Support Information

Multiple energy transfer in luminescenc-tunable single-phased phosphor $NaGdTiO_4$: Tm^{3+}, Dy^{3+}, Sm^{3+}

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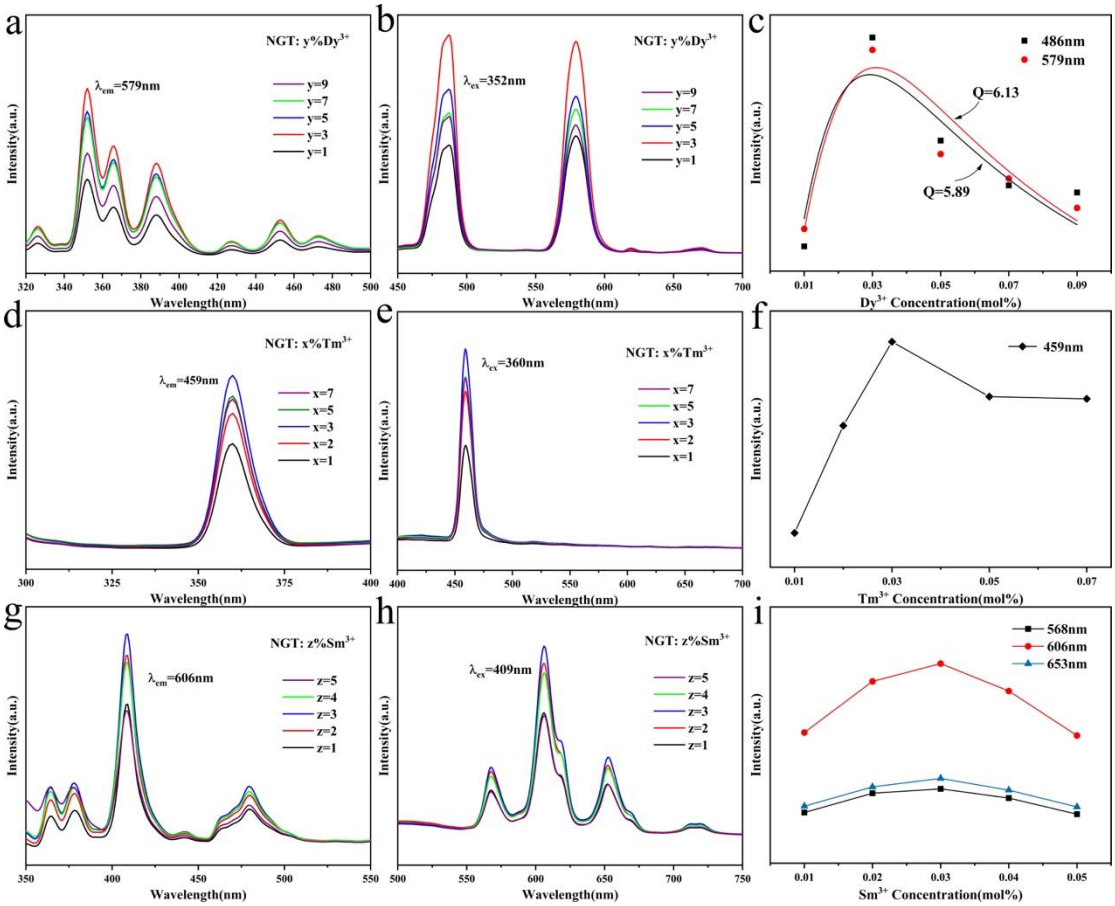

Figure S1. (a, b) The PLE and PL spectra of NGT: y%Dy^{3+}(y = 1, 3, 5, 7, 9) phosphors; (c) the variation of the emission intensity with respect to the concentration of Dy^{3+} ions; (d-e) The PLE and PL spectra of NGT: x%Tm^{3+}(x = 1, 2, 3, 5, 7) phosphors; (f) variation of the emission intensity with respect to the concentration of Tm^{3+} ions; (g-h) PLE and PL spectra of phosphors NGT: z%Sm^{3+} (z = 1, 2, 3, 4, 5); (i) variation of the emission intensity with respect to the concentration of Sm^{3+} ions.

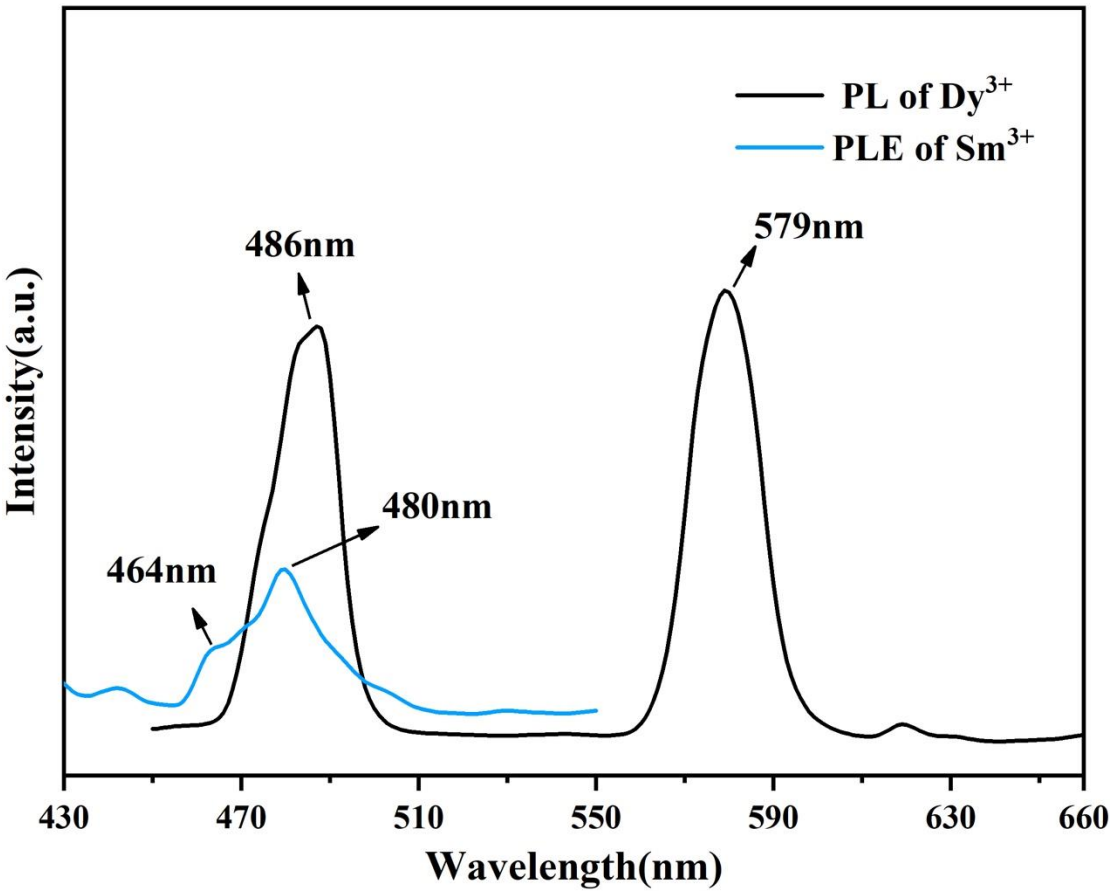

Figure S2. The overlap between PL emission spectrum of NGT: Dy^{3+} phosphor and PL excitation spectra of NGT: Sm^{3+}.

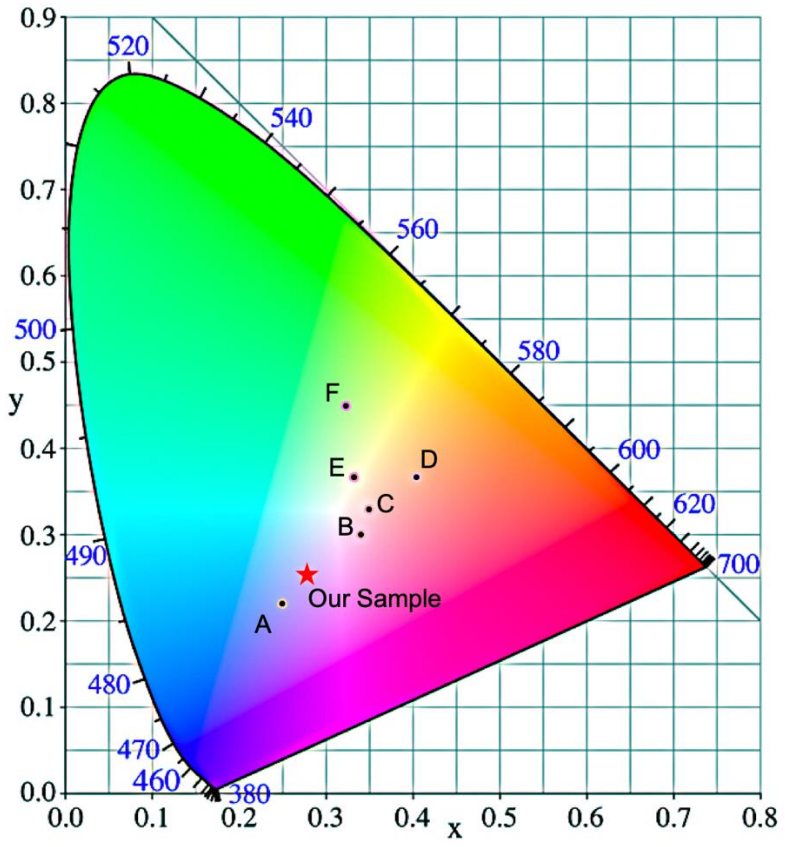

Figure S3. Comparison of the CIE chromaticity diagram of the WLED phosphors in previous literatures.

$$I = \frac{C}{k(1+\beta C^{Q/3})} \quad \text{Eq. S1}$$

In this formula, I represents the luminescence intensity of the as-prepared samples, C is the doping concentration of the activator ions, k and β are constants, and Q represents the interaction between the rare-earth ions.

$$I_t = I_0 + A_1 \cdot \exp(-t/\tau_1) + A_2 \cdot \exp(-t/\tau_2) \quad \text{Eq. S2}$$

$$\tau = (\tau_1^2 A_1 + \tau_2^2 A_2)/(\tau_1 A_1 + \tau_2 A_2) \quad \text{Eq. S3}$$

where τ_1 and τ_2 are the decay times of different components with intensities A_1 and A_2, respectively.

$$\eta = 1 - {}^{\tau_s}/_{\tau_0} \quad \text{Eq. S4}$$

where η is the energy transfer efficiencies, τ_s and τ_0 are the decay time.

$$I_t = I_0 + A \cdot \exp(-t/\tau) \quad \text{Eq. S5}$$

where I_t is the luminescence intensity at the time t and I_0 and A are the constants.

Table S1. CIE coordinates of the as-prepared phosphors.

Number	Samples	Excitation wavelength (nm)	CIE coordinates	
			x	y
A1	NGT: 1%Dy^{3+}	352	0.3664	0.3881
A2	NGT: 3%Dy^{3+}		0.3544	0.3794
A3	NGT: 7%Dy^{3+}		0.3504	0.3783
A4	NGT: 9%Dy^{3+}		0.3471	0.3770
B1	NGT: 1%Tm^{3+}	360	0.1773	0.1164
B2	NGT: 2%Tm^{3+}		0.1698	0.1028
B3	NGT: 3%Tm^{3+}		0.1673	0.0953
C1	NGT: 1%Sm^{3+}	409	0.5537	0.4351
C2	NGT: 2%Sm^{3+}		0.5638	0.4270
C3	NGT: 3%Sm^{3+}		0.5737	0.4189
D1	NGT: 3%Tm^{3+}/1%Dy^{3+}	360	0.2029	0.1673
D2	NGT: 3%Tm^{3+}/2%Dy^{3+}		0.2315	0.2114
D3	NGT: 3%Tm^{3+}/3%Dy^{3+}		0.2468	0.2359
E1	NGT: 3%Tm^{3+}/1%Sm^{3+}	360	0.2204	0.1518
E2	NGT: 3%Tm^{3+}/2%Sm^{3+}		0.2363	0.1708
E3	NGT: 3%Tm^{3+}/4%Sm^{3+}		0.2891	0.2171
F	NGT: 3%Tm^{3+}/5%Dy^{3+}/2%Sm^{3+}	360	0.2767	0.2536

Table S2. Fitting parameters of the PL decay curves.

Sample	I_0	A_1	τ_1(μs)	A_2	τ_2(μs)
NGT: 3%Tm^{3+}/0%Dy^{3+}	1.367	1.375	8.229	1.084	390.0
NGT: 3%Tm^{3+}/1%Dy^{3+}	0.701	1.024	2.171	1.817	239.0
NGT: 3%Tm^{3+}/3%Dy^{3+}	0.990	1.036	3.242	1.553	192.5
NGT: 3%Tm^{3+}/5%Dy^{3+}	1.065	1.150	2.780	1.347	182.8
NGT: 3%Tm^{3+}/7%Dy^{3+}	1.028	1.809	2.644	1.072	138.1
NGT: 3%Tm^{3+}/0%Sm^{3+}	1.367	1.375	8.229	1.084	390.0
NGT: 3%Tm^{3+}/1%Sm^{3+}	1.118	1.321	8.131	1.120	371.1
NGT: 3%Tm^{3+}/2%Sm^{3+}	0.991	1.272	10.227	1.149	343.4
NGT: 3%Tm^{3+}/4%Sm^{3+}	1.107	1.409	8.181	1.069	253.7
NGT: 3%Tm^{3+}/5%Dy^{3+}/1%Sm^{3+}	1.271	109.175	10.786	1.075	320.0
NGT: 3%Tm^{3+}/5%Dy^{3+}/2%Sm^{3+}	1.163	123.920	10.383	1.069	266.0
NGT: 3%Tm^{3+}/5%Dy^{3+}/3%Sm^{3+}	0.994	144.943	9.971	1.024	349.2

Table S3. Comparison of the CIE coordinates of the WLED phosphors in previous literatures.

	Sample	x	y	Ref.
Our Sample	$NaGdTiO_4$: $0.03Tm^{3+}/0.05Dy^{3+}/0.02Sm^{3+}$	0.2767	0.2536	-
A	YAG: $0.05Ce^{3+}$	0.2498	0.2201	[1]
B	CdSe/ZnS/CdSe	0.34	0.30	[2]
C	$Sr_3MgSi_2O_8$: $0.02Eu^{2+}$, $0.05Mn^{2+}$	0.35	0.33	[3]
D	BaY_2ZnO_5: $0.14Dy^{3+}$, $0.04Sm^{3+}$	0.404	0.367	[4]
E	$LaMgAl_{11}O_{19}$: $0.1Dy^{3+}$	0.3324	0.3665	[5]
F	$Na_3YSi_3O_9$: $0.03Sm^{3+}$, $0.09Tb^{3+}$, $0.02Tm^{3+}$	0.3231	0.4491	[6]

References

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