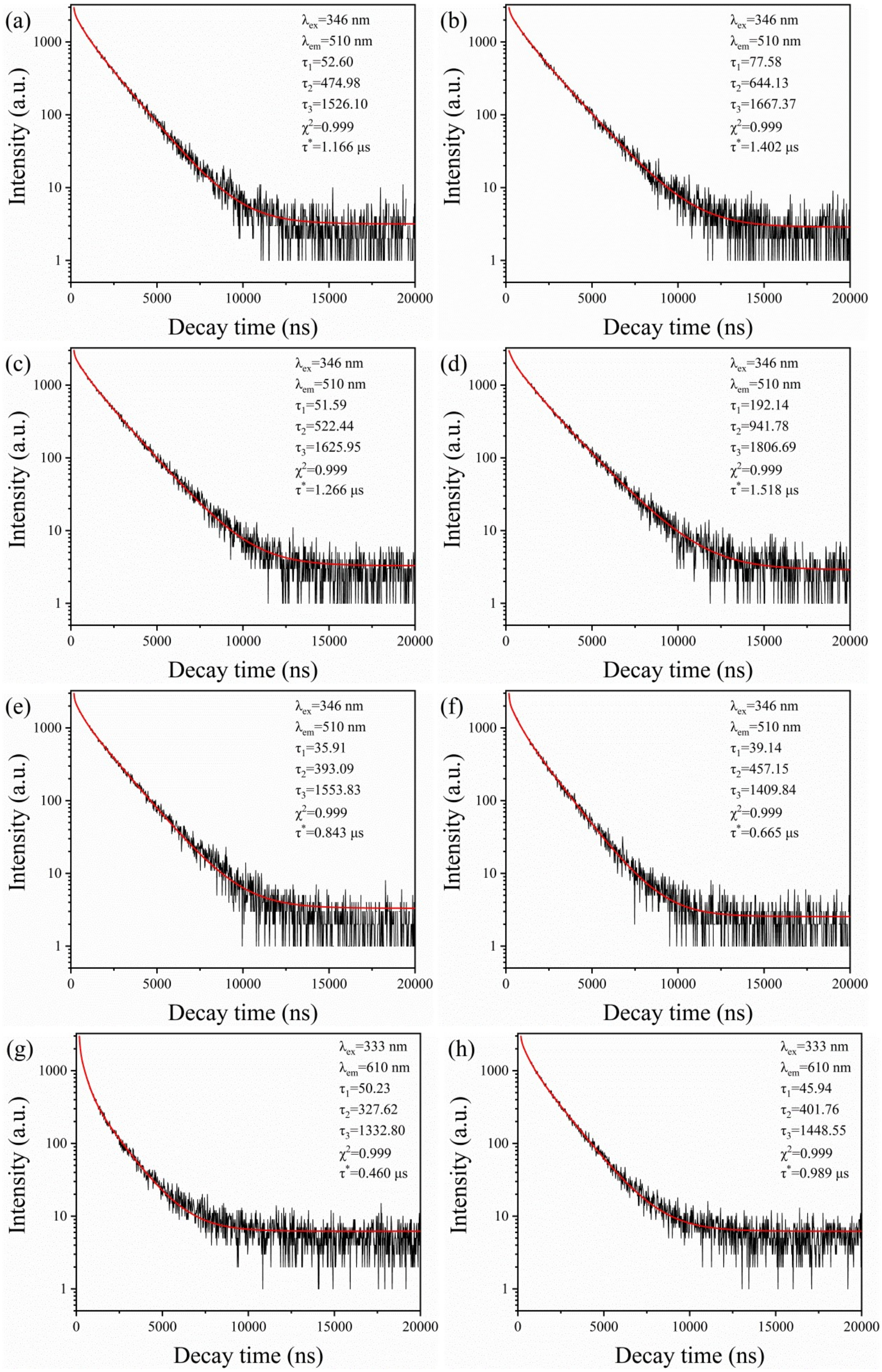

Fig. S9 Decay curves for the main emissions of $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$, with (a) x=0; (b) x=0.02; (c) x=0.05; (d) x=0.10; (e) x=0.25; (f) x=0.50; (g) x=0.75; (h) x=0.99.

Table S7. A summary of the fluorescence decay parameters for $(Lu_{0.99-x}Gd_xBi_{0.01})_2WO_6$

x value	A_1	A_2	A_3	τ_1	τ_2	τ_3	χ^2	τ^*(μs)
x=0	12849.54	1045.50	1990.42	52.60	474.98	1526.10	0.999	1.166
x=0.02	4091.39	958.66	2007.73	77.58	644.13	1667.37	0.999	1.402
x=0.05	13774.78	925.99	2092.18	51.59	522.44	1625.95	0.999	1.266
x=0.10	1409.46	1008.53	1734.12	192.14	941.78	1806.69	0.999	1.518
x=0.25	65043.61	1226.31	1901.12	35.91	393.09	1553.83	0.999	0.843
x=0.50	62742.30	1286.73	1579.15	39.14	457.15	1409.84	0.999	0.665
x=0.75	35108.49	2209.20	705.04	50.23	327.62	1332.80	0.999	0.460
x=0.99	19292.59	1505.46	1787.55	45.94	401.76	1448.55	0.999	0.989

Table S8. The Ra value, CCT and CIE chromaticity coordinates of LED1 under different driving currents.

Current (mA)	CIE (x, y)	CCT (K)	Ra
20	(0.38,0.38)	3951	91.3
30	(0.38,0.38)	3959	89.4
40	(0.38,0.37)	3957	88.5
50	(0.38,0.37)	3948	87.8
60	(0.38,0.37)	3951	87.3
70	(0.38,0.36)	3917	84.9
80	(0.38,0.37)	3935	85.1
90	(0.38,0.36)	3902	82.4
100	(0.38,0.36)	3923	82.8

Table S9. The Ra value, CCT and CIE chromaticity coordinates of LED2 under different driving currents.

Current (mA)	CIE (x, y)	CCT (K)	Ra
20	(0.39, 0.39)	3721	83
30	(0.39, 0.38)	3712	86
40	(0.39, 0.37)	3725	87
50	(0.39, 0.36)	3737	89
60	(0.38, 0.36)	3763	91
70	(0.38, 0.35)	3795	92
80	(0.37, 0.35)	3838	91
90	(0.37, 0.34)	3881	93
100	(0.37, 0.34)	3904	94