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Low temperature synthesis and characterization of zinc gallate quantum dots for optoelectronic applications

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ABSTRACT

Quantum dots of zinc gallate ($ZnGa_2O_4$) has been synthesized by wet chemical route at a temperature of 90 °C. The structural, linear and nonlinear optical properties of $ZnGa_2O_4$ were investigated. Electronic band structure calculations are carried out for $ZnGa_2O_4$, using density functional approach and the electron effective mass, hole effective mass and band gap are evaluated as 0.27m_e, 16.10m_e and 4.58eV respectively, from which the exciton Bohr radius is estimated to be 2.72 nm. From transmission electron microscopy, size of cubic spinel $ZnGa_2O_4$ quantum dots is obtained as 8.3 nm. The theoretical band gap for $ZnGa_2O_4$ estimated using Brus equation is 4.6eV and it agrees with band gap assessed from diffuse reflectance measurements. The sample shows blue emission under UV excitation. Nonlinear optical characterization of $ZnGa_2O_4$ is done using open and closed aperture z scan technique and it shows saturable absorption and self-defocusing behavior making it suitable for display and nonlinear photonic devices.

1. Introduction

Low temperature synthesis of zinc gallates ($ZnGa_2O_4$) which are generally grown at elevated temperatures is of great interest because, low temperature leads to reduction in particle size and its significant applications in the area of optoelectronics. Zinc gallium oxide [$ZnGa_2O_4$], known as zinc gallate is one of the prominent gallate which possess self-activated blue emission under UV excitation [1,2]. It owns varied application in low voltage field emission displays (FEDs), high definition television (HDTVs), electroluminescent devices (ELDs) and vacuum fluorescent displays (VFDs) [1–5]. Since it has a low resistivity at room temperature [6], it finds application in transparent conducting oxides (TCO) [1]. This ternary oxide material crystallizes in normal cubic spinel structure with Fd3m space group [7]. The tetrahedral and octahedral sites are occupied by Zn^{2+} and Ga^{3+} ions respectively. The band gap of this material is well suited to make it an excellent phosphor host material [8,9]. There are no reports of the nonlinear optical characterization of this material. The exciton Bohr radius of the material is also evaluated for the first time.

The common methods used for the synthesis of zinc gallate are sputtering [10], pulsed laser ablation [11], hydrothermal synthesis [12] and solid state reaction [1,13,14]. In these techniques, high synthesis temperature is needed for the formation of zinc gallate. But sol-gel method is simple and involves low temperature precipitation. There are reports in which the sol-gel method is used for the zinc gallate synthesis but most of them required post annealing at a higher temperature [15,16]. In some cases there is consumption of chemicals which are expensive and sometimes toxic, for synthesis [17]. In our work, we employed an environmental friendly wet chemical route for the growth of the zinc gallate at a lower temperature of 90 °C, using normal laboratory hot air oven. Here the formation of quantum dots of zinc gallate takes place without any post calcination and capping agent.

The synthesized zinc gallate quantum dots are characterized structurally by x-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and transmission electron microscopy (TEM). Scanning electron microscopy (SEM) is used for the surface morphological analysis. The quantum dots are optically analyzed with linear and nonlinear techniques like UV–Vis–NIR absorption

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