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Wet chemical approach for the low temperature synthesis of $ZnGa_2O_4:Tb^{3+}$ quantum dots with tunable blue-green emission

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ABSTRACT

This is the primary report on the formation of blue-green tunable zinc gallate quantum dots, doped with Tb^{3+} by simple wet chemical method. The synthesis temperature was kept at a low value of 90 °C and only ecofriendly chemicals were used. Effect of Tb^{3+} concentration on the structural and optical properties were investigated using characterization techniques like x-ray diffraction (XRD), transmission electron microscopy (TEM), diffuse reflectance (DRS) and photoluminescence (PL). Quantum dot formation with spinel structure was confirmed from XRD and TEM. Doping led to the introduction of strain in the lattice, verified by Williamson-Hall (WH) plot. There exists a blue shift in band gap energy for every sample due to the quantum confinement effect. Commission Internationale de L'Eclairage (CIE) chromaticity diagram illustrates the transformation from blue to green colour effectively and the critical distance was estimated to be 18 Å. The highly intense green emission observed for the Tb^{3+} concentration of 4 mol%, may find applications in display devices and biomarkers.

1. Introduction

The unique properties of nanomaterials, derived from their high specific surface area, direct them to have a considerable attention in a wider research area. Nanophosphor is one of such field of interest, where the enhanced luminescence efficiency finds applications in display devices, bio markers, luminescent paints etc. So there is a great interest in the synthesis of chemically and thermally long-standing nanophosphor which is simple to manufacture and eco-conscious like oxides.

Zinc gallium oxide [$ZnGa_2O_4$- zinc gallate] is a renowned luminescent oxide which finds applications in electroluminescent devices, field emission displays [1,2], vacuum displays [3,4], light emitting diodes [5,6] etc. Solid state reaction [7–9], hydrothermal method [10,11], sputtering [12], chemical vapour deposition [13], sol gel [14,15] etc. are the main manufacturing techniques for $ZnGa_2O_4$. Doping with transition metals like Mn^{2+} and Cr^{3+} or rare earths like Tb^{3+} and Eu^{3+} generate green and red emitting zinc gallate phosphor respectively. But the high luminescence efficiency and narrow emission peak govern the practice of using rare earth elements as the activator. There are reports on green emitting Tb^{3+}doped zinc gallate by solid state reaction [16], pechini method [17] and non-hydrolytic hot solution chemistry [18]. But they require high temperature and consist of tedious steps involving variety of chemicals. So there is demand of a simple and user friendly synthesis technique and we adopted the wet chemical synthesis. Authors have already reported the pure $ZnGa_2O_4$ quantum dots [19] and red emitting $ZnGa_2O_4:Eu^{3+}$ nanophosphor [20] using the same synthesis technique.

Terbium doping in $ZnGa_2O_4$ nanophosphor was done for the first time using wet chemical method. Neither any capping agent nor expensive chemicals were utilized for the nano phosphor synthesis. The preparation temperature is also very low [90 °C] as compared with the previous reports on $ZnGa_2O_4:Tb^{3+}$ like 1250 °C [16], 550 °C [17] and 280 °C [18]. We implemented the characterization techniques like X-ray diffraction (XRD), diffuse reflectance spectroscopy (DRS), transmission electron microscopy (TEM) and photoluminescence (PL) for the analysis of resultant $ZnGa_2O_4:Tb^{3+}$ nanophosphor.

2. Experimental

2.1. Materials

All the chemicals used are of analytical grade with high purity and they are zinc acetate [Zn $(CH_3COO)_2$, Sigma, 99.9%], gallium

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