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Influential incorporation of RE metal ion (Dy^{3+}) in yttrium iron garnet (YIG) nanoparticles: Magnetic, electrical and dielectric behaviour

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Abstract

Dy^{3+} incorporated yttrium iron garnet ($Y_{3-x}Dy_xFe_5O_{12}$) nanoparticles were fabricated via self-combustion assisted solution gelation route. The mono-phase formation and nanocrystalline nature of the fabricated samples were confirmed through X-ray employed diffraction studies. It demonstrates mono phasic garnet-cubic-spinel lattice formation along with an average particle size varying between 6 and 9 nm. The lattice constant determined via XRD analysis is found within the scope of 12.356 Å to 12.424 Å. The morphological aspects were visualized by the SEM analysis which uncovered the spherical shaped nature of grains with the size in nanometer range. The compositional verification was undertaken with the help of EDAX analysis which ensured the presence of elements in desired proportions. The magnetic parameters were diminished with Dy^{3+} content x while the magneton number n_B increased with increasing Dy^{3+} content x. The electrical properties were measured using 'two probe technique' with varying temperature. The electrical resistivity diminishes with increment in temperature demonstrating semiconducting conduct. Values of various dielectric parameters show strong frequency dependence. With the increase in frequency, the dielectric parameters get decreases within the scope of 10^4 Hz–10^6 Hz. The magnetic, electrical and dielectric conduct of these prepared nanoparticles show its relevance in high frequency device development applications.

Introduction

Yttrium iron garnets (YIG) are the individual member of the significant classes of ferrite generally valuable in microwave gadget applications [1]. These materials display astounding electrical and magnetic properties. Based on its effective treatment of microwave control and with phenomenal electrical, magnetic and magneto-optical properties; it has become a mechanically significant material for making microwave recurrence gadgets [2]. Communication frameworks have made the need of materials having limited resounding line width and low immersion charge [3,4]. Yttrium iron garnets are reasonable for these requests since they have the restricted full line width, low immersion polarization, high electrical resistivity, high radiation and substance security, low warm development, better electromagnetic properties, low misfortune, and so on [[5], [6], [7]].

YIG is a delicate ferrimagnetic material having the cubic garnet structure which has a place with Ia-3d space gathering. The structure of YIG comprises of three sub-lattice sections to be specific the 'octahedral' (a) involved by 2 Fe ions, the 'dodecahedral' (c) involved by 3 yttrium ions & tetra (d) locale involved by 3 Fe ions [8]. Both (Y^{3+} and Fe^{3+}) the trivalent metallic ions present in these destinations make YIG a particularly reasonable material for attractive examinations. The most significant connection is the super-trade association between iron ions at octahedral and tetrahedral destinations.

YIG, because of their great attributes in Faraday turn (Faraday impact or Faraday pivot is a magneto-optical marvel for example, a collaboration among the light and magnetic field in a medium); they are in effect broadly utilized for magneto-optical applications like optical isolators, attractive sensors, circulators, shifter, and so on [5,[9], [10], [11]]. The unadulterated and subbed YIG are broadly utilized in numerous innovative applications [[12], [13], [14]]. The subbed YIG have been utilized in non-complementary microwave gadgets. The significant magneto-electrical properties of YIG rely upon different factors, for example, technique for readiness, type and measure of dopant and microstrain [[15], [16], [17], [18], [19], [20]]. It is verifiable truth that the microstructure of sintered materials depends especially on the attributes of the underlying powders, for example, purity. In writing, different amalgamation strategies have been accounted for the blend of garnets, for example, co-precipitation [21,22], sol-gel [[23], [24], [25]], strong state sintering procedure, reverse micelle, self-burning [26,27], and so on [[28], [29], [30], [31], [32], [33]].

The nanocrystalline YIG as a component of preparative parameters viz. sintering time, temperature and so on are examined by the number of analysts. Geller et al have revealed magnetic conduct of heavier rare earth garnets [34]. Guo et al have revealed the union of (YIG) by auto ignition and antecedent plasma splash forms [35]. V. R. Caffarena et al have revealed the magnetic parameters of samarium-iron (Sm–Fe) garnet nano-powder got by co-precipitation [36]. Modi et al have revealed the spectral investigation of Fe^{3+} subbed YIG [37]. Guo Cuijing et al. have revealed impacts of In^{3+} on magneto-structural behaviour of YIG ferrites with lower immersion polarizations [38]. Pinkas et al have detailed sono-chemical blend of undefined yttrium iron oxide implanted in the acetic acid derivation grid [39].

The attractive associations in YIG which are identified with the entomb sub-grid trades, that is super trade cooperation amid Fe^{3+} at octa & tetra locales via O^{2-}. These sub-cross sections of YIG can be custom fitted by subbing different cations in a structure prompting changes in attractive properties. The synthesis and homogeneity are the fundamental parts, as both unequivocally decide its attractive properties. Yttrium ferrites formed by $Y_3Fe_5O_{12}$ (YIG) display intriguing dielectric properties, being a potential possibility for electronic applications. Y. Kohara et al. has displayed electro-magnetic impact in YIG [40]. Qinghui Yang et al. reported magnetic and dielectric studies of YIG exposed to a microwave enabled heat source [41]. They presumed that, the samples sintered in microwave radiation possess astounding magneto-dielectric properties. Y. J. Wu et al. detailed the magneto-dielectric parameters of Bi-subbed YIG ceramics [42]. Hongjie Zhao et al. revealed the Bi doped YIG [43]. In literature, diverse properties of YIG in the unadulterated and subbed structure has been accounted for. Notwithstanding, as far as we could possibly know the properties of Dy doped YIG nanoparticles are not detailed in the literature.

In perspective on the developing enthusiasm of YIG nanoparticles the point of the present studies was to improve the magnetic, electrical and dielectric parameters of YIG by incorporating Dy^{3+} ions in YIG. Nanoparticles of Dy doped YIG ($Y_{3-x}Dy_xFe_5O_{12}$) were set up and the impact of Dy^{3+} ions on magnetic, electrical and dielectric behaviour of YIG was explored utilizing standard strategies and results are displayed here.

Section snippets

Experimental procedure

For the synthesis purpose, all the source materials in the form of nitrates with purity of 99.99% were acquainted from the Sigma-Aldrich. Dy doped YIG nanoparticles (DYIG NP's) with chemical formula $Y_{3-x}Dy_xFe_5O_{12}$ ($0.0 \le x \le 1.0$) were obtained through self-generated solution-gelation route. The in detail information of the self-generated solution-gelation reaction is explained in our previous reports. The schematic for reaction is given in Fig. 1. The step wise synthesis procedure is shown in …

X-ray diffraction

The samples of DYIG NP's was structurally characterized by X-ray diffraction (XRD) technique. All the XRD patterns of DYIG NP's are displayed in Fig. 3. The close observation of XRD pattern proves the development of mono phase cubic garnet structure. The XRD patterns show the reflections peaks (321), (400), (420), (431), (422), (521), (532), (444), (640), (642), (800), (840) and (842) indexed using standard dataset (PDF 83–1027). No impurity peaks other than garnet structure are observed in XRD …

Conclusions

Dy doped YIG NP's was successfully fabricated by self-ignition solution-gelation route. The mono phasic development and nanocrystalline nature was verified through XRD analysis. Average crystallite size was found in the range of 6–9 nm. Lattice constant increased with the increase in Dy content x. The morphological aspects was visualized by the SEM analysis which uncovered the spherical shaped nature of grains with the nanometric size. The compositional verification was undertaken with the help …

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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