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# Mini-Review: Advances in Garnet Ferrite Nanoparticles

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## ABSTRACT

**Garnet ferrite is needed to be continuously studied for the advancement of materials and applications in various fields. The physical properties of the garnet ferrite are structure-dependent. The various species in garnets are pyrope, almandine, spessartine, grossular are a group of silicate minerals that have been used since the Bronze Age as gemstones and abrasives found almost in every color. Various structural groups in garnet can be represented from the formula: $\{M_3^{II}\}$ $[M_2^{III}]$ $(Si_3)$ $O_{12}$ ; ($M_3^{II}$ = $Ca^{2+}$, $Mg^{2+}$, $Fe^{2+}$, $Mn^{2+}$ etc., $M_2^{III}$ = $Al^{3+}$, $Fe^{3+}$, $Cr^{3+}$ etc., Si = Si, As, V, Fe, Al). The garnet has played a crucial role in the newly designed world of science research, agriculture, biotechnology, technology, medicine, etc. In this critical review, we have written the reports given by several researchers of the current time.**

**Keywords: Garnet; Synthesis techniques; Applications of Garnet**

## I.INTRODUCTION

Garnet materials have unique electrical and magnetic properties best suited for high- frequency applications. All the way development in the use of garnet has been a topic of high- quality research due to their advanced technological applications. new materials research is focused on the invention of novel synthesis route enhanced the size-dependent properties structural, electrical, and magnetic properties, magneto-optical properties, luminescence properties, etc., which are greatly affected by several factors such as the method of preparation, nature, and type of dopant, synthesis parameters, and the synthesis conditions [1, 2]. Ferrites areclassified into three main groups as garnets ferrite; garnet ferrite and; Magnetoplumbite(Hexagonal ferrite) representing their significance [3].

### A) WHAT IS GARNET

Garnet is a naturally occurring silicate mineral deposit in the form of rocks, alluvial or aeolian deposits, mine deposits (granulated), river (or lacustrine), and beach deposits. Most mineral sands deposits are found in unconsolidated fossil shorelines several hundreds of meters to tens or even hundreds of

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kilometers inland from the present coastline due to an accumulation process of sedimentation that progressively brought eroded minerals from ancient volcanoes to fill the existing shoreline and having it regress till its actual position. **Figure 1** shows a naturally occurring garnet.

**Figure 1: Shows Naturally occurring garnet**

**B) GARNET GEOMETRY**

The general formula for garnet is;

$$M_3Fe_5O_{12} \qquad (1)$$

Where, M is one of the rare earth metal ions, including Y, La , Gd etc. The cubic unit cell contains 8 formula units or 160 atoms, which can be described as a spatial arrangement of 96 $O^{2-}$ with interstitial cations. The general chemical formula for garnet can also be written more informatively as;

$$(3R_2O_3)^c(2Fe_2O_3)^a(3Fe_2O_3)^d \qquad (2)$$

Here, R = Y, La, Ho, Dy, Gd, Yb, Nd, Sm, Er, Eu, Sc, Ce, Tb, Tm, Pr, Lu. In the above equation, the superscripts **c, a, d,** refer to the lattice sites such as dodecahedral or {c} - sites, octahedral or [a]-sites, and tetrahedral or (d)-sites. Usually, in the garnets the metallic ions are trivalent. The analogous mineral garnets are silicates of the form $Ca_3^c\ Fe_2^a\ Si_3^d\ O_{12}$. The prototype ferrimagnetic iron garnet is yttrium iron garnet:

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$$(YIG)\ \{Y3\}\ [Fe_2]\ (Fe_3)O_{12} \tag{3}$$

OR

$$Y_3Fe_5O_{12} \tag{4}$$

These two formulas have been preferentially adopted over many years in the magnetic community.

**C) APPLICATIONS OF GARNET**

The grooming highlighted applications of garnet nanoparticles make them suitable for various applications viz. biotechnology [4], Electro-Magnetic Interference (EMI) suppression [5], electrical switching applications [6], canting of the spins [7], superparamagnetic gesture [8],tissue imaging [9], multimodal diversity [10] telecommunication [11] recording heads [12], antenna rods [13], microwave devices [14], power switches, resonators, computer devices [15], targeted drug delivery [14], MRI [16], sensor [17], magnetic fluid [18], photocatalysis [19], electronic devices [20], energy storage [21], magnetic refrigeration, catalyst [22], transformer core [23] etc. It is important to take a simple look to address the unhighlighted or insufficient information regarding the garnet. There are many trust areas or the unleaded area in the field of characterization of garnet nanoparticles. Garnet nanoparticles could be continuously improved. Extensive work is needed by the research community to encounter the specific to broadly accepted applications of these garnet nanoparticles.

**D) SYNTHESIS ROUTES**

The novel synthesis methods, structural electrical, magnetic, optical properties of pure and substituted garnet studies are seen to be important from the application point of view. The synthesis of garnet nanoparticles can be carried out by the renowned synthesis methods in this race were the conventional ceramic method [24], micro-emission method [25, 26], hydrothermal method [27], wet chemical route [28], spray pyrolysis method [29], sol-gel auto-combustion [30,31], ball milling [32], ultra-fast pyro-synthesis [33], electro-deposition method [34], chemical co-precipitation method, etc. [35], the alkoxide route [36], sol-gel hybrid gel-derived precursors [37], glycolate method [38], hydrazine [39] and citrate-nitrate method [40]. The most popular and commonly used method of preparation is the solid-state reaction/ceramic method [41]. VinaySharma, Bijoy Kumar Kuanr [42] have synthesized Lanthanide doped YIG powders synthesized using the solid-state sintering method and predicted their uses as an efficient microwave broad bandwidth filter. Davis Campbell, Changsong Xu, Temuujin Bayaraa, and L. Bellaiche

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[43] have reported the Finite-temperature properties of rare-earth iron garnets in a magnetic field. Davis Campbell, Changsong Xu, Temuujin Bayaraa, and L. Bellaiche [43] have reported the Finite- temperature properties of rare-earth iron garnets in a magnetic field. Muhammad Yousaf et.al [44] has reported the magnetic characteristics and optical band alignments of rare earth ($Sm^{+3}$, $Nd^{+3}$) doped garnet ferrite nanoparticles. Dustin Witkowski and David A. Rothamer [45] have investigated the emission properties and temperature quenching mechanisms of rare-earth elements doped in garnet hosts. Rushikesh Fopase, Varun Saxena, Papori Seal, J.P. Borah, and

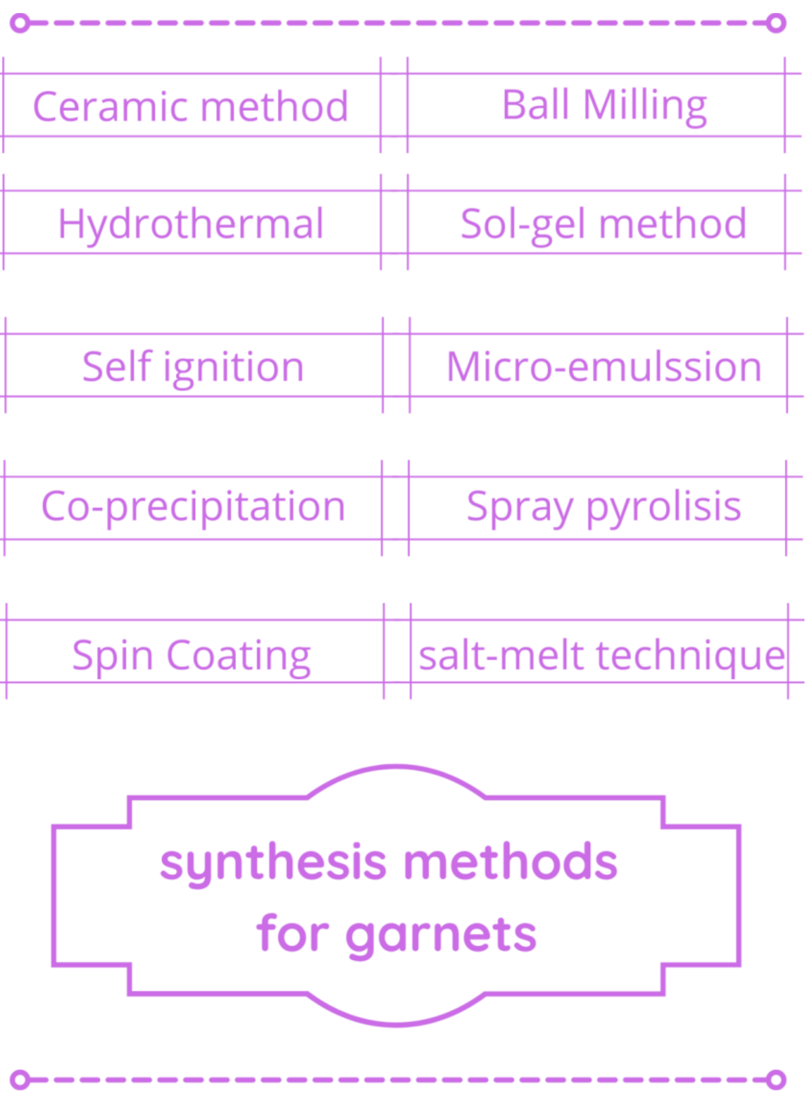


**Figure 2:Shows Synthesis methods adopted worldwide for the preparation of garnet ferrite**

Lalit M.Pandey [46] has reported the sol-gel synthesis and characterization of Yttrium Iron Garnet (YIG) and studied its applications for hyperthermia. Ankush B. Bhosale, Sandeep B.Somvanshi, V.D. Murumkar and K.M.Jadhav [47] have incorporated RE metal ion ($Dy^{3+}$) in yttrium iron garnet (YIG) nanoparticles to study their Magnetic, electrical, and dielectric behavior. Muhammad Yousaf et.al [44] has reported the magnetic characteristics and optical band alignments of rare earth ($Sm^{+3}$, $Nd^{+3}$) doped garnet ferrite nanoparticles R.Peña-Garcia[48] has prepared $Y_3(Fe_{1-x}Ni_x)_5O_{12}$, ($x = 0$, 0.01, 0.03 and 0.05) by sol-gel method. Davis Campbell, Changsong Xu, Temuujin Bayaraa, and L. Bellaiche [43] have reported the Finite-temperature properties of rare-earth iron garnets in a magnetic field. J.M. Santos et.al [49] have performed the synthesis and structural characterization of rare-earth iron garnet: $(Sm, Gd)_3Fe_{4.9}Al_{0.1}O_{12}$. Dustin Witkowski and David A. Rothamer [45] have investigated the emission properties and temperature quenching mechanisms of rare-earth elements doped in garnet hosts. Majid Niaz Akhtar, T. Hussain, Muhammad Azhar Khan, and Mukhtar Ahmad [50] have studied the Bi- doped rare earth iron garnets $Bi_{3-x}R_xFe_5O_{12}$, R = Y, Gd, Pr, Ho, and Yb prepared via using the sol-gel method. They studied the structural, magnetic, dielectric property for electromagnetic microwave absorption and high-frequency applications and devices. J.M. Santos et.al [49] have performed the synthesis and structural characterization of rare-earth iron garnet: $(Sm, Gd)_3Fe_{4.9}Al_{0.1}O_{12}$. Ethan R. Rosenberg et. al [51] have reported the magnetism and spin transport in rare-earth-rich epitaxial terbium and europium iron garnet films. Natalia Tsidaeva et.al [52]has discussed the hydrothermal synthesis of various magnetic properties of controlled micro/nanostructured powders and films of rare-earth iron garnet.

## II.SUMMARY OF THE MINI REVIEW

In this mini-review, we have focused on the major advances mentioned by the many researchers in worked upon the garnet. The garnet has a wide range of applications and has a large thrust area that can be an ever-ending playground for industries, research, and development. In the due course of time, the importance of 'garnet ferrite' in diverse fields viz. surgical implants, catalyst, biomedical drug delivery, space research, etc. have been highlighted in this mini-review. The major challenges, gaps, and the future scope of the garnet research need to improve the quality of garnet families have also been mentioned.

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