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Study of the structural, magnetic and dielectric properties of $GdMnO_3$-$GdMn_2O_5$ nanocomposites via sol-gel route

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Highlights

- $GdMnO_3$-$GdMn_2O_5$ nanocomposite was synthesized via sol–gel route.
- Raman, magnetic and dielectric studies were analyzed for $GdMnO_3$-$GdMn_2O_5$ samples.
- $GdMnO_3$-$GdMn_2O_5$ was also analyzed by XRD, W-H plot, EDX and TEM studies.
- Weak ferromagnetic behavior was found from the HT-VSM measurement.
- Applied frequency & temperature play a vital role on electrical properties.

Abstract

Using the sol–gel route, $GdMnO_3$-$GdMn_2O_5$ nanocomposite was synthesized at 1000 °C. For the first time, in the above room temperature conditions, Raman, magnetic, and dielectric measurements were taken of the synthesized $GdMnO_3$-$GdMn_2O_5$ composite.The diffraction peak position resulting from a XRD pattern confirmed the formation of $GdMnO_3$ and $GdMn_2O_5$, as well as an orthorhombic structure. Using the Raman spectra, three Raman peaks (363,475 and 608 cm^{-1}) were detected for the synthesized composite at 350 and 400 K, indicating the formation of a bi-phase of gadolinium manganese oxide. A TEM image of the synthesized product revealed agglomerated spherical particles with a polycrystalline structure. A weak ferromagnetic behavior was found for the synthesized composite using the high-temperature vibrating sample magnetometer. From the dielectric study, it is inferred that the applied frequency and temperature play a vital role affecting the dielectric constant, dielectric loss and AC conductivity values in the synthesized composite.

Graphical abstract

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Introduction

Gadolinium manganese oxides, such as $GdMnO_3$ and $GdMn_2O_5$ composites, have an orthorhombic crystal structure with paramagnetic behavior at room temperature, whereas they have an antiferromagnetic nature at low temperatures [1], [2]. In addition, the above-said materials have been studied for electrical and magnetic characterization by many researchers, and they claimed that $GdMnO_3$ and $GdMn_2O_5$ materials have multifunctional properties like ferroelectricity, good dielectric constant, and magnetic electric couple effect [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12].The above properties are very useful in spintronics-based devices and electrical device applications [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12]. Strong or weak interaction between magneto-electric couple effects depends on the formation of $GdMnO_3$ or $GdMn_2O_5$ material. According to recent reports, dopants such as Ba, Ca, Yb, Fe, Zr, and Cr introduced into the $GdMnO_3$ or Nd-doped $GdMn_2O_5$ material improve the electrical and magnetic behavior when compared to the undoped $GdMnO_3$ or $GdMn_2O_5$ material [2], [13], [14], [15], [16], [17], [18]. Deepa Singh et al. [2], Ye et al. [4], Guo et al. [19] and Wang et al. [20] investigated the electrical and magnetism behavior, catalytic activity, and optical properties of the $GdMn_2O_5$ admixture on $GdMnO_3$ compounds using various chemical routes including co-precipitation method, solid-state reaction, sol–gel method followed by in-situ generated by acid treatment and polymerized complex method. In the present work, using the sol–gel reaction, $GdMn_2O_5$ admixture on the $GdMnO_3$ material has been synthesized and followed by investigation into the structural (Raman spectra) characteristics, magnetic and dielectric properties at above room temperature conditions for the first time. In addition, the above sol–gel methods have some merits for synthesizing of the title compound, such as fast hydrolysis and condensation at short reaction intervals, size control and low cost.

Section snippets

Experimental

$GdMnO_3$-$GdMn_2O_5$ nanocomposite was synthesized by mixing 1.734 g of gadolinium nitrate ($Gd(NO_3)_3{\cdot}6H_2O$) and 0.6877 g of manganese nitrate ($Mn(NO_3)_2{\cdot}4H_2O$) in 50 mL of water medium under magnetic stirring. 1.164 g of carbonyl diamide (NH_2-CO-NH_2) was added to the above solution and magnetically stirred for 5 hrs at 70–80 °C. Following this chemical reaction, a carbonyl diamide-gadolinium-manganese oxide precursor gel was formed, which was heat-treated at 400 °C to yield the as-prepared $GdMnO_3$-$GdMn_2O_5$…

Results and discussion

Using an X-ray instrument, X-rays passed on the synthesized $GdMnO_3$ powder, diffraction angles were scanned, and the XRD pattern is shown in Fig. 1b. After that, a careful examination of the XRD pattern of the synthesized material reveals that all the diffraction peaks' positions are indexed as well as their respective miller index planes. When the obtained diffraction peak positions are compared to the previously reported XRD patterns of $GdMnO_3$ and $GdMn_2O_5$, the formation of the orthorhombic…

Conclusion

In summary, a $GdMnO_3$-$GdMn_2O_5$ nanocomposite was synthesized using the sol–gel route and its crystalline structure, particle size, vibration modes, magnetism behavior, and dielectric properties were investigated. XRD analysis revealed that the synthesized product has an orthorhombic crystal structure with a bi-phase compound ($GdMnO_3$ and $GdMn_2O_5$).

The slight variation in the Raman shift was detected in the Raman spectra of the $GdMnO_3$-$GdMn_2O_5$ at temperatures applied from 350 to 400K. The Raman…

CRediT authorship contribution statement

J. Gajendiran: Methodology, Investigation, Writing – original draft, Writing – review & editing, Conceptualization. **S. Gnanam:** Investigation, Writing – original draft, Writing – review & editing, Conceptualization. **K. Ramachandran:** Formal analysis. **V.C. Bharath Sabarish:** Methodology, Conceptualization. **A. Durairajan:** Formal analysis. **M.P.F. Graça:** Formal analysis. **M.A. Valente:** Formal analysis. **S. Gokul Raj:** Writing – review & editing. **G. Ramesh Kumar:** Conceptualization, Investigation, Writing…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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