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To cite this version:
B Munisudhakar, C Nageswara Raju, P Sreenivasulu Reddy, S Hemasundara Raju. Optical Analysis of Ho 3+ Ions Doped BaGd2Ti4O12 Ceramics. Mechanics, Materials Science Engineering MMSE Journal. Open Access, 2017, 9, <10.2412/mmse.84.39.432>. <hal-01499561>

HAL Id: hal-01499561
https://hal.archives-ouvertes.fr/hal-01499561
Submitted on 4 Apr 2017

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Optical Analysis of Ho\(^{3+}\) Ions Doped BaGd\(_2\)Ti\(_4\)O\(_{12}\) Ceramics

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Keywords: XRD, SEM, emission, excitation.

ABSTRACT. Ho\(^{3+}\) (5 mol %) ions doped Barium Gadolinium Titanate (BaGd\(_2\)Ti\(_4\)O\(_{12}\)) powder ceramics were synthesized by solid state reaction method. From the X-ray diffraction profiles it is observed that the prepared ceramics were crystallized in the form of orthorhombic structure. Agglomeration and the nanometer particle size were observed from the SEM images of the ceramics. The emission spectrum Ho\(^{3+}\): BaGd\(_2\)Ti\(_4\)O\(_{12}\) powder ceramics has shown blue emission at 467 nm (\(^{5}F_3 \rightarrow ^{5}I_8\)) with an excitation wavelength 208 nm.

Introduction. One of the most important electro ceramics is barium titanate. Barium titanate is a good dielectric material with a high dielectric constant and it is a ferroelectric, piezoelectric and pyroelectric with good nonlinear optical properties. Barium titanate compound is an electrical insulator because of its energy and it has been used for a wide range of scientific and industrial applications such as capacitors, ultrasonic transducers, piezoelectric sensors, Barium titanate ceramics applications in various fields such as optical limiting, switches, flat panel displays, modulated-type optical devices and second harmonic generation. Rare-earth ions doped titanate based phosphors have attracted significant importance for potential applications in white-light emitting diodes [1]. Gadolinium compounds doped with rare earth ions are used as the red phosphors for the preparation of WLEDs and gadolinium containing host lattices are also used for making green phosphors for colour TV tubes. From the literature, it is observed that many authors have been reported on PL analysis of titanate based systems such as gadolinium titanate, zirconium titanate, compounds can find potential applications in optoelectronic devices [2]. Rare earth ions doped ceramic hosts have a wide range of applications in the fields of lamp phosphors, solid state lighting in display devices, white light generation [3]. So for no reports have been made on the photoluminescence property of thulium doped barium gadolinium titanate (BaGd\(_2\)Ti\(_4\)O\(_{12}\)) ceramics. In this paper, we report on the synthesis, XRD, SEM and PL analysis of Ho\(^{3+}\) ions doped BaGd\(_2\)Ti\(_4\)O\(_{12}\) ceramics for novel applications.

Experimental studies. BaGd\(_2\)\(_x\)Ti\(_4\)O\(_{12}\): RE\(^{3+}\) (RE = Ho and x = 5 mol %) ceramics were prepared by solid state reaction method. The starting chemicals used for the preparation of these ceramics were purchased from the Sigma Aldrich with 99.9 % purity and the chemicals purchased were used as received without any further purification. The starting materials such as BaCO\(_3\), Gd\(_2\)O\(_3\), TiO\(_2\) and Ho\(_2\)O\(_3\) were taken in an appropriate stoichiometric ratio. Then, these powders were grounded thoroughly in an agate mortar and the mixtures were put into alumina crucibles. They were heated in
an electric furnace at a temperature 1000°C for 2h. The final samples were white powders and then used for the characterization.

Structural characterization of these samples has been carried out from the X ray powder diffraction measurements on a XRD 3003 TT Seifert diffractometer with CuKα radiation (λ=1.5406Å) at 40 kV and 20 mA and the 2θ range was varied between 10° and 80°. Morphology of the ceramic powder was examined on a ZEISS-EVO-MA15 ESEM. The scanning electron microscopy (SEM) image was obtained for samples by using a 35mm camera attached to a high resolution recording system. Both the excitation and emission spectra were obtained on a SPEX Fluorolog-2 Fluorimeter (Model II) with data max software to acquire the data with a Xe-arc lamp (150 W) as the excitation source.

Results and Discussion

XRD analysis. Fig. 1. shows the XRD profile of 5 mol% of Ho³⁺: BaGd₂Ti₄O₁₂ ceramics, from the XRD profiles, it is observed that these powder ceramics are having the orthorhombic structure (using the software namely JCPDS No: 43-0233) having diffraction peaks which are consistent. The rare earth ions Ho³⁺: doped BaGd₂Ti₄O₁₂ ceramic does not influence the crystal structure.

SEM analysis. Fig. 2 shows SEM micrograph of the 5 mol% of Ho³⁺: BaGd₂Ti₄O₁₂ ceramic powder, from this image shows that the particles are agglomerated with various shapes and sizes and the average grain size is around at ~200 nm.
Fig. 2. SEM image of Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ ceramics.

Fig. 3. Excitation spectrum of 5 mol% of Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ ceramics.

**Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ ceramics.** Fig. 3 shows the excitation spectrum of 5 mol% Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ powder ceramics, from this spectrum the excitation wavelengths at 208 nm and 249 nm corresponding to the transitions $^5$I$_8$→$^3$F$_3$, $^5$I$_8$→$^3$D$_3$ respectively. Among these transitions the transition at $^5$I$_8$→$^3$F$_3$ is most intense transition compared to other one and has been selected for the measurement of emission spectrum of Ho$^{3+}$: Ba$_3$Y$_2$WO$_9$ powder ceramics. The emission spectrum of 5 mol% Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ powder ceramics is shown in Fig. 4. From the emission spectrum, the wavelengths at 467 nm, 560 nm, 606 nm and 628 nm corresponding to the transitions $^5$F$_3$→$^5$I$_8$, $^5$S$_2$→$^5$F$_4$→$^5$I$_8$, $^5$F$_5$→$^5$I$_8$ and $^5$F$_5$→$^5$I$_8$ respectively. Among these the transition $^5$F$_3$→$^5$I$_8$ is most intense compared to others and is the characteristic of blue emission. From the emission spectra Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ powder ceramics shows tricolor emissions at blue (465 nm), green (558 nm) and red (609 nm). Assignments to these bands have been made by the previously published articles [24]. Among these transitions the transition at $^5$S$_2$→$^5$I$_8$ is more efficient for laser action.
Summary. It is concluded that, 5 mol % of Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ powder ceramics have been synthesized by using a solid state reaction method. The XRD profile indicates the tetragonal phase structure of the prepared ceramics. The emission spectrum of Ho$^{3+}$: BaGd$_2$Ti$_4$O$_{12}$ powder ceramics have shown an intense blue emission at 467 nm with the excitation wavelength $\lambda_{\text{exci}} = 208$ nm. These powder ceramics may be used as novel luminescent materials in various optical systems.

References


Cite the paper