Article

Structural, Optical and Photoluminescence properties of Bi^{3+}doped $LaGaO_3$ Nanoparticles: Synthesized By Polyol Method

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Abstract

Pure and Bi^{3+} doped $LaGaO_3$ nanoparticles ($LaGaO_3$: Bi^{3+}) were synthesized by Polyol mediated method and subsequently have been characterized by their structure, optical and photoluminescence studies. XRD revealed the formation of single-phase $LaGaO_3$ nanoparticles with orthorhombic symmetry. From UV-Vis studies, it is found that the absorption of Pure $LaGaO_3$ is less compared with Bi^{3+} doped $LaGaO_3$ nanoparticles and the optical band gap decreases in $LaGaO_3$: Bi^{3+}, Eu^{3+} nanoparticles. From Absorption spectra and FE-SEM analysis the synthesized nanoparticles size found to be around 20nm. Photoluminescence studies revealed that the samples are with high structural and optical quality which can be used in photonic and optoelectronic devices.

INTRODUCTION

Research on nanosized semiconductors stimulated great interest in the recent past due to their unique properties and potential applications in diverse areas such as photocatalysis, solar cells, display panels, etc. [1].$LaGaO_3$ oxide perovskites are receiving renewed attention because of their potential use as substrates for high-temperature superconducting thin films [2]. As $LaGaO_3$ is a wide band gap semiconductor, it can be effectively used in photonic and optoelectronic devices [3].The lanthanum gallate crystal has an orthorhombically distorted centro symmetric $GdFeO_3$-type perovskite like structure with space group *Pbnm*[4].The structure consists of a three dimensional sublattice of corner connected GaO_6 octahedra and the La^{3+} is in eightfold coordination of oxide ions, which have the potential to serve as a host material in phosphor applications. There are no of methods such as solid state reaction, co-precipitation, hydrothermal, sol-gel, polyol and wet chemical methods used for the synthesis of oxide nanoparticles, however among all, the polyol mediated method is one of the more widely recognized methods due to its several advantages like soft chemistry, easy to handle and requiring no special or expensive equipment and formation of nanoparticles with very fine particle size distribution[5-6].In the present study, we have synthesized the undoped and Bi^{3+} doped $LaGaO_3$ nanoparticles by Polyol mediated route and the

work was aimed to investigate the structural, optical and Photoluminescence properties of the synthesized material.

EXPERIMENTAL

For the preparation of undoped and Bi^{3+} doped $LaGaO_3$ nanoparticles, stoichiometric amounts of Lanthanum(III) Nitrate Hexahydrate(Sigma-Aldrich,99.99%), Gallium(III) Nitrate Hydrate(Sigma-Aldrich,99.99%), Bismuth(III) Nitrate Pentahydrate(Sigma-Aldrich,99.99%) used as precursor salts. Ethylene glycol (MERCK, 99.99%) was used as a solvent and stabilizing ligand. First, an accurate weighed amount of precursors are taken in 10 ml double distilled water and stirred well for 20 minutes. After that 20 ml of ethylene glycol was added to the solution. Solution was shaken and kept under stirring. A thermometer was used to measure the temperature. When the temperature was raised to 100^{o}C, around 4 gm. of urea was added and temperature was raised further to 120^{o}C and maintained at this temperature for 2 hours. The precipitate obtained after 2 h of reaction was cooled, centrifuged, washed twice with methanol, and twice with acetone. The precipitate was dried overnight under ambient conditions. Then the samples were fully ground and fired to the desired temperatures 500–900 °C for 5 hours.

RESULTS AND DISCUSSION

Powder X-Ray Diffraction

The powder X-ray diffraction pattern of the synthesized sample LaGaO3:Bi^{3+}) was recorded using powder X-ray diffraction system. X-ray diffraction was recorded for the sample by means of a slowly moving radiation detector in the range of 10°-100° where monochromatic wavelength of 1.5405 Å (Cu) was used. The Fig-1 shows the X-ray diffraction pattern of $LaGaO_3$: Bi^{3+} nanomaterial. The peaks of the X-ray diffraction pattern can be compared with the standard available data for the confirmation of the structure, with the use of JCPDS (Joint Committee on Powder Diffraction Standards-card.no.24-1102).Pure $LaGaO_3$ phase can be obtained at 900^{o}C. The crystalline sizes were approximately estimated to be below 50 nm by using the Scherer's formula from the full-width at half maximum (FWHM) of diffraction peaks. The diffraction pattern of $LaGaO_3$:Bi^{3+} is observed between the 2θ values of 10° and 90°.

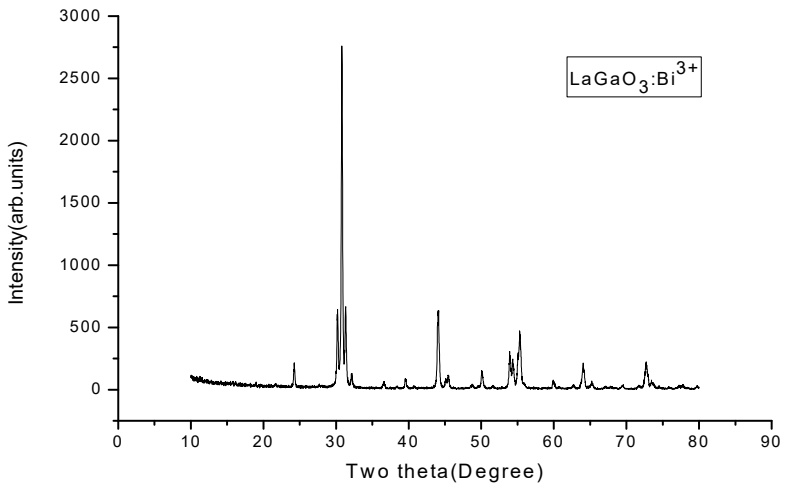
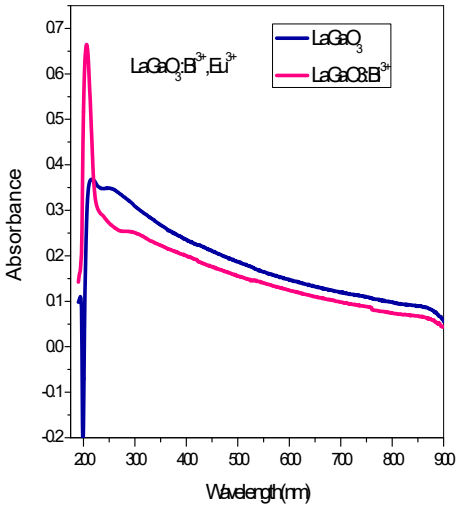


Fig-1: X-ray diffraction pattern of $LaGaO_3$:Bi^{3+} nanoparticles.

UV-Vis Spectroscopy and Band gap calculation

The UV-Vis absorbance of the sample was measured using a LABINDIA UV 3092 UV-Vis Spectrophotometer. The observed spectrum is shown in Figure-2(a).The UV-Vis spectrum shows that the absorbance is high below 235 nm wavelength region and the dopant increases the absorbance of $LaGaO_3$ considerably. From UV-Vis studies, it is found that the absorption of Pure $LaGaO_3$ is less compared with Bi^{3+} doped $LaGaO_3$ nanoparticles and the optical band gap decreases in $LaGaO_3$: Bi^{3+} nanoparticles (Figure-2(b)).The calculated optical band gap is 3.89 eV which is near to the estimated band gap of $LaGaO_3$ (4.2-5.2eV)[5].This suggests that semiconductors with smaller band gaps are preferred in order to show high photoluminescence properties by absorbing visible light. From the absorption spectra the synthesized nanoparticle size is found to be around 20 nm.



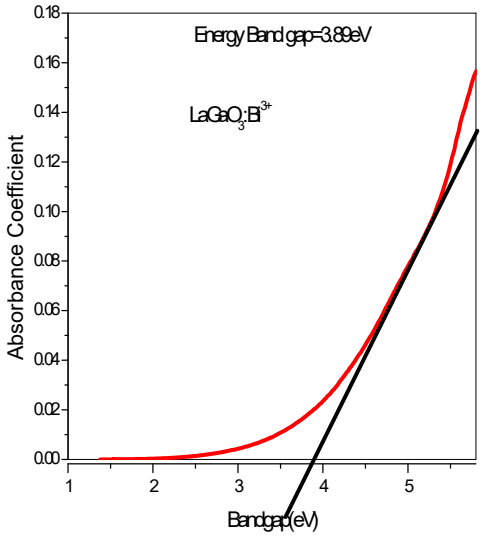
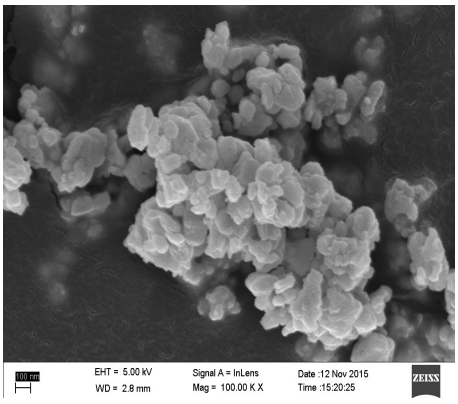


Fig-2: a) UV-Vis Absorbance spectrum of the pure and LaGaO3:Bi^{3+} nanoparticles b) Optical bandgap of Bi^{3+} doped $LaGaO_3$ nanoparticles

Field Emission Scanning Electron Microscopy (FE-SEM)



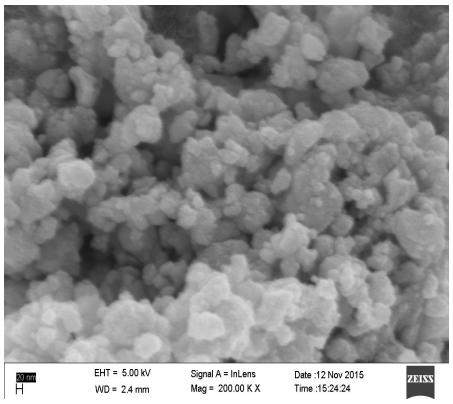


Fig-3: FE-SEM micrographs of the pure and $La_{0.99}GaO_3$:0.01Bi^{3+} nano powders annealed at 900°C

The surface morphology of the synthesized samples was investigated by applying FE-SEM on pure and $La_{0.99}GaO_3$:0.01Bi^{3+} samples. Fig-3 shows FE-SEM micrographs of the pure and $La_{0.99}GaO_3$:0.01Bi^{3+} nanoparticles annealed at 900°C. The particle sizes increase with the increase in the temperature, because at higher temperature, the growth of particles is significantly promoted, leading to excessive sintering and aggregation of particles. It is found that both the samples have same morphology. It is clearly seen that the powder consists of agglomerated particles with quasi spherical shape with an average particle size ranging from 20 to 100 nm and average crystallite size around 50 nm.

Photoluminescence study

The photoluminescence (PL) spectrum of Bi^{3+} doped $LaGaO_3$ and undoped nanoparticles is obtained from the use of a PL spectrometer. PL spectrum of Bi^{3+} doped $LaGaO_3$ nanoparticles after heat-treatment at 900°C are shown in the Figure-3. Photoluminescence (PL) spectra of Bi^{3+} doped $LaGaO_3$ nanoparticles are measured with an excitation wavelength of 254 nm. The intensity of PL emission is found to be increasing on doping Bi^{3+} ions with increase in temperature. This clearly confirms that the effect of doping Bi^{3+} ions has enhanced the luminescence properties of the host lattice. High Photoluminescence (PL) is observed when 1 mol% of Bi^{3+} and is doped into $LaGaO_3$ host lattice. This could be attributed to the high purity and perfect crystallinity of the synthesized nanoparticles.

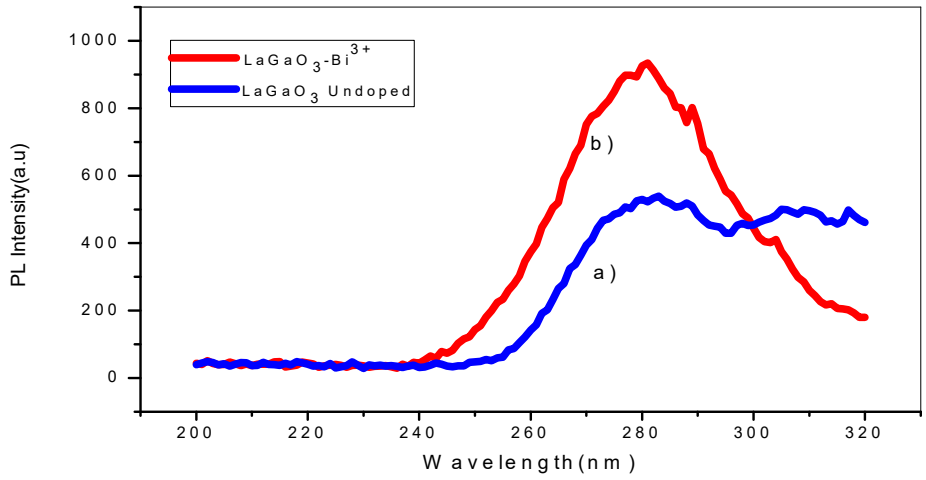


Fig-4: PL Emission spectra of $LaGaO_3$:Bi^{3+} nanoparticles after heat-treatment at 900°C for 5hrs.

CONCLUSIONS

The Bi^{3+} doped $LaGaO_3$ nanoparticles were synthesized by simple and inexpensive Polyol mediated technique. When the synthesis temperature was 120- 170 ° C in the Polyol process, we obtained $LaGaO_3$: Bi^{3+} nanoparticles not only with a small size but also with good absorption in the Ultraviolet and Visible regions. The powder XRD confirms the crystallinity of the synthesized sample and from absorption spectra we got an average particle size of 20 nm for the doping concentration of 1 mol %(0.01). The surface morphology of the synthesized nanopowder is observed from FE-SEM analysis. It is evident that from the photoluminescence spectrum, the PL intensity increased on doping Bi^{3+} ions into the host lattice. These results showed a great promise for the Bi^{3+} doped $LaGaO_3$ nanoparticles for applications in optoelectronic and display devices.

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