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Sol-Gel Synthesized $Y_{3-x}Bi_xAl_{0.5}Fe_{4.5}O_{12}$ nanoparticles: Structural and electrical investigations

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ABSTRACT

Sol-gel auto-combustion synthesized $Y_{3-x}Bi_xAl_{0.5}Fe_{4.5}O_{12}$ nanoparticle powders were finally sintered at 1150 °C for 10 h, on the basis of DTA/TG analysis. The crystalline structure was investigated by using X-ray diffractograms. The XRD analysis confirms a single phase garnet structure for $x \geq 1.0$. The DC resistivity as a function of temperature was studied using the two-probe method and it gives the decreasing trend with increasing temperature for all samples.

Key words Sol-Gel Synthesis, garnet, D.C. resistivity

INTRODUCTION

Pure and substituted yttrium iron garnet (YIG) is an important substance used in magneto-optical and microwave application [1, 2]. Yttrium iron garnet useful for microwave devices like phase shifters, circulators oscillators and optical isolators because they have comparatively low dielectric loss behavior, narrow line width at GHz frequencies and low magnetization [3,4]. YIG with chemical formula ($Y_3Fe_5O_{12}$) has unique electromagnetic, thermal and

Effect of Bismuth Ions on the Structural, Dielectric and Morphological Properties of Aluminum Doped Yttrium Iron Garnet Nanoparticles Powders Synthesized by Sol-Gel Auto-Combustion Method

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Abstract

The nanocrystalline $Y_{3-x}Bi_xAl_{0.5}Fe_{4.5}O_{12}$ powders with x = 0.0, 0.5, 1.0, 1.5 and 2.0 composition were synthesized by a sol-gel auto-combustion route. The elemental compositions of the synthesized samples were confirmed by the EDAX. The structural properties were studied by using X-ray diffractometry (XRD). The morphology of the samples was studied with the help of transmission electron microscopy (TEM). The frequency dependence dielectric measurements were carried out by LCR-Q meter. The micrographs of TEM established that nanoparticles are nano-sized grains with the cluster. The particle sizes are in 100-150 nm range observed from the TEM. It is observed that the porosity and specific surface area decreases with increasing Bi composition. The dielectric permittivity and dielectric loss tangent decreases with applied frequency and follow Maxwell-Wagner's two-layer model. The dielectric parameters were found to be increases with the substitution of bismuth concentration. AC conductivity increases with applied frequency and Bi composition.

Keywords: Stoichiometric; structural; morphological; dielectric properties

INTRODUCTION

Yttrium iron garnet has superior properties like low magnetization, low dielectric loss behavior, low propagation and high electrical resistivity hence it is used in microwave devices [1, 2]. The properties of yttrium iron garnet (YIG) can be altered for the specific application by substituting magnetic and non-magnetic dopants in YIG. Trivalent ion substituted YIG is an important substance used in magneto-optical devices [3, 4]. Yttrium iron garnets crystallize in the cubic crystal structure, exist three crystallographic lattices a, b and c sites. The non-magnetic Y^{3+}ion occupy dodecahedral sites 24(c), magnetic Fe^{3+} ions occupy both octahedral 16(a) and tetrahedral 24(d) sites. The structural, electrical, dielectric, magnetic properties of YIG can be changed by substituting various trivalent ions like Dy^{3+}, Ce^{3+}, Er^{3+}, Tb^{3+} or Bi^{3+} with dodecahedral sited Y^{3+} ion [5, 6]. In the recent years, many researchers work on YIG and substituted YIG. Ftema W. Aldeba et al [7] fabricated $Tb_xY_{3-x}Fe_5O_{12}$ by sol-gel method. They observed nanoparticles prepared with 40-59 nm grain size. Rodziah et al [8] prepared indium substituted YIG and observed that the FMR linewidth broadening decreases up to x = 0.3 after that FMR increases. G. B. Turpin [9] explains the anisotropy in the electrical resistivity of Ca-substituted YIG. Hongjie Zhao et al [10] prepared $Bi_xY_{3-x}Fe_5O_{12}$ using the sol-gel route. They reported that the dielectric constant and loss reduces with the substitution of Bi.

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Polycrystalline to preferred-(100) single crystal texture phase transformation of yttrium iron garnet nanoparticles†

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Nanocrystalline Ce-substituted yttrium iron garnet (YIG) powders of different compositions, $Y_{3-x}Ce_xFe_5O_{12}$ ($0 \leq x \leq 2.0$), were synthesized by a combination of sol–gel auto-combustion and solid-state synthesis techniques. The as-obtained powder samples were sintered at 1150 °C for 10 h. The garnet structure formation is confirmed by the X-ray diffraction pattern, which shows that the calculated lattice parameter increased for $x = 1.0$ and shows a decreasing trend for $x \geq 1.0$ with the addition of cerium ions. The lattice parameter increased from 12.38 Å to 12.41 Å for $x \leq 1.0$ whereas it decreased from 12.412 Å to 12.405 Å with the cerium composition for $x > 1.0$. The average particle size determined by high resolution transmission electron microscopy is in the range of 50 to 90 nm and found to increase with the substitution of cerium ions in YIG. The room temperature magnetic parameters such as saturation magnetization, coercivity and remanence magnetization are greatly affected by the substitution of cerium ions. The values of saturation magnetization decrease from 25.5 to 15 emu g^{-1} whereas coercivity increases from 1 to 28 Oe with the substitution of cerium ions. The pure YIG sample shows polycrystalline nature that changed towards a single-crystal structure leading to a preferred-(100) orientation with the Ce substitution. The change from a ring to a spotty pattern observed in SAED confirmed the crystalline phase transformation and is well supported by HRTEM and magnetic measurements. The behavior of magnetic and electrical properties is well supported by the poly- and single-crystalline nature of YIG and Ce-YIG, respectively. The crystal structure transformation in YIG brought about by Ce substitution could unveil enormous opportunities in the preparation of single-crystal materials from their polycrystalline counterparts.

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1. Introduction

The unique properties of single crystals are often different compared to their polycrystalline counterpart. These properties provide numerous opportunities for a variety of applications; however, manufacturing cost often precludes their widespread application. For many unique applications, such as optical lasers and X-ray scintillators, the growth of single crystals is highly complicated owing to the requirement of optimized concentrations and uniform distribution of "active" chemical dopants. It would be revolutionary and highly advantageous if single crystals of a specific compound could be cost-effectively synthesized from their polycrystalline counterpart. The crystal growth method is a common method to fabricate single crystals through solidification known as Bridgman–Czochralski processes.[1,2] Controlled abnormal grain growth at one or several sites in the polycrystalline sample at high temperatures is also a promising methodology to grow large-sized single crystals.[3–5] Further, the polycrystalline to single crystal growth can be achieved without passing the material through a melting stage denoted as solid-state crystal conversion.[6] Though these methods are highly sophisticated and produce good quality single crystal materials, they are time consuming. The present work presents early attempts, results and observations on converting polycrystalline yttrium iron garnet (YIG) into preferred (100)-oriented single crystals with the combination of sol–gel autocombustion and solid-state reaction methods.

Polycrystalline YIG is a well-known ferromagnetic material that shows magneto-optic properties and is applicable in different devices, ranging from optical communications to

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Influence of gadolinium (Gd^{3+}) ion substitution on structural, magnetic and electrical properties of cobalt ferrites

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ABSTRACT

In present work, $CoFe_{2-x}Gd_xO_4$ nanoparticles with compositions x = 0.0, 0.02, 0.04, 0.06, 0.08 and 0.1 were successfully synthesized by a sol-gel auto-combustion route sintered at 700 °C for 5 h. The effect of Gd^{3+} substitution on structural, morphological, magnetic and dielectric properties has been investigated. The X-ray diffraction with Rietveld refinement reveals that Gd-substituted Co-ferrites are prepared in a single-phase cubic spinel structure. Fourier transform infrared and Raman spectra confirm the single-phase formation of cubic spinel structure. It is observed that the lattice constants decrease from 8.3776 to 8.3711 Å with the substitution of Gd composition from x = 0.0 to 0.1. This is because of the distortion of the lattice structure with the introduction of Gd^{3+} ions. The crystallite size calculated from X-ray diffraction decreases from 29 to 19 nm with Gd^{3+} composition which confirms the formation of nanocrystalline samples. These values are good agreement with crystallite size calculated by the Williamson Hall method. The distribution of cations among the octahedral B and tetrahedral A-site was estimated by the computational method. Field emission scanning electron microscopy (FE-SEM) also confirmed the nanostructural nature in the range of 200–300 nm. Energy dispersive analysis (EDAX) proves chemical purity and stoichiometry. Fourier transform infrared spectra show the main vibration band of spinel structure. Gd-doped Co-ferrite shows the characteristics Raman active modes of spinel structure. Magnetic study reveals that saturation magnetization decreases from 77.37 to 51.38 emu/g with an increase of Gd composition in cobalt ferrites. It is observed that the coercivity of samples is increased from 976 to 1281 Oe with Gd substitution. Dielectric properties measured from LCR-Q meter exhibits the Maxwell–Wagner model.

1. Introduction

The research of the doped ferrites is more attracted in recent years because of their wide applications in various technologies. Spinel ferrites with chemical formula MFe_2O_4 (Where, M = Ni, Co, Zn, etc.) have superior properties like optical, electrical and magnetic, therefore, they are technologically and scientifically important [1,2]. In MFe_2O_4 structure, metal cation M occupies tetrahedral (A) site, Fe occupies octahedral (B) site and oxygen anions form a close-packed face-centered cubic structure [3,4]. Among these ferrites, $CoFe_2O_4$ was widely studied in the last decade due to its properties like high Curie temperature, high electrical resistivity, high coercivity, high mechanical and chemical stability, high magnetocrystalline anisotropy and moderate saturation magnetization [5,6]. These properties give extensive technological applications such as recording media, drug delivery systems, catalysis, sensors, and microwave devices [7–10]. $CoFe_2O_4$ crystallizes in spinel cubic structure with space group Fd-3m in nanoparticles and it crystallizes in inverse spinel in case of bulk samples. In the case of the spinel structure, divalent cobalt ions (Co^{2+}) occupy at both octahedral and tetrahedral sites and its occupancy depends on

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Effect of Ho^{3+} Ion Doping on Thermal, Structural, and Morphological Properties of Co–Ni Ferrite Synthesized by Sol-Gel Method

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Fabrication of Bi^{3+} substituted yttrium aluminum iron garnet (YAIG) nanoparticles and their structural, magnetic, optical and electrical investigations

Rameshwar B. Borade, S. B. Kadam, Devendra S. Wagare, R. H. Kadam, Sagar E. Shirsath, S. R. Nimbore & A. B. Kadam

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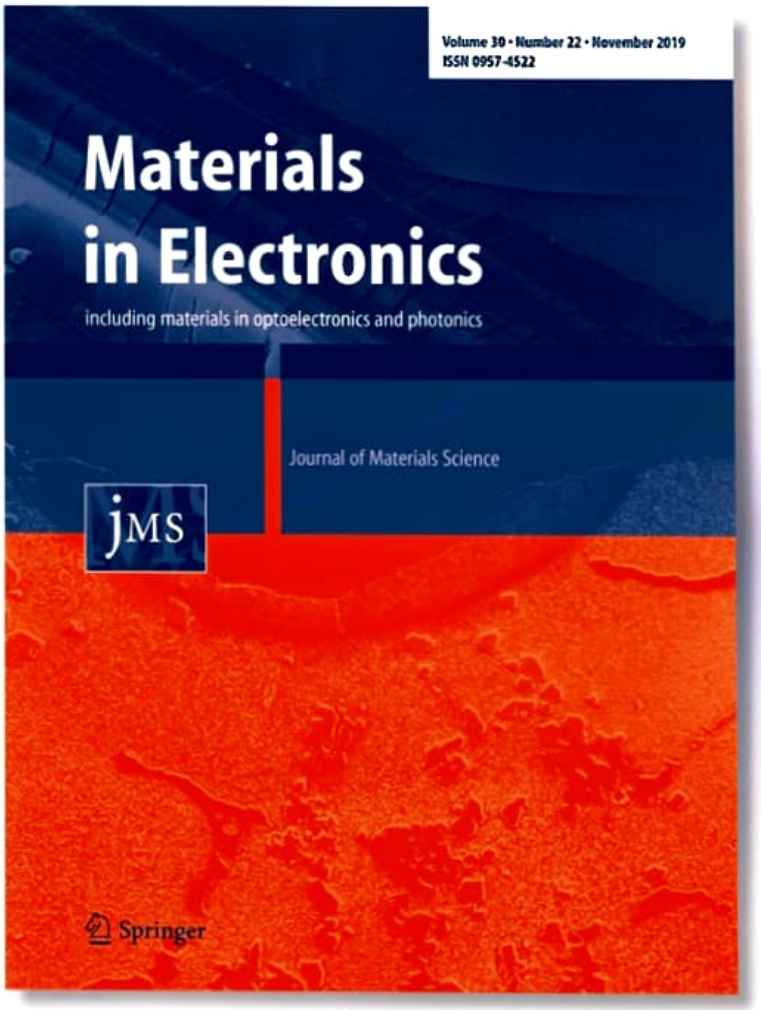

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