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Structural, optical and magnetic properties of gadolinium sesquioxide nanobars synthesized via thermal decomposition of gadolinium oxalate

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ABSTRACT

Gadolinium oxide nanobars were obtained by thermal decomposition of gadolinium oxalate, which was synthesized by the chemical precipitation method along with glycerol. The functional group analysis and formation of gadolinium oxide from gadolinium oxalate were characterized by the Fourier transform infrared spectroscopy and thermo gravimetric analyzer. The crystal structure, average crystallite size, and lattice parameter were analyzed by X-ray diffraction technique. Moreover, Raman shifts, elemental composition and morphology of the gadolinium oxide was widely investigated by the laser Raman microscope, X-ray photoelectron spectroscopy, FE-SEM-EDAX and HR-TEM, respectively. Furthermore, the optical properties like band gap, absorbance measurement of the gadolinium oxide were extensively examined. In addition, the paramagnetic property of gadolinium oxide nanobars was explored by the vibrating sample magnetometer.

1. Introduction

Metal oxide nanomaterials have great interest within the researchers and have shown considerable attention in the last few years to the field of technological importance and scientific application. The application of such materials as memory devices [1], primary gate dielectric material [2], medical imaging and cancer therapy [3], electrochemical sensor [4], phosphor screens and fluorescent materials [5] were due to its unique magnetic, electrical, electronic, absorption and emission properties. In particular, the paramagnetic behavior of the nanostructured rare-earth metal oxides was due to the unpaired f-electron spin values which have been applied to the biomedical field of therapeutic agent combining imaging [6], MRI contrast agent [7] and anticancer drug delivery [8].

Gadolinium, the most abundant element in the rare-earth metal family has tremendous importance, because of its high magnetic moment due to the seven unpaired electrons ($^8S_{7/2}$) [9]. Moreover, compared with other metal ions, gadolinium possesses more unpaired electrons. In gadolinium chelates, gadolinium (III) ions can very efficiently induce the longitudinal relaxation of a water proton [10]. Since, it has been suggested that gadolinium sesquioxide nanoparticles were preferred than gadolinium chelates, because chelates have higher molecular weight and shorter spin lattice relaxation time (T) [11]. Furthermore, it was well known that, the behavior of nanostructured metal oxides purely depends on their grain size [12–14].

Gadolinium sesquioxide has some unique chemical and optical features, such as sharp emission lines, long lifetimes, superior photostability, large Stokes shifts, good chemical/physical stability, and low toxicity [15–17]. Gadolinium based nanoparticles were promising host matrix for upconversion fluorescence [18], single phase multifunctional bio-probes [19]. In addition, size modification in the structural, optical and electronic properties of a variety of nanomaterials has been widely reported [1,20,21]. Gadolinium sesquioxide was synthesized as nanostructured material with the assistance of surfactants or polymers [22,23]. By varying the concentration of glycerol (1–10%) during the reaction, the size of the nanoparticles was regulated from 270 nm to 10 nm [24]. The focus of this work has been to explore the structural, optical, and magnetic property of size-reduced gadolinium sesquioxide obtained by absence of any polymer, capping agents or surfactants. In this present work, we have synthesized nanostructured gadolinium sesquioxide (Gd_2O_3) in the presence of glycerol by the chemical precipitation–decomposition method. The detailed investigation and discussion about thermal stability, crystal structure, optical energy band gap, morphology, elemental composition and magnetic property of the Gd_2O_3 nanobars were reported.

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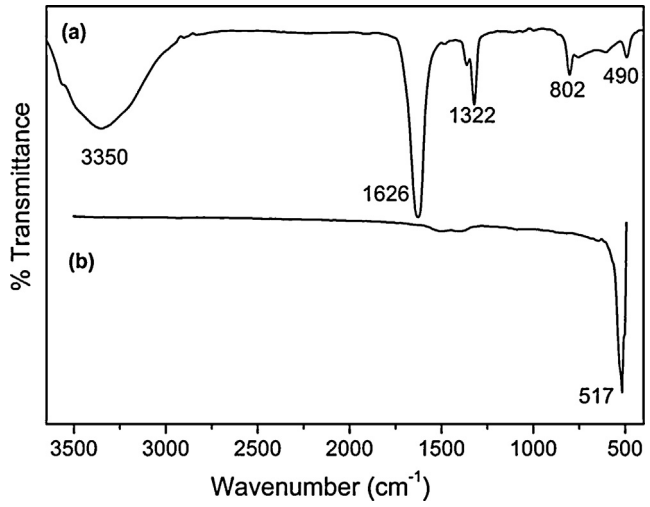

Fig. 1. FTIR spectra of (a) $C_6H_{20}Gd_2O_{22}$ and of (b) Gd_2O_3.

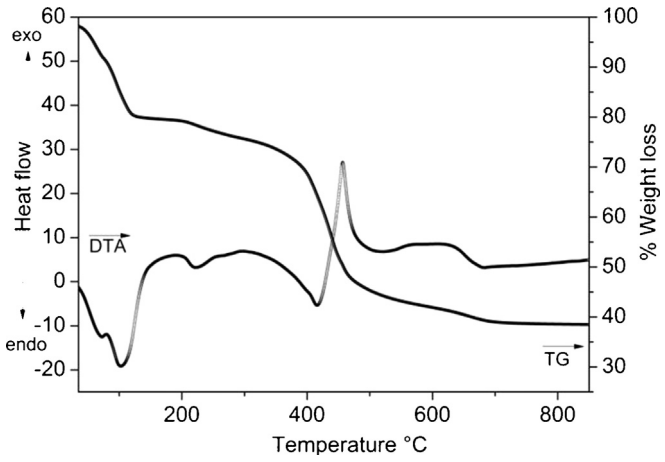

Fig. 2. TGA-DTA analysis of as-prepared $C_6H_{20}Gd_2O_{22}$.

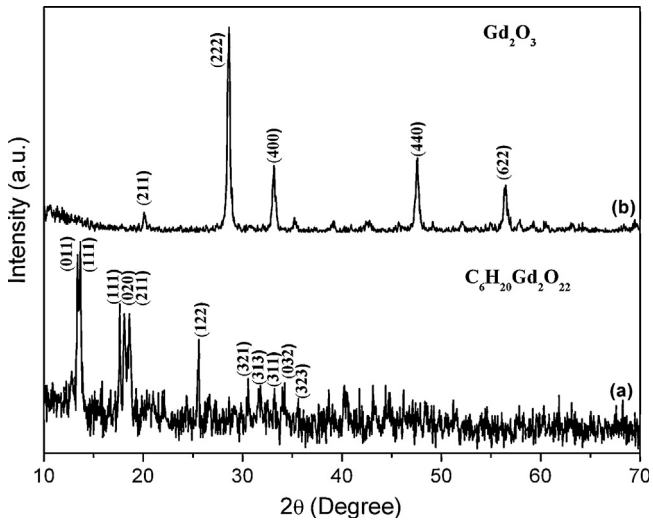

Fig. 3. XRD pattern of (a) $C_6H_{20}Gd_2O_{22}$ and of (b) Gd_2O_3.

2. Experimental

2.1. Materials

Gadolinium nitrate hexahydrate ($Gd(NO_3)_3{\cdot}6H_2O$) was purchased from Sigma–Aldrich. Ammonium oxalate ($(NH_4)_2C_2O_4$), glycerol and ethanol were purchased from SRL and used as received. Double distilled water used as solvent throughout the experiment.

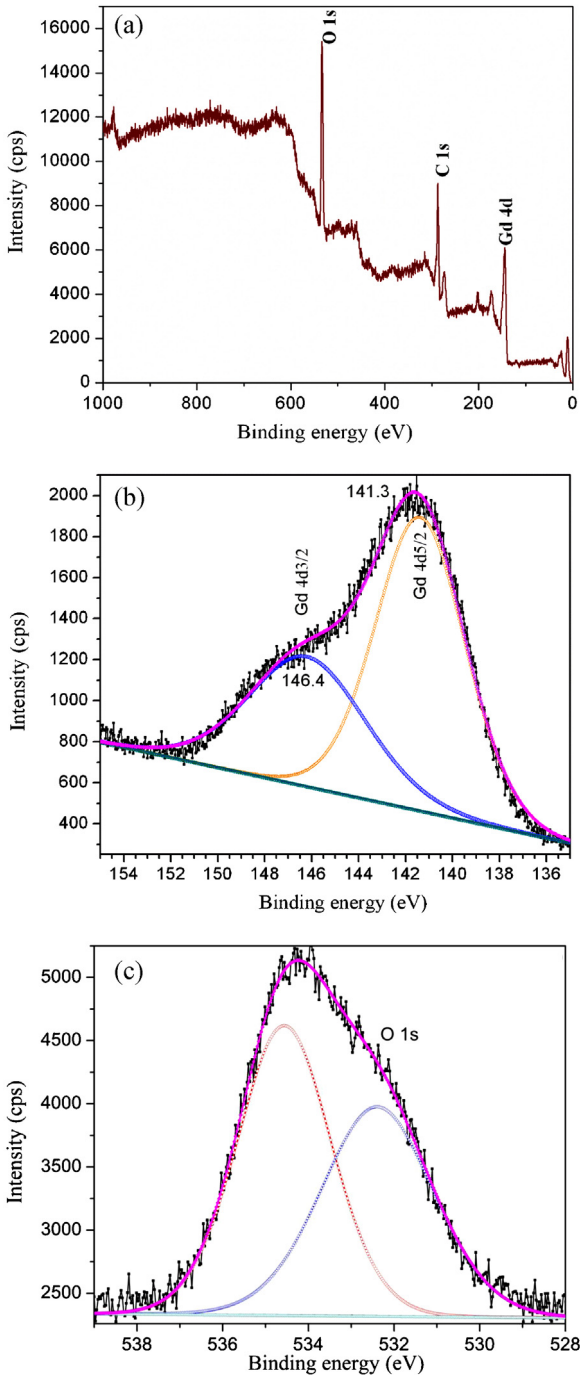

Fig. 4. XPS spectra of Gd_2O_3 (a) survey spectrum, (b and c) core level spectrum of Gd (4d) and O (1s), respectively.