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Supplementary Information

Dy^{3+} doped $LaInO_3$: A host-sensitized white luminescence phosphor with exciton-mediated energy transfer

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Table S1 Structural parameters of LIO: xDy^{3+}

Doping level (x)	**0.00**	**0.01**	**0.02**	**0.03**	**0.05**	**0.07**	**0.09**
a (Å)	5.9369	5.9352	5.9353	5.9342	5.9323	5.9315	5.9296
b (Å)	8.2175	8.2167	8.2161	8.2144	8.2118	8.2101	8.2069
c (Å)	5.7240	5.7227	5.7216	5.7191	5.7154	5.7122	5.7077
V (Å^3)	279.253	279.083	279.014	278.783	278.425	278.174	277.757
α (°)	90	90	90	90	90	90	90
β (°)	90	90	90	90	90	90	90
γ (°)	90	90	90	90	90	90	90
R_p (%)	5.10	5.16	4.75	4.94	5.45	4.56	4.37
R_{wp} (%)	6.69	6.86	6.34	6.49	6.80	5.96	5.74
χ^2	4.87	4.65	4.12	4.60	4.69	3.74	3.25

The Structural parameters of LIO: xDy^{3+} are obtained by refining the measured XRD patterns. The parameters i.e. R_p and R_{wp} finally converge to less than 10%, and χ^2 is also less than 10, indicating the refined results are reliable. The lattice constants *a*, *b*, *c* decrease with the increasing of Dy^{3+} doping levels, revealing that the host lattice shrinkage after introducing Dy^{3+} ions.

Table S2 Bond angle and bond length of LIO: xDy^{3+}

Doping level (x)	Bond angle (°)		Bond length (Å)				
	In-O_1-In (along b axis)	In-O_2-In (along a, c axis)	In-O_1 (along b axis)	In-O_2 (along c axis)	In-O_2 (along a axis)	La-O_1	La-O_2
0.00	143.348	144.748	2.164	2.216	2.111	2.583	2.668
0.01	143.355	144.745	2.164	2.215	2.110	2.581	2.667
0.02	143.359	144.745	2.164	2.215	2.110	2.581	2.667
0.03	143.366	144.743	2.163	2.214	2.109	2.581	2.666
0.05	143.377	144.740	2.162	2.213	2.109	2.580	2.665
0.07	143.388	144.738	2.162	2.212	2.108	2.579	2.664
0.09	143.400	144.735	2.161	2.211	2.107	2.578	2.663

Both In-O bond length and La-O bond length are shortened with the incorporation of Dy^{3+} into LIO host. Meanwhile, the In-O_1-In bond angle increases from 143.348 to 143.400 ° with increasing the Dy^{3+} doping levels, and the In-O_2-In bond angle decreases from 144.748 to 144.735 °. However, the increase is far greater than the decrease, which results in the reduced lattice distortion in the higher doped phosphors.

Table S3 CIE chromaticity coordinates (x, y) and color correlated temperature (CCT) for the emission of LIO: xDy^{3+} under 328 nm excitation at room temperature

Doping level (x)	x	y	CCT (K)
0.00	0.1963	0.1079	2180
0.01	0.2781	0.2359	-
0.02	0.3324	0.3239	5494
0.03	0.3474	0.3422	4873
0.05	0.4332	0.4681	3497
0.07	0.4320	0.4674	3512
0.09	0.4317	0.4666	3512

Color correlated temperature (CCT) is given by the McCamy empirical formula,[1, 2] CCT = $-437n^3+3601n^2-6361n+5514.34$, where $n = (x-x_e)/(y-y_e)$ is the inverse slope line and chromaticity epicenter is at $x_e = 0.3320$ and $y_e = 0.1858$. The CIE chromaticity coordinates of LIO: 0.02Dy^{3+} and LIO: 0.03Dy^{3+} are (0.3324, 0.3239) and (0.3474, 0.3422), respectively, which are nearing the natural white light (0.3333, 0.3333). The luminescence CCT of LIO: 0.03Dy^{3+} is 4873 K. The results indicate that the warm-white-light has been achieved in single phosphor of Dy-LIO.

Table S4 CIE chromaticity coordinates (x, y) and color correlated temperature (CCT) of the luminescence from LIO: 0.03Dy^{3+} under 328 nm excitation at different temperature

Temperature (K)	x	y	CCT (K)
298	0.3474	0.3422	4873
328	0.3475	0.3436	4875
358	0.3472	0.3450	4892
388	0.3472	0.3462	4896
418	0.3479	0.3484	4877
448	0.3482	0.3500	4872
478	0.3480	0.3507	4882

Table S5 Phosphors with high reported efficiency of host-sensitized energy transfer

Sample	Energy transfer	Maximum η_τ	Maximum η_I	References
$LuNbO_4$:Dy	Host→Dy	68.79%	90.3%	[3]
$LaNbO_4$:Eu	Host→Eu	88.23%	98.23%	[4]
$LaNbO_4$:Tb	Host→Tb	88.82%	97.92%	
$LaNbO_4$:Dy	Host→Dy	80.88%	91.44%	
$CaNb_2O_6$:Eu	Host→Eu	39.23%	98%	[5]
$CaNb_2O_6$:Tb	Host→Tb	34.93%	80%	
$CaNb_2O_6$:Dy	Host→Dy	22.95%	67%	
$CaNb_2O_6$:Sm	Host→Sm	24.83%	72%	
$CaWO_4$:Eu	Host→Eu	61.23%	90%	[6]
$CaWO_4$:Tb	Host→Eu	66.67%	95%	
LIO:Dy	Host→Dy	51.3%	77.2%	**This work**

These typical phosphors are selected to be listed in this table, because the previous references have reported that the efficiency of host-sensitized energy transfer of these materials is very high. Previous reports also showed that the energy transfer efficiency η_τ is less than η_I. Similar phenomenon is also observed in this work, where the η_τ and η_I are 51.3% and 77.2%, respectively.

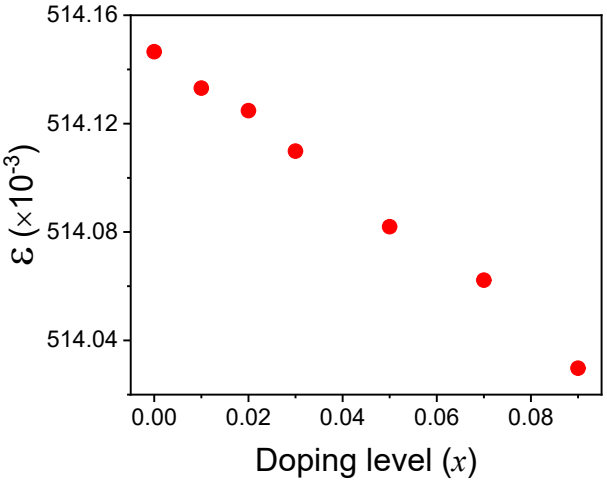

Fig. S1 Variation of metric distortion parameter (ε) with Dy^{3+} doping levels in LIO: *x*Dy^{3+} phosphors.

The metric distortion (ε) is described as follows:[7]

$$\varepsilon = \frac{1}{3}[\{\frac{a_{norm} - a_{ps.cubic}}{a_{ps.cubic}}\}^2 + \{\frac{b_{norm} - a_{ps.cubic}}{a_{ps.cubic}}\}^2 + \{\frac{c_{norm} - a_{ps.cubic}}{a_{ps.cubic}}\}^2]^{0.5} \quad (1)$$

where the parameters of a_{norm}, b_{norm}, c_{norm} and $a_{ps.cubic}$ can be calculated by the following equations:

$$a_{ps.cubic} = \sqrt[3]{V} \quad (2)$$

$$a_{norm} = \frac{a}{\sqrt{2}\sqrt[3]{V}} \quad (3)$$

$$b_{norm} = \frac{b}{\sqrt{2}\sqrt[3]{V}} \quad (4)$$

$$c_{norm} = \frac{c}{\sqrt{2}\sqrt[3]{V}} \quad (5)$$

a, b and c are the lattice parameters of perovskite, and V is the lattice volume.

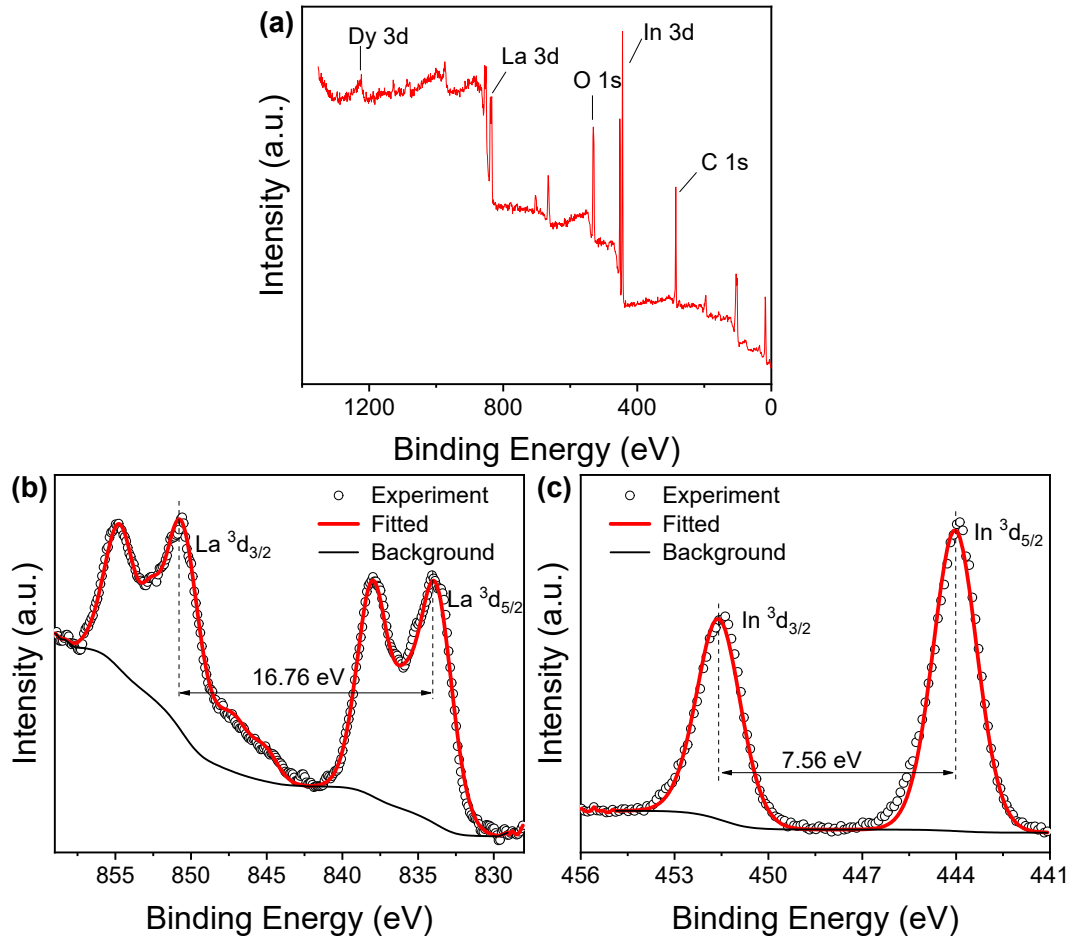

Fig. S2 XPS spectra of the LIO: 0.09Dy^{3+}. (a) Spectrum of survey scan. It is shown that the material is composed of Dy, La, In, O and C elements, without any other exotic elements were observed. **(b) Spectrum of La 3d core level.** The measured binding energy of core level La $^3d_{5/2}$ is 833.88 eV, and the binding energy of La $^3d_{3/2}$ is 850.64 eV, thus the energy difference is 16.76 eV. These results indicate that the La element exists in +3 oxidation state. **(c) Spectrum of In 3d core level.** The core level In $^3d_{5/2}$ with binding energy of 444.03 eV, as well at the core level In $^3d_{3/2}$ at 451.59 eV, is observed, and the energy difference of them is 7.56 eV, revealing that the In element also exists in +3 oxidation state.

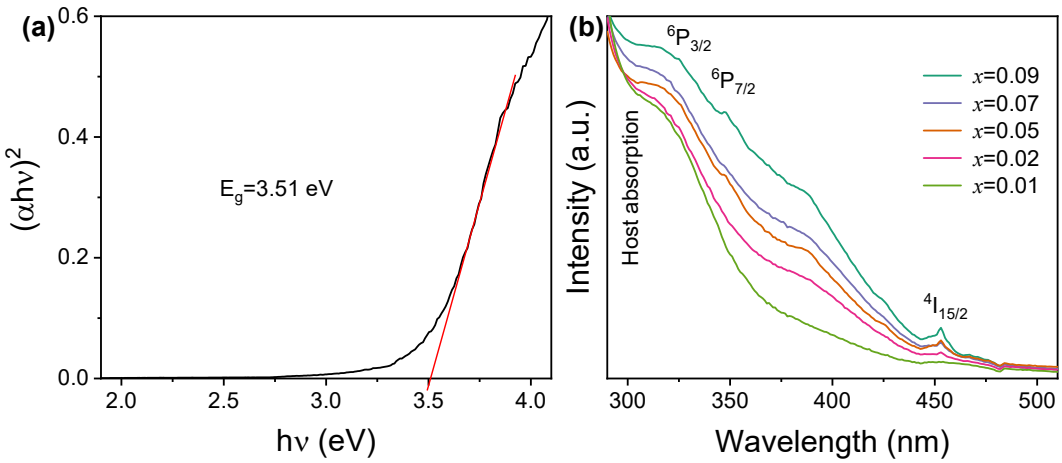

Fig. S3 (a) The relation of (αhν)^2 vs. hν for LIO host. The obtained band gag of LIO is about 3.51 eV. **(b) UV-vis absorption spectra of LIO: xDy^{3+} in the range of 280-520 nm.** The broad absorption band from 300 to 340 nm is due to the electronic interband transition. The absorption was enhanced through increasing the Dy^{3+} doping levels.

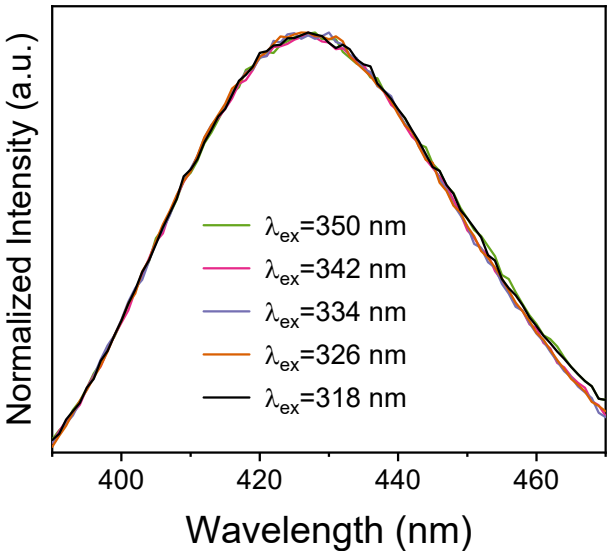

Fig. S4 PL spectra of LIO under 318, 326, 334, 342 and 350 nm excitation. The normalized PL spectra are almost identical, indicating that the excitation can generate the same emission.

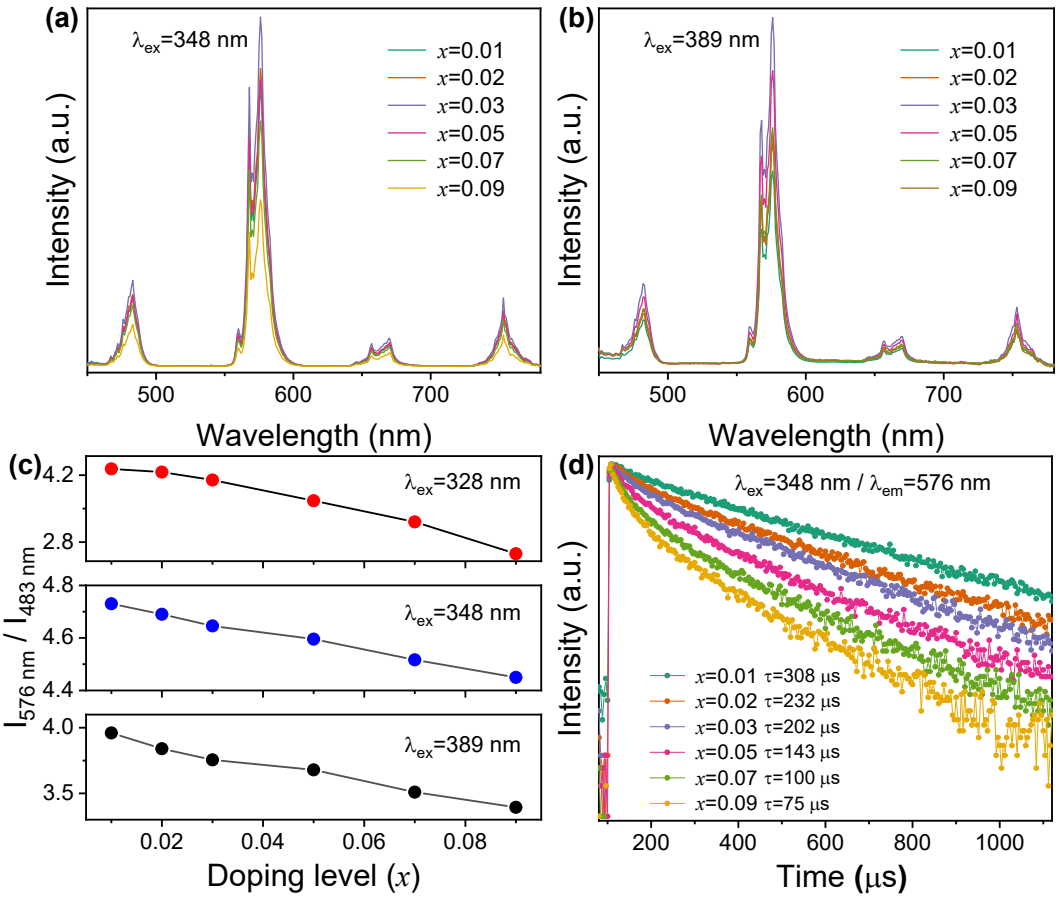

Fig. S5 PL spectra of LIO: xDy^{3+} excited by the lights with the wavelength of (a) 348 nm and (b) 389 nm respectively. As the doping level is increasing, the emission intensity increases firstly, and reaches the maximum as x=0.03, and then decreases due to the concentration quenching. **(c) The intensity ratio ($I_{576\ nm}$ / $I_{483\ nm}$) of the emission from the electric dipole (ED) transition and that from the magnetic dipole (MD) transition.** The emission intensity ratio decreases with increasing the Dy^{3+} doping level, indicating that the symmetry of Dy^{3+} site becomes higher. **(d) Fluorescence decay curves monitored at 576 nm when the LIO: xDy^{3+} phosphors are excited by the 348 nm light.** The lifetime (τ) decreases from 308 μs to 75 μs as the Dy^{3+} doping level increases from x=0.01 to x=0.09.

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