Chapter 10

Thermo, Photo and Mechanoluminescence Studies of Eu$^{3+}$ Doped Y$_4$Al$_2$O$_9$ Phosphors: TL, PL, and ML Analysis of YAM: Eu$^{3+}$

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ABSTRACT

The chapter reports synthesis and characterization of europium-doped Y4Al2O9 phosphor for display and dosimetric applications. The europium-activated Y4Al2O9 (YAM) phosphor is synthesized via solid state reaction method. Synthesized phosphors were characterized by powder x-ray diffraction (PXRD) techniques, scanning electron microscopy (SEM) technique, and transmission electron microscopy (TEM) technique. Particle size calculated from TEM analysis and crystallite size was calculated by Scherer’s formula. All synthesized phosphor for different concentration of europium ion were studied by photo, thermo, and mechanoluminescence study. It is found that for photoluminescence analysis of Eu$^{3+}$ doped phosphor has prominent spectra in red region and electric dipole transition (5D0 $\rightarrow$ 7F2) dominant over the magnetic dipole transition (5D0 $\rightarrow$ 7F1) due to non-centro symmetry between rare earth ions. Broad excitation spectra found for photoluminescence study.

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INTRODUCTION

During the past decades, nanostructured materials have attracted considerable attention for their novel and enhanced properties, e.g., the Mn doped ZnS phosphor can yield both high luminescent efficiencies and short lifetime Bhargava et al. (1994) and Zhang et al. (1998). Nanostructured materials may be developed to form a novel type of luminescent materials for display applications.

The Y$_2$O$_3$–Al$_2$O$_3$ system is a promising material for refractory coatings and for ceramic and semiconductor processing technology Lo et al. (1998) and Aguilar et al. (2000). Doped yttrium aluminium garnet (YAG) is widely used as a laser host material Lupei et al. (2002) and Vodopyanov et al. (1998), and yttrium aluminiumperovskite (YAP) used as scintillation host material Glodo et al. (2000). In addition, rare earth doped YAG is also employed as a phosphor Lu et al. (2002) and Choe et al. (2001). However, there are few reports on rare earth doped Y$_3$Al$_2$O$_9$ (YAM). It has been reported that the space group for the crystal structure of Y$_3$Al$_2$O$_9$ is P2$_1$/c of monoclinic Yamane et al. (1998 a & b). The Al atoms are coordinated to four oxygen atoms, the Y atoms are coordinated to either six or seven oxygen atoms Yamane et al. (1998 a & b), and its site symmetry is C1 Rabinovitch et al. (2004). There are four formula units in the unit cell of the room temperature phase of Y$_3$Al$_2$O$_9$ and four different rare earth sites in the asymmetric unit. Xia et al. (2005) have synthesized the Y$_3$Al$_2$O$_9$:Eu$^{3+}$ phosphor through a sol–gel combustion method, where the Y$_3$Al$_2$O$_9$ phase can form through sintering at 800 °C. However, higher doping concentration could be realized in Y$_3$Al$_2$O$_9$:Eu$^{3+}$nano-crystal host lattice. Shengli Liu et al. have also prepared the Y$_3$Al$_2$O$_9$:Tb$^{3+}$, Eu$^{3+}$) by sol–gel process Shengli and Su (1997) Wang et al. (2006), Kaur et al. (2012) and Dubey et al. (2013) have studied the VUV excitation and photoluminescence characteristics of this Y$_{3.8}$Al$_2$O$_9$:Re$^{3+}$ (Re = Tb$^{3+}$, Eu$^{3+}$) phosphor synthesized via a citric-gel method. This phosphor shows strong absorption in VUV region. The results indicate that this phosphor could be one of the potential candidates for PDPs applications.

The rare-earth ions show abundant emission colors based on their 4f–4f or 5d–4f transitions. Eu$^{3+}$ show red/orange emission, respectively. Y$_2$O$_3$:Eu$^{3+}$phosphor emit red emission and have excellent chemical stability. This phosphor is the only existing red/green phosphor used in three-band fluorescent lamps. For Y$_2$O$_3$:Eu$^{3+}$ nanoparticles, the intensity of 5D$_{0}$ emission of Eu$^{3+}$ ions from the C3i site (S6) is significantly less compared to the emission from Eu$^{3+}$ ions in the C$_2$ site for these samples Jeong et al. (2003). The Eu–O charge transfer band resulting from an electron transfer from the ligand O$^{2-}$(2p) orbit to the empty states of the 4f$^6$ configuration (Eu$^{3+}$–O$^{2-}$ transition) and the energy transfer efficiency between the Y$_2$O$_3$ host and Eu$^{3+}$ ions were investigated by Kelley et al. (2006).

Plasma display panels (PDPs) dominate the segment of the next generation flat panel displays which uses VUV excitation of Red, Green and Blue (RGB) phosphors for image display. For full coloured large area flat display, PDP is a very promising technique due to the progress made in technology by way of improvements in cost, resolution, lifetime, power consumption, high performance and luminescence efficiency which results in the reductions of thickness and weight Tian et al. (2006) and Rao et al. (2006). Motivated by the advances in PDP technique, the demand of highly efficient vacuum ultraviolet (VUV) phosphors has increased tremendously in the past decade Yang et al. (2006). The demand became crucial as phosphors play a very important role in PDPs in terms of augmented performance such as higher efficiency for lower power consumption and higher reliability for longer lifetime. Luminescence characteristics of phosphors and their behaviour under panel making process, energetic discharge ions, electrons and solarization from VUV generated by the Xe-Ne gas plasma are important factors for PDP. In PDP’s plasma resonance, vacuum ultraviolet (VUV) radiation lines of Xe atoms at 147 nm and a mo-