Synthesis and Photoluminescence Dynamics of Europium (III) and Terbium (III) Co- Doped of GdSrAl3O7 Color- Tunable Nanophosphors

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Abstract

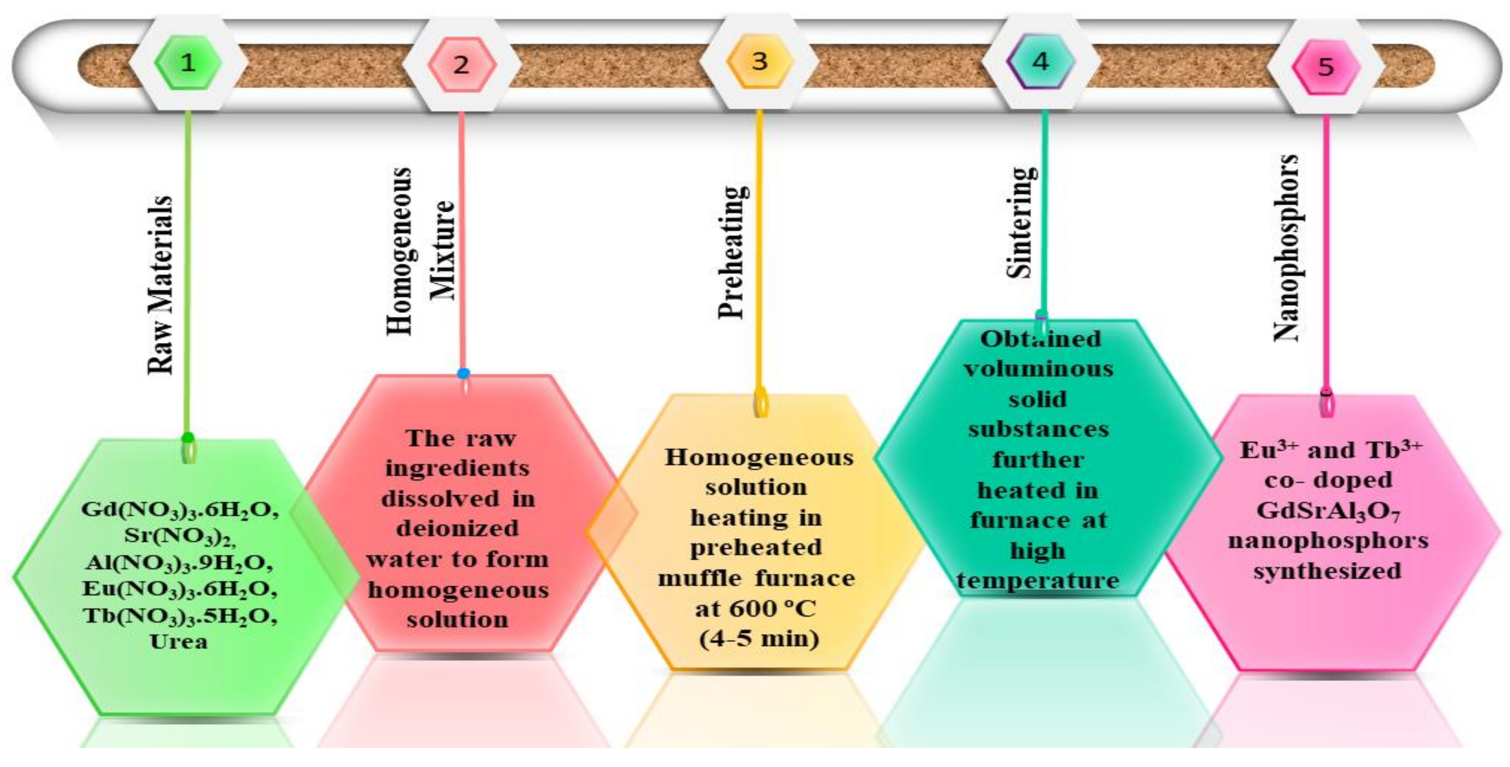
A series of Europium (III) and Terbium (III) co- doped $GdSrAl_3O_7$ color- tunable nanophosphors were synthesized by a simplistic, streamlined and self- propagating, urea- assisted solution combustion synthesis process. The structural, and luminescence characteristics of synthesized Eu^{3+}/ Tb^{3+} co- doped Gadolinium Strontium Aluminate nanocrystalline phosphors were validated using powder X- ray diffraction (PXRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy dispersive X- ray analysis (EDAX), and photoluminescence spectra studies. The morphological studies revealed that the synthesized co- doped phosphor crystals seemed to be agglomerated spherical-shaped porous nanocrystalline particles with interconnected boundaries. Through diffuse reflectance (DR) spectroscopy, the optical band gap values for nanocrystalline phosphors were also studied. The simultaneous presence of these two rare earth ions may provide specific luminous assets, including efficient energy transfer along with controlled emissions. The detailed analysis of the photoluminescence excitation (PLE) and photoluminescence emission (PL) spectra of Europium (III) and Terbium (III) co-doped $GdSrAl_3O_7$ revealed that Tb^{3+} effectually sensitized Eu^{3+} ion and that the energy transfer could be precisely controlled to achieve color- tunable emission by varying the proportions of doped ions. The non- radiant energy loss *i.e.* concentration quenching phenomenon was also probed in detail. Additionally, by using their emission data, colorimetric traits including Commission International de l'Eclairage 1931 color coordinates, color purity (CP), and correlated color temperature (CCT) were also obtained. The photometric properties of developed nanocrystalline co- doped phosphor materials introduce new prospects and layout potentials for upgraded luminous materials that can be used in field emission displays, solid- state technologies, multicolor display applications and a variety of illumination strategies.

Keywords: solution combustion, nanocrystalline, phosphors, photoluminescence, color coordinates.

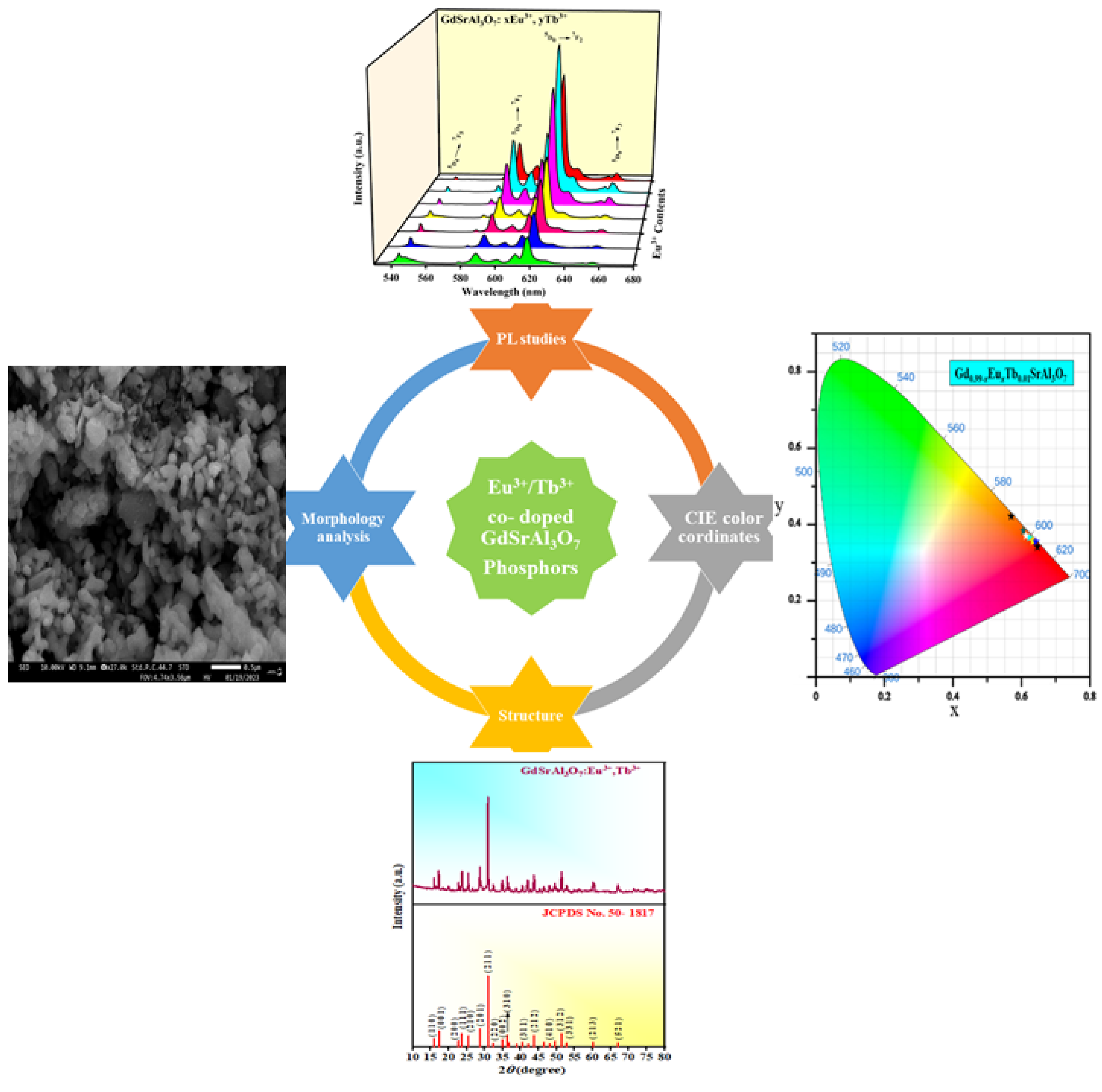
Introduction

The field of luminescent materials research and innovation has undergone a transformation due to the growing demand for white-light emitting diodes (W-LEDs) and the emergence of phosphors that possess the ability to emit white light. Researchers in materials science are working more and harder to develop inexpensive, sustainable, and more effective luminous materials [1,2]. At the moment, there is a sharp increase in the design and research of lighting devices, optoelectronic devices, sensors, W-LEDs, and other devices using inorganic phosphors [3–5]. In recent decades, numerous attempts have been made to improve the properties of luminescent materials. These have included the use of doping ions with different concentrations, the application of different temperatures during the synthesis process, and the use of numerous synthesis processes with advancements. Furthermore, reports in the literature have demonstrated the use of co-dopants in the production of luminous materials with improved photoluminescent characteristics [6–9]. Amongst trivalent rare earth metal ions, Tb^{3+} and Eu^{3+} due to their characteristics emission in visible region may be predominantly explored for the blossoming of phosphors. Due to the $^5D_{0\to}{}^7F_J$ (J=0-4) transitions, Eu^{3+} shows emission in the red-orange light region and predominantly used for the synthesis of the red phosphors. But near UV region, Eu^{3+} shows weak absorption due to inefficacious narrow-line excitation peaks corresponding to the parity- forbidden 4f→4f transitions which retard the useful application of Eu^{3+} ions. The procedure of co-doping additional rare earth metal ions has been started in order to fix this oversight. Mainly, due to broad and strong absorption in near UV region Ce^{3+} ion could be used to sensitize Eu^{3+} ion but in Ce^{3+} and Eu^{3+} ions co- doped systems the metal- metal charge transfer mechanism (MMCT) always occurs [10–12]. Conversely, Tb^{3+} ion observed suitable sensitizer of Eu^{3+} due to the effective energy transfer between Tb^{3+} and Eu^{3+} ions. Tb^{3+} ions shows emission in the blue-green region corresponding to $^5D_4 \to {}^7F_J$ (J = 3, 4, 5, 6) transitions [13–15]. In Eu^{3+}, Tb^{3+} co-doped phosphors, co-doping of Tb^{3+} not only enhance the emitting intensity of Eu^{3+} but also widen the absorption bands. Moreover, color tunable Eu^{3+}, Tb^{3+} co-doped phosphors can be achieved by tuning the mole ratio of Tb^{3+} to Eu^{3+} ion or changing the temperature. The energy transfer phenomenon from $Tb^{3+} \to Eu^{3+}$ has been examined in numerous luminescent materials in literature. On the other hand, choosing the right host is another essential prerequisite for the synthesis of high-efficiency phosphors. To the best of our knowledge, no reports of co-doping Europium (III) and Terbium (III) in $GdSrAl_3O_7$ phosphors have been made thus far.

Set up



Results



Conclusions

Single- phase $GdEu_xTb_ySrAl_3O_7$ color tunable luminous nanocrystalline materials were synthesized using a simple, cost effective, less time consuming, self- propagating solution combustion synthesis route. The synthesized co- doped phosphor sample illustrated the loosely organized bunches of spherical -shaped nanoscale particles. With altering the contrast ratio of Tb^{3+} and Eu^{3+}, specific emission based on energy transfer (ET) from $Tb^{3+} \to Eu^{3+}$ was also feasible to be altered color hue. The observed color- tunable emission for co- doped nanoluminescent demonstrates their future use as a foundation for sophisticated displays, full- color displays, photonic appliances, pc- LEDs, and numerous lighting devices.

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