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Morphological and Photoluminescence Studies of Er^{3+} Doped Y_2O_3 Phosphor Synthesized by Solid State Reaction Method

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Abstract— *Er^{3+} doped Y_2O_3 novel phosphor was successfully synthesized by solid state reaction process using boric acid as a flux. The Structural characterization was done by using simple X-ray diffraction technique. The Morphological studies were done by scanning electron microscope and transmission electron microscope. From X-ray diffraction, it was observed Er^{3+} doped Y_2O_3 nanoparticles (NPs) have cubic structure and further crystallite sizes were calculated by Debye Sherrer's formula. The particle Size was found in the range of ≈70 nm confirmed by TEM result. The optical property of prepared phosphor was examined by Photoluminescence spectra. The emission spectra was recorded under 275nm excitation and found in the range 350-700 nm*

Keywords— *Er^{3+} doped Y_2O_3, Solid state reaction, XRD, SEM, TEM, Photoluminescence.*

1. INTRODUCTION

Trivalent erbium ion (Er^{3+}) doped Oxide phosphor such as yttrium oxide (Y_2O_3) has been intensively investigated for green laser applications. These oxide materials attracted most interest among luminescent rare earth ions in recent year. An Er^{3+} ion possesses favourable metastable energy levels with longer excited states in yttrium oxide materials with less phonon energy [1-4]. Low dimension phosphor has advantage over the micro sized phosphors. The particle having low dimension have great advantage [5-12].

Yttrium oxide (Y_2O_3) is the most attractive doping host for rare earth metals because they are close in ionic radius to yttrium. Here the erbium ion and yttrium can therefore, be incorporated in large amount without significant lattice distortions. Y_2O_3 plays an important role in the preparation of novel light-emitting materials. It's have high refractory properties with a melting point of about 2550°C, a very high thermal conductivity of 35 W/mK, a density of5.05 g cm^{-3} and have a high energy band gap of ≈ 5.7 eV [13-15]. The most widely used method for the preparation of solids is solid state reaction wherein there is a direct reaction between the mixtures of solid constituents. Solids do not usually react together at room temperature over normal time scales and it is necessary to heat them to much higher temperatures often 1000 to 1500°C or even more, in order for reaction to occur at an appreciable rate[16-18].

In this paper Y_2O_3:Er^{3+} nanophosphor have been prepared by solid state synthesis using boric acid as a fuel. The Structural characterization was done by using simple X-ray diffraction technique. From X-ray diffraction, it was observed Er^{3+} doped Y_2O_3 nanoparticles (NPs) have cubic structure and further crystallite sizes were calculated by Debye Sherrer's formula. The Morphological studies were done by scanning electron microscope and transmission electron microscope. The structural comparison through XRD and TEM also discussed in brief [4, 16, 18].

2. EXPERIMENTAL DETAILS

2.1 Synthesis of $Er3^{+}$ Doped Y_2O_3 Nanoparticles

The conventional solid state method was used for the synthesis of the phosphor. Yttrium oxide (Y_2O_3), Erbium Oxide (Er_2O_3) of high purity (99.9%) and Boric acid (H_3BO_3 as Flux) chemicals purchased from Sigma Aldrich were used as starting materials to prepare Er^{3+} doped Y_2O_3 phosphor. The stoichiometric ratios of 2.5% H_3BO_3 were used of these chemicals were weighed and grinded into a fine powder by using agate mortar and pestle. The ground sample was placed in an alumina crucible and heated at 1000^0C for 1 hour and 1400^0C for 4 hours in a muffle furnace. The sample is allowed to cool at room temperature in the same furnace for about 15h.

The crystallinity as well as the particle size of the phosphor were monitored X-ray diffraction measurement. The X-ray powder diffraction data was collected by using Bruker D8 Advanced X-ray diffractometer using Cu Kα radiation. The X-rays were produced using a sealed tube and the wave length of X-ray was 0.154 nm. The X-rays were detected using a fast counting detector based on Silicon strip technology (Bruker Lynx Eye detector).

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Molecular structure was determined by FTIR analysis done by Nicolet Instruments Corporation USA MAGNA-550. The surface morphology of the prepared phosphor was determined by field emission scanning electron microscopy (FESEM) JSM-7600F. Energy dispersive X-ray analysis (EDX) was used for elemental analysis of the phosphor. Particle diameter and surface morphology of prepared phosphor were determined by Transmission Electron Microscopy (TEM) using Philips CM-200

3. RESULTS AND DISCUSSIONS

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3.1 XRD Result

The X ray diffraction (XRD) patterns for Er^{3+} doped Y_2O_3 synthesized by solid state reaction Method at high temperature of 1400 °C shown in Figure 1. Five different peaks are obtained at 2Θ values of 29.15°, 33.86°, 43.39°, 48.53° and 57.74° correspond to diffraction at (222), (400), (440), (622) and (444) planes, respectively.

The result shows that the samples crystallized in cubic Y_2O_3 with spatial group *Ia*3 (ICDD no. 89-5591). No other peak is observed here. This indicates that the dopant ion completely occupies by the Y_2O_3 host lattice. The crystallite size *D* can be estimated by following Scherrer's equation [19-20]:

$$D = \frac{k\lambda}{\beta Cos\theta}$$

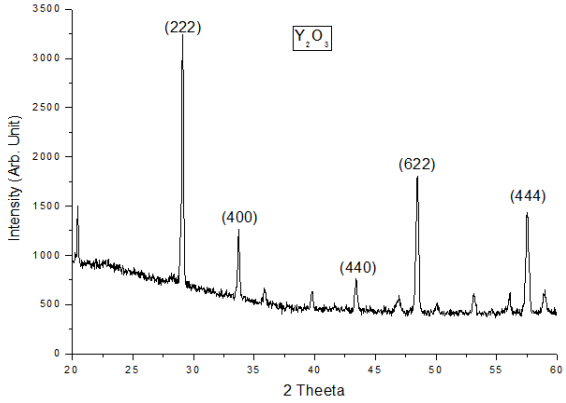

Fig. 1: XRD Patterns of Er^{3+} doped Y_2O_3 phosphor

Here, *D* is the crystallite size for the *(hkl)* plane, λ is the wavelength of the incident X-ray radiation [CuKα(0.154056 nm)], β is the full width at half maximum (FWHM) in radians, and θ is the diffraction angle for the *(hkl)* plane particle size are found in the range of 69nm.

3.2 Scanning Electron Microscope (SEM) Result

A scanning electron microscope (SEM) is a type of electron microscope that images a sample by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition, and other properties such as electrical conductivity. Figure 2 show the SEM image of Er^{3+} doped Y_2O_3 synthesized by solid state reaction Method at high temperature of 1400 °C.

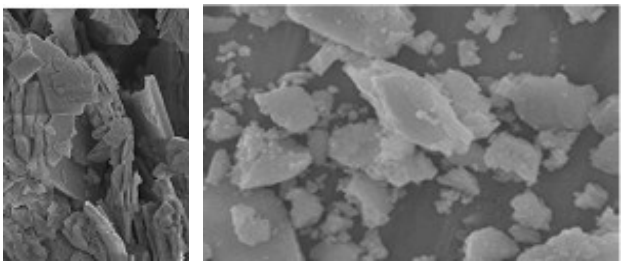

Fig. 2: Scanning Electron Microscope (SEM) Results of Er^{3+} doped Y_2O_3 phosphor

3.3 Energy Dispersive X Ray Analysis (EDAX) Results

Here, the characteristics x-rays are identified by their energy using solid state detectors. The energy dispersive system can analyze whole x-ray spectrum simultaneously Figure 3 show the energy dispersive spectroscopy (EDX) spectra of the sample, which confirm the presence of erbium ions in yttrium lattice.

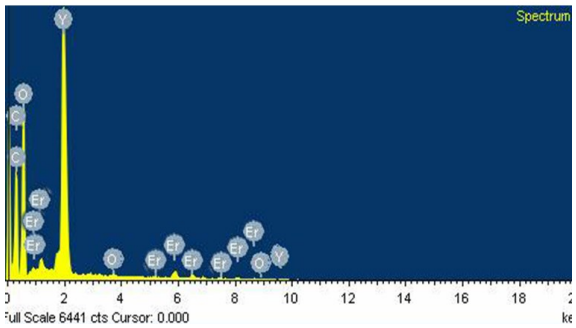

Fig. 3: EDX result of Er^{3+} doped Y_2O_3 phosphor

3.5 Transmission Electron Microscope (TEM) Results

The particle size is found to be ~ 70 nm, which is close to the size determined from XRD studies (69 nm). The particles are well defined without much agglomeration.

The selected area electron diffraction (SAED) shown in figure 4 confirms the high crystallinity for the nanoparticles.

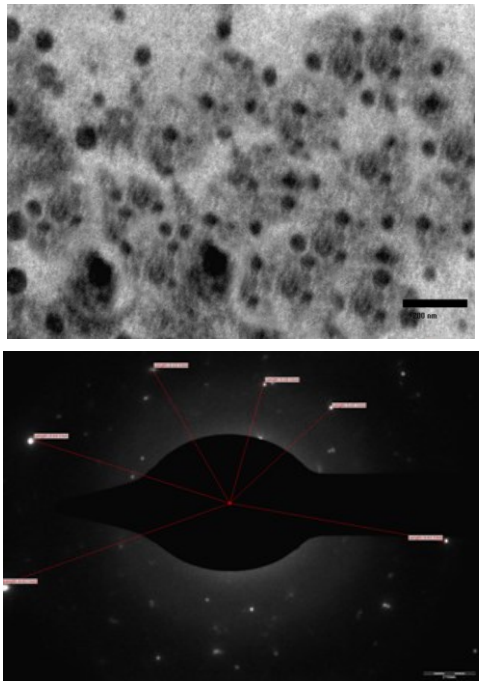

Fig. 4: HRTEM image of Er^{3+} doped Y_2O_3 phosphor

3.4 Photoluminescence

The emission spectra was recorded under 275nm excitation and found in the range 50-700 nm. These spectra consist of three groups of emission peaks around 530-565 nmand 645-683 nm, which are attributed to $^2H_{11/2}$, $^4S_{3/2}\rightarrow{}^4I_{15/5}$ transition and $^4F_{9/2}\rightarrow 4I_{15/2}$ transition of Er^{3+} ions, respectively. It is clear from the emission spectra that the green emission is much stronger than that of red emission.

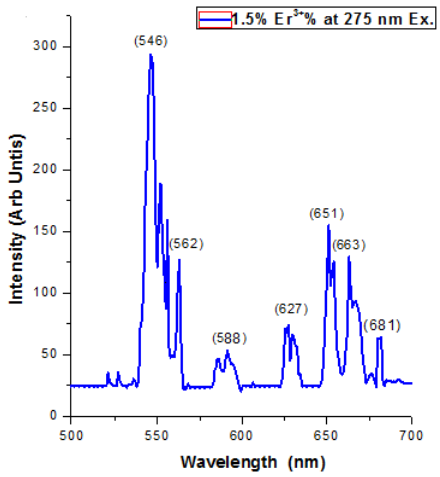

Fig. 5

4. CONCLUSION

From XRD patterns, the particle size has been calculated. The size of particle was found in the range of 69 nm calculated by Debye Scherer formula and confirmed by TEM micrograph. Fine phosphor particles of Y_2O_3: Er^{3+} has been prepared by Solid state reaction method, using boric acid as a flux. : The emission spectra was recorded under 275nm excitation and found in the range 50-700 nm. These spectra consist of three groups of emission peaks around 530-565 nmand 645-683 nm, which are attributed to $^2H_{11/2}$, $^4S_{3/2}\rightarrow{}^4I_{15/5}$ transition and $^4F_{9/2}\rightarrow 4I_{15/2}$ transition of Er^{3+} ions, respectively. It is clear from the emission spectra that the green emission is much stronger than that of red emission.

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