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DECAY TIME DETERMINATION FROM LUMINESCENCE EMISSIONS OF Eu^{3+} DOPED Y_2O_3 POWDER

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Abstract

Yttrium oxide (Y_2O_3) is a phosphor material, since as an inorganic solid compound that can absorb energy and transfer it to a luminescent center and subsequently emit it as light when the excitation source is removed. The emitted color intensity and decay time of the emission of the phosphor depend strongly on the structure of the host material and the choice of the emission center. The aim of this research is to determine the decay times at different molar concentrations of europium doping ion into yttrium oxide matrix. The experimental methodology involved synthesizing yttrium oxide via the sol-gel method doping at concentrations ranging from 0 to 5 mol % of Eu^{3+}. Upon exposing the experimental matrix to an excitation source of λ = 254 nm, different intensities of red emissions were obtained. These emissions were characterized by emission spectroscopy and luminescent decay times were determined. Based on the results, europium-doped yttrium oxide powder with a cubic structure and decay times ranging from 1632 to 1857 µs is a promising phosphor for applications in fields such as optics and/or biomedicine.

Keywords: *sol-gel, Y2O3, europium, luminescence, decay time*

1. INTRODUCTION

Yttrium oxide (Y_2O_3) is a widely used phosphor in materials science due to its effectiveness as a host matrix for rare earth ions, which introduce new emission bands across various regions of the electromagnetic spectrum [1]. Luminescent materials, or phosphors, are predominantly solid inorganic compounds composed of a host matrix deliberately doped with activator ions capable of absorbing energy and subsequently emitting light once the excitation source is removed [2], [3]. Light emission in phosphor materials is generated from electronic transitions within the solid-state structure. When energy is absorbed, electrons are promoted to higher energy states, and visible light is subsequently emitted as they return to lower energy levels [4]. The emission color and intensity are predominantly influenced by the characteristics of the luminescent center and the crystallographic environment of the host matrix. Europium-doped yttrium oxide (Y_2O_3:Eu^{3+}) is widely recognized as an efficient red-emitting phosphor under ultraviolet excitation [5], [6]. However, the practical application of a phosphor depends not only on its emission intensity but also on its emission duration after the excitation source is removed. For example, in emissive displays, such as mobile phone screens, the decay time must be as short as possible to prevent image retention. Conversely, for illumination devices like LEDs, longer decay times are preferable to ensure consistent light output.

2. EXPERIMENTAL PROCEDURE

2.1 Materials and methods

Yttrium oxide powders were synthetized by sol-gel method following the route proposed by Mellado et. al.[7] 0.001044 mol of yttrium nitrate hexahydrate ($Y(NO_3)_3{\cdot}6H2O$, 99.8 %, Sigma Aldrich), europium nitrate pentahydrate ($EuNO_3)_3{\cdot}5H2O$, 99.9 %, Sigma Aldrich) were dissolved in methyl alcohol (CH_3OH, 99.8 %, Sigma Aldrich) in a molar ratio of $CH_3OH/Y=123$ under vigorous stirring during 15 minutes. Acetylacetone, AcAc; ($C_5H_8O_2$, 99.9 %, Sigma Aldrich) was added into solution in a molar ratio of AcAc/Y= 1:1 to obtain a stable solution of Y_2O_3. Sol was obtained after 15 minutes. Sol was dried in an oven at 100 °C for 24 h. Finally, the xerogel obtained was calcined at 300, 500 and 700 °C for 1 h. Yttrium oxide pure and yttrium oxide doped at 0.5, 1.5, 2.5, 3.5, 4.5 y 5 % mol of europium ions were obtained. The europium ions concentrations were proposed in according of Kumar at al. [8], in their research determine that the maxima luminescent intensity is in 5 % mol of europium.

2.2. Characterizations

Structural characterization for the undoped powder of Y_2O_3 synthetized was carried out in a D8 ADVANCE Bruker diffractometer equipment with CuKα (λ=1.5406 Å) radiation, from 20° to 80° with steps of 0.2°. Luminescent analyses were made in a Fluorescence Spectrophotometer F-700 HITACHI equipped with a 150 W xenon lamp, R955 Hamamatsu photomultiplier tube for visible emissions, and a stigmatic concave diffraction grating (900 lines/mm). All luminescent measurements were performed at room temperature.

3. RESULTS AND DISCUSSION

3.1 Structural studies

Figure 1(a) shows the X-ray diffraction pattern of doped-yttrium oxide powders obtained by sol-gel process after an annealing treatment at 700 °C for 1 h. The diffraction peaks correspond to BCC yttrium oxide with representative planes (211), (222), (400), (440) and (622) in according to crystallographic cubic structure of Y_2O_3 cart ICDD# 41-1105.

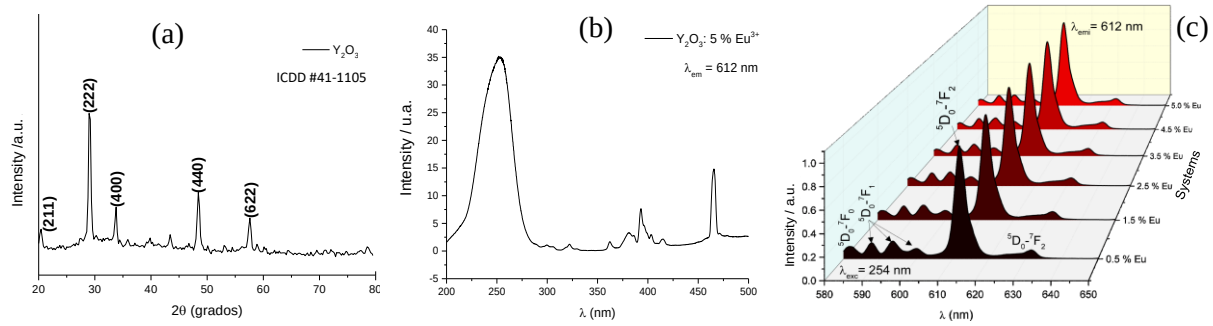

Figure 1. DRX pattern of Y_2O_3 powder heat-treated at 700 °C (a), absorption spectrum of Y_2O_3: 5 mol% Eu^{3+} (b), and emission results of Eu^{3+} doped Y_2O_3 (c).

3.2 Luminescence analyses

Luminescence emissions were studied trough emission spectroscopy excited under UV radiation. The wavelength of excitation was determined by absorption analysis to produce the typical 612 nm line reddish emission of europium ions. The absorption spectra of Y_2O_3: 5 mol % of Eu^{3+} is presented in Figure 1(b). The wide absorption band is observed in 254 nm, corresponding to the so-called Charge transition Band (CTB) which implies that the energy is absorbed by the Y_2O_3 structure and is transferred to the emission centers by the Eu-O bond.

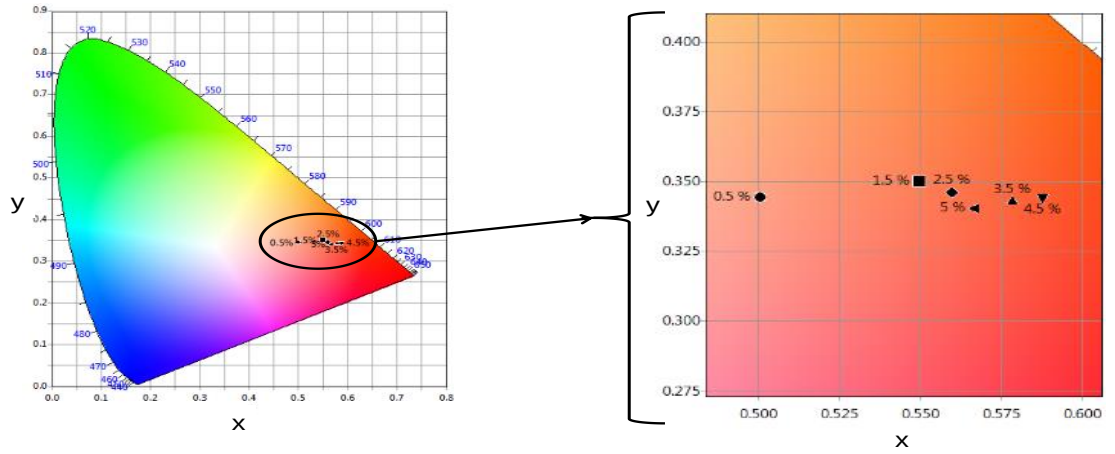

Figure 2. CIE diagram of luminescence red systems excited at λ= 254nm.

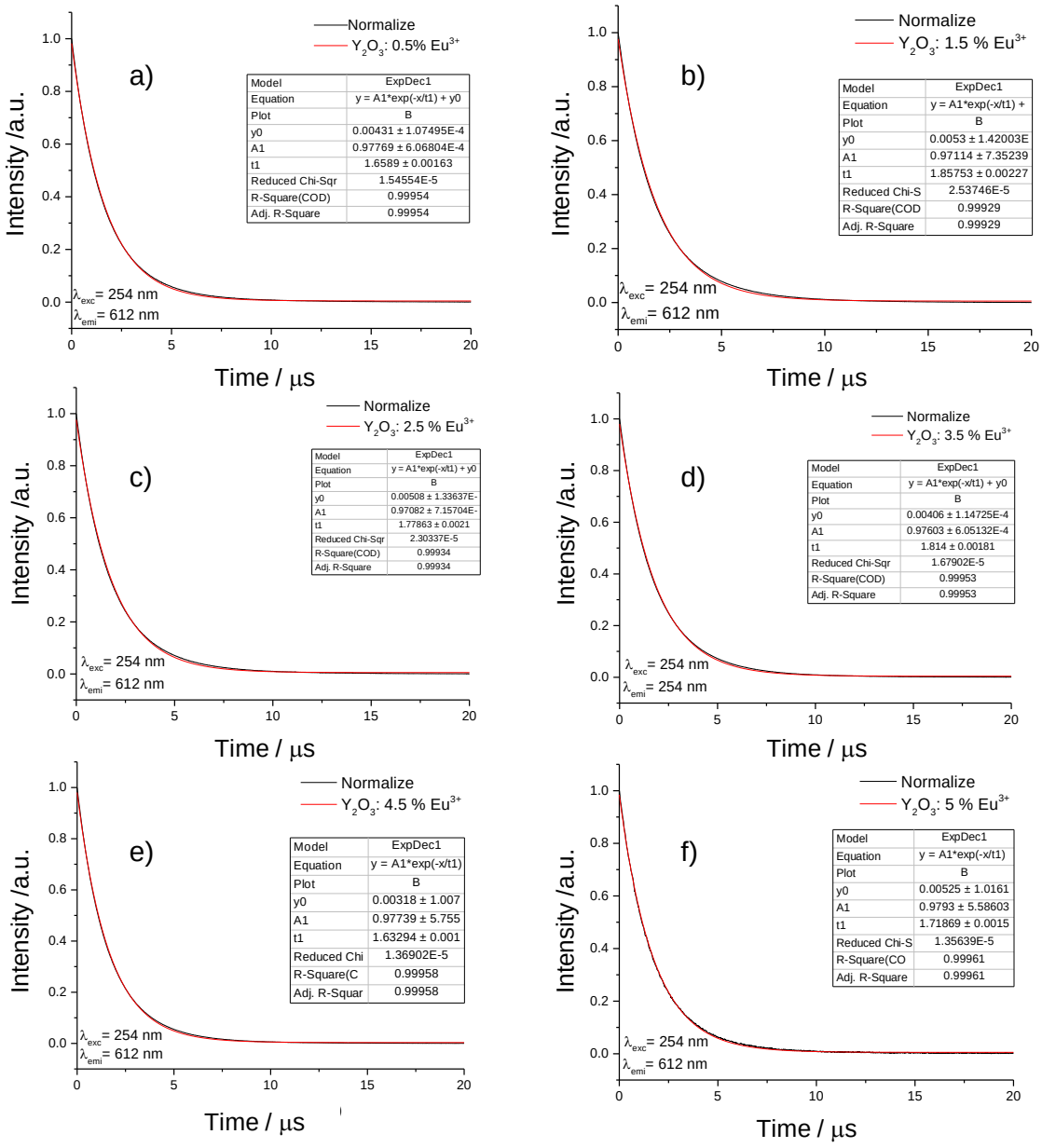

Figure 3. Decay time of the a) 0.5 %; b) 1.5 %; c) 2.5 %; d) 3.5 %; e) 4.5 % and f) 5.0 %mol of europium doped Y_2O_3 systems measurement at room temperature.

Since this the most prominent band, the luminescent measurements were carried out under this wavelength. For this reason, the system of europium doped yttrium oxide powder was excited at 254 nm. In Figure 1(c) emission spectra of europium doped yttrium oxide excited at 254 nm are presented. The doped system at 0.5, 1.5, 2.5, 3.5, 4.5, 5.0 % mol of Eu^{3+} ion presented the characteristic emission lines of Eu^{3+} ion. The emission at 612 is attributed to $^5D_0 \rightarrow {}^7F_2$ transition associated to red region of electromagnetic spectrum [9][10]. In Figure 2 are presented the coordinated of europium doped yttrium oxide system in the CIE diagram. The coordinates were: 0.5006 & 0.3442, 0.5498 & 0.35, 0.5597 & 0.3462, 0.5783 & 0.3429, 0.5876 & 0.3447, 0.5669 & 0.3405 for 0.5, 1.5, 2.5, 3.5. 4.5 and 5.0 %mol of europium in Y_2O_3 powder. Decay time of luminescent system were measurement at λ=612 nm. The obtained values were normalized and adjusted to ExpDec1 model with R>0.99. In Figure 3 are shown the luminescence lifetime for europium doped yttrium oxide systems at different concentration of doping ion excited at λ=254 nm. It´s observed that, as the Eu^{3+} content increases, the life-time also increases, as result of a boost of emission centers, however after 3.5 mol %, the values decrease, due to quenching effects.

4. CONCLUSION

Europium-doped yttrium oxide powders exhibited a body-centered cubic structure and luminescent lifetimes ranging from 1632 to 1857 μs. This is due to their capability to absorb ultraviolet radiation and emit visible light, particularly in the red region of the spectrum. The study of their luminescent behavior under UV excitation at 254 nm demonstrated efficient energy transfer from the Y_2O_3 host lattice to the Eu^{3+} emission centers. The CIE chromatic coordinates confirm the red luminescence, and decay time measurements revealed a strong dependence on europium concentration. The luminescence lifetime increases with Eu^{3+} content up to 3.5 mol %, after which it decreases due to concentration quenching effects. These findings highlight the potential of Y_2O_3:Eu^{3+} as an efficient red-emitting phosphor for advanced technological applications.

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