Materials Research Bulletin 83 (2016) 186–192

Contents lists available at ScienceDirect

Materials Research Bulletin

journal homepage: www.elsevier.com/locate/matresbu

Enhanced photoluminescence due to $Bi^{3+} \rightarrow Eu^{3+}$ energy transfer and re-precipitation of RE doped homogeneous sized Y_2O_3 nanophosphors

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ARTICLE INFO

Article history:
Received 19 April 2016
Received in revised form 30 May 2016
Accepted 8 June 2016
Available online 8 June 2016

Keywords:
Optical materials
Chemical synthesis
Phosphors
Luminescence
Nanostructures

ABSTRACT

Precipitation and re-precipitation of metal ions has been carried out from original and supernatant solution producing Bi^{3+} – Eu^{3+} doped Y_2O_3:Eu^{3+} and Eu^{3+}/Tb^{3+} doped Y_2O_3, respectively. Shorter reaction time is unable to consume all metal ions present in the solution which can be utilized through re-precipitation process. The doping of Bi^{3+} – Eu^{3+} in Y_2O_3 helps to absorb maximum UV light. The activation of Y_2O_3 matrix by Bi^{3+} and Eu^{3+} ions, together and separately, were studied considering the excitation energy transfer to the luminescence centers. The successful replacement of Y^{3+} by RE^{3+} ions can help for fine tuning of emission wavelength. Re-precipitation of supernatant solution by adding terbium precursor can successively produce uniform sized Tb^{3+} doped Y_2O_3:Eu^{3+}. The re-precipitation of the supernatant solution ensures maximum consumption of metal ions for higher product yield and possible fine tuning of emission wavelengths.

1. Introduction

The research works on white light emitting diodes (LEDs) or so called fourth generation solid state light received considerable attraction in recent years. Their excellent properties such as small volume, long lifetime, high energy efficiency, energy saving and environment friendliness make them suitable candidate for display applications [1–5]. The theoretical concept put forward by Keodam and Postelten [6] fluorescent lamps with very high color rendering efficiency could be achieved by the combination of red, green and blue phosphors which emit in narrow wavelength intervals centered on 450, 545 and 610 nm, respectively. These tricolor lamps have color rendering index (CRI) values of 80–85 at high efficiencies of 100 Lm/W. Europium doped yttrium oxide is a top ranking red phosphor with high quantum efficiency of nearly 100% when excited by high energy UV radiation (254 nm). The strongest emission is located at 613 nm while other emission lines are weaker one [7]. The excitation wavelength for UV-LEDs lies in the region of 360–400 nm and Y_2O_3:Eu could be excited due to the 4f – 4f transition which was strongly forbidden by the parity selection rule.

Yttrium oxide (Y_2O_3) is an important sesquioxides within the general class of ceramics which can find applications such as sintering aids in the various ceramic materials, substrates for semiconducting films, optical windows and most important component for rare earth doped lasers [8]. The selection of suitable host and dopants has been done by considering their crystal structure, ionic radii, emission efficiency, thermal conductivity, refractive index and phonon frequency [9]. Y_2O_3 shows wide band gap, low phonon frequency, wide transmission region and matching of ionic radii with many rare earth ions which make it favorable oxide host [8]. The incorporation of Bi^{3+} as a codopant into Y_2O_3:Eu^{3+} can be helpful for effective absorption of UV radiation in the range of 300–400 nm through its allowed ${}^1S_0 \rightarrow {}^3P_1$ transition [10,11]. Bi^{3+} ion under UV region of the spectrum shows two strong absorption bands such as ${}^1S_0 \rightarrow {}^3P_1$ and ${}^1P_1$ [12] and Eu^3

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http://dx.doi.org/10.1016/j.materresbull.2016.06.016
0025-5408/

$^+$ ion shows a charge transfer absorption band in the same region where the position of the band depends strongly on the nature of the surrounding ions [13]. The transfer of electronic excitation between ions in the solids has been extensively studied for various applications. Along with intrinsic decay processes, excited donor ions have been found to relax by direct interaction with energy transfer to acceptor ions or by migration of the excitation among donor ions until it comes into the vicinity of an energy acceptor where direct transfer occurs. In any case, observation of the time evolution of the donor luminescence under pulsed laser excitation provides help in identifying the dominant relaxation mechanisms [14].

In present paper, we have carried out synthesis of high emitting red emission phosphor from the original as well as first supernatant solution of urea precipitation reaction. While the emission wavelength was tuned by addition of terbium precursor to supernatant solution to obtain Tb co-doped Y_2O_3:Eu^{3+}. To obtain small particle size in homogeneity the reaction time is an important factor to control the particle growth. During smaller reaction time in precipitation reaction, limited amount of metal ions got precipitated and some part of metal ions still remain in the solution. Usually the supernatant solution (obtained from removal of precipitated particles by centrifuge without any addition of DI water for washing) is discarded after the removal of precipitated particles and the valuable and sometime expensive metal ions are lost in trash. Thus to recover the metal ions which are still in the solution, the second urea precipitation reaction was carried out and the obtained product was high emission red and green-white phosphor. By this method we can certainly avoid the loss of expensive materials and maximize % yield of the product.

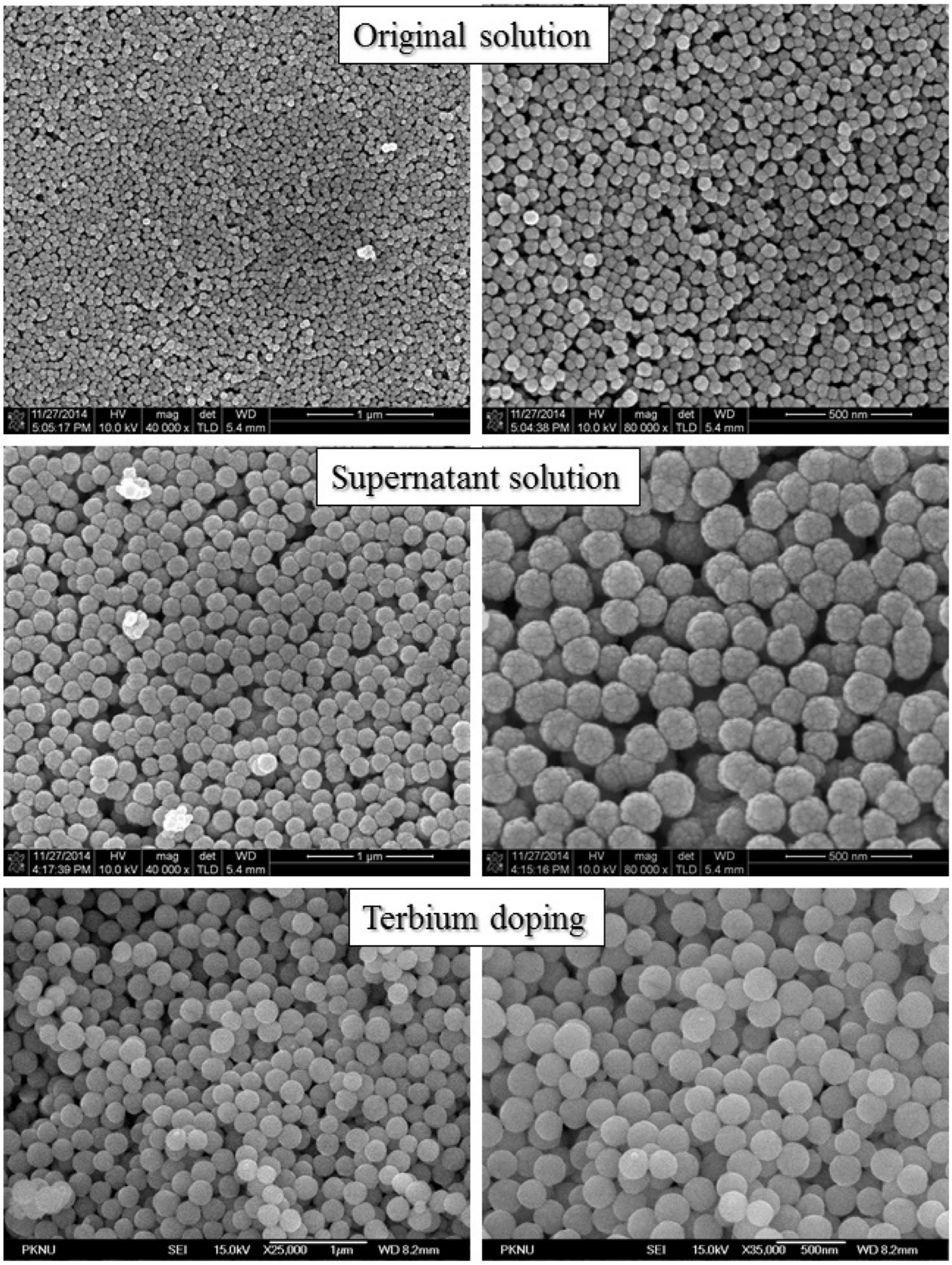

Fig. 1. SEM images of Y_2O_3:$Eu^{3+}Bi^{3+}$ (original and supernatant solution) and Y_2O_3:$Eu^{3+}Tb^{3+}$ (supernatant solution) nanostructures. The samples were calcinated at 800 °C for 2 h in air atmosphere.