

Supporting Information

Synthesis of ZnAl₂O₄:(Er³⁺,Yb³⁺) spinel-type nanocrystalline upconverting luminescent marker in HeLa carcinoma cells, using a combustion aerosol method route

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Table S1. Lattice parameters obtained from the XRD measurements of spherical ZnAl₂O₄ spinels doped Er³⁺ and Yb³⁺ in the form of powders.

Sample name	Phase					
	ZnAl ₂ O ₄		ZnO			Main phase size (nm)
	a (Å)	%	a (Å)	c (Å)	%	
A1C ^{a)}	8.0901(1)	85.2(8)	3.2494(2)	5.2026(6)	14.8(7)	21
A2 ^{b)}	8.0894(3)	97.2(6)	3.2541(6)	5.185(2)	2.8(1)	11
A2C/PVP ^{c)}	8.0893(1)	100	-	-	-	17
A3C ^{d)}	8.0857(2)	100	-	-	-	15
ZnAl ₂ O ₄ From the database JCPDS ^{e)}	8.0848	100	-	-	-	-

^{a)}4 M, urea, calcined at 990 °C for 3 h; ^{b)}4 M, urea, ethanol; ^{c)}4 M urea, ethanol calcined at 990 °C for 3 h, then coated with a PVP; ^{d)} 2.7 M, ethanol calcined at 990 °C for 3 h;
^{e)}2001 JCPDS - International Centre for Diffraction Data, ICCD Card File No. 5 - 669.

Table S2. Size comparison selected nanoparticles.

SAMPLE	2R _{TEM} (nm)	2R _{SEM} (nm)
A1C/PVP	136	128
A2C/PVP	82	133
A3C/PVP	140	108

Table S3. The microanalysis of chemical composition EDX of selected samples.

Ratio	A1		A1 calcined 3h-990 °C	
	In reaction	EDX	In reaction	EDX
Al ³⁺ /Zn ²⁺	2.39	1.81±0.23	2.39	1.80±0.26
Al ³⁺ /Er ³⁺	93.38	86.73±0.10	93.38	99.56±0.11
Al ³⁺ /Yb ³⁺	19.36	20.33±0.13	19.36	19.35±0.12
Zn ²⁺ /Er ³⁺	38.97	47.75±0.18	38.97	55.29±0.19
Zn ²⁺ /Yb ³⁺	8.08	11.14±0.21	8.08	10.74±0.20
Yb ³⁺ /Er ³⁺	4.82	4.26±0.08	4.82	5.14±0.06

Structural properties

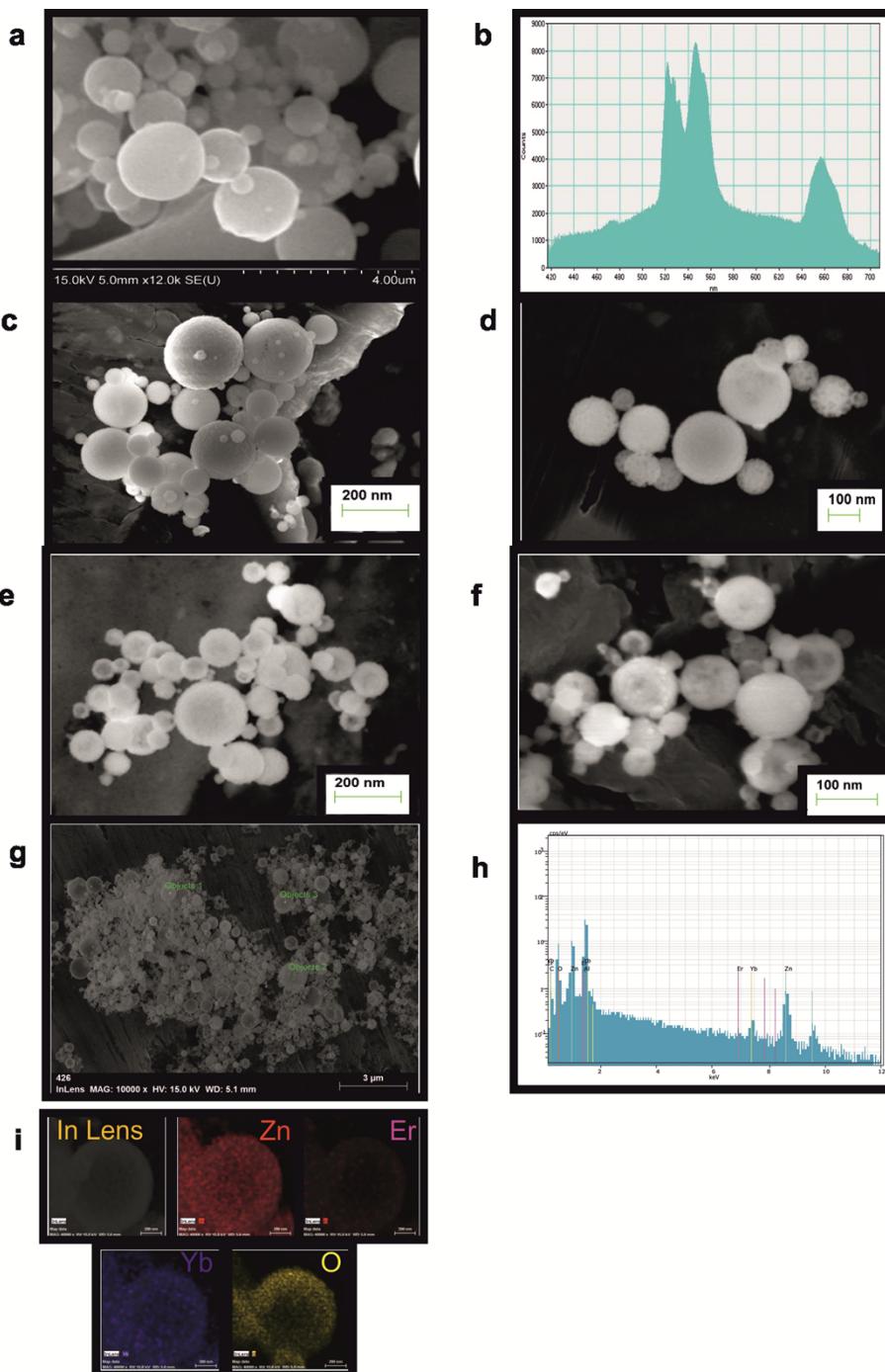


Fig. S1. SEM images for the selected samples of ZnAl_2O_4 doped Er^{3+} , Yb^{3+} particles (a) A1, distilled water solution with urea, 4 M (b) cathodoluminescence A1 sample (c) A2, ethanol solution with urea, 4 M (d) sample A2 calcined at 990 °C for 3 h and coated PVP (e) A4, ethanol solution without urea, 0.1 M (f) sample A5 calcined at 990 °C for 3 h (g-h) example microanalysis of the chemical composition point, the sample A1. (i) Chemical maps the distribution of elements: Zn, Er, Yb and O (EDX) in sample A1.

Table S4. Relative number of photons emitted and obtained from the spinel ZnAl₂O₄:Er³⁺,Yb³⁺ samples.

SAMPLE	POWER DENSITY (mW/mm ²)							
	120		400			584		
	RELATIVE NUMBER OF PHOTONS (arb. units)							
	I _{RED} (661 nm)	I _{GREEN} (547 nm)	I _{RED} (661 nm)	I _{GREEN} (547 nm)	I _R / I _G	I _{RED} (661 nm)	I _{GREEN} (547 nm)	I _R / I _G
A1	1.26E+04	-	1.87E+05	6.38E+03	29.31	4.14E+05	1.53E+04	27.05
A1C/PVP	2.78E+04	-	2.90E+05	-	-	5.31E+05	-	-
A2	2.10E+04	-	1.32E+05	1.54E+03	85.71	3.10E+05	4.06E+03	76.35
A2C/PVP	3.38E+05	-	5.45E+05	2.28E+03	239.03	1.10E+06	4.33E+03	254.04
A3	2.18E+03	-	3.23E+04	-	-	7.78E+04	-	-
A3C/PVP	9.98E+03	-	1.20E+05	-	-	2.59E+05	-	-
A4	1.97E+03	-	1.85E+04	-	-	4.23E+04	-	-
A4C/PVP	8.40E+03	-	8.96E+04	-	-	1.84E+05	-	-
A5	2.04E+03	-	2.81E+04	1.02E+03	27.55	6.76E+04	1.68E+03	40.24
A5C/PVP	1.10E+04	-	7.68E+04	1.16E+03	66.20	2.79E+05	4.00E+03	69.75