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# Synthesis of ultrafine β-$Ga_2O_3$ nanopowder via hydrothermal approach: A strong UV "excimer-like" emission

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ABSTRACT

Interest in nano-oxides has emerged from their technological applications in fields like microelectronics, catalysis, coatings, energy storage, and environment protection and remediation. There are various available methods for preparation and production of materials, but developing new routes to nanocrystalline materials is a challenging task for materials scientists. An innovative newly developed pathway to the synthesis of gallium oxide nanopowders, so-called "high-productivity/high-yield" process is presented here. The utilized method is simple, fast and environmental friendly. Ultrafine nanopowders of gallium oxide is prepared by addition of hydrogen peroxide ($H_2O_2$) to metal gallium (Ga) via a hydrothermal route at a low temperature (100 °C) and without any surfactant. β-$Ga_2O_3$ nanopowders are achieved directly in an autoclave when the initial molar ratio of Ga to O is 1:4. Combination of X-ray diffraction (XRD) and fluorescence analysis are employed to characterize the resulting nanopowders. Detailed results are discussed.



## 1. Introduction

One of the challenges faced by materials scientists today is the synthesis of materials with desired composition, structure, and properties for specific applications. The worldwide need for perfectly controlled materials devoted to specific applications is continuously increasing, especially in high potential fields such as energy, pharmacology or optic. While one can evolve a well-reasoned approach to the synthesis of oxide materials, serendipity has played an important role in making new materials. Rational synthesis of materials requires knowledge of crystal chemistry, besides thermodynamics, phase equilibrium, and reaction kinetics. The physiochemical properties of many materials are determined by the choice of synthetic methods. Selection of the synthetic route is crucial to control the composition, structure, and morphology of a chosen material. Nonuniform powder compositions make reproducible component fabrication difficult because of chemical inhomogeneity and voids in a microstructure. Greater purity and homogeneity from novel methods can lead to improved physical properties. Oxide materials are usually prepared by solid-state reactions, i.e., either by the ceramic method or by precipitation from a solution and subsequent decomposition. A variety of metal oxides, both simple and complex, are prepared by the conventional ceramic method. This involves the mixing of constituent metal oxides, carbonates, etc., and their repeated heating and grinding. These methods are used on both laboratory and industrial scale. However, there is an increasing demand for alternate routes to the synthesis of oxide materials that give superior properties when compared with those available from conventional methods. The present trend is looking for a better control of stoichiometry, structure, and phase purity of metal oxides. Soft chemical routes are now increasingly becoming important to prepare a variety of oxides including nanocrystalline oxide materials. These approaches make use of simple chemical reactions like co-precipitation, sol–gel, ion exchange, hydrolysis, acid leaching, and so on, at considerably low temperatures compared to the ceramic method. Use of precursors, intercalation reactions, electrochemical methods, hydrothermal process, and self-propagating high-temperature synthesis (SHS) are some of the other contemporary methods. Gallium oxide $Ga_2O_3$ is an important wide-band-gap semiconductor (4.9 eV) having a wide range of applications from semiconductor lasers, and switching memories to high-temperature gas sensors [1–4]. In view of the technological applications of $Ga_2O_3$ low-dimensional nano-structures, the studies on $Ga_2O_3$ atomic clusters have also been revived [5–7]. Gallium oxide $Ga_2O_3$ has five polymorphs, α, β, γ, δ and ε. Among these polymorphs, β-$Ga_2O_3$ with a monoclinic structure is the only thermodynamically stable phase, while the others are metastable and the ε-$Ga_2O_3$ exhibits the lowest symmetry [8–11]. It is observed to undergo a transition to the hexagonal α-$Ga_2O_3$ phase at 4.4 GPa, 1000 °C [12]. After quenching to room temperature and pressure, α-$Ga_2O_3$ remains in a metastable phase. The nano-structures of $Ga_2O_3$ are also found to be in the α phase [13]. β-$Ga_2O_3$ emits a wide range of wavelengths from infrared to ultraviolet (UV) [15–17]. This property makes it a candidate also for catalytic, and optoelectronic device applications [18–20]. Recently, the study of the synthesis and optical properties of one-dimensional β-$Ga_2O_3$ nano-structures has attracted

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