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APPLICATIONS OF SPINEL FERRITE NANOPARTICLES 2021: A SHORT- REVIEW

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Abstract: **In the present mini-review, we aimed to study the developments in the research of the 'spinel' structure ferrite nanoparticles, on the global platform. The research has been carried out by many researchers and scientists to encounter the various needs of society and to solve social problems by applying scientific and engineering approaches. Recently the simple structure of the ferrite i.e. spinel has played a crucial role in the newly designed world of science research, agriculture, biotechnology, technology, medical, etc. to address the technical glitch in the targeted application of these spinel ferrites, several important synthesis methods have been adopted such as conventional method (ceramic technique); wet chemical method (sol-gel); Co- precipitation, hydrothermal, micro-emulsion, etc. In the recent era, many characterizations techniques like X-ray diffraction analysis, Atomic force micrography, Scanning electron micrography, HR-TEM, FTIR, UV-Vis, spectroscopy, Raman spectroscopy, VSM, were used in accordance to meet the analytical data for the determination of their physical and chemical properties.**

Keywords*: Spinel ferrite; Synthesis methods; Characterization techniques; Applications of ferrites*

I.INTRODUCTION

Since the discovery of ferrite, researchers were exploring their structural, electrical, and magnetic properties aiming to their numerous applications. Ferrite nanomaterials (1 nm – 100 nm) are being highly investigated and studied due to their novel and unmatched physic-chemical characteristics that are not shown by the bulk-sized. Ferrites are classified into three main groupsas *1) spinels ferrite 2) garnet ferrite and 3) Magnetoplumbite (Hexagonal ferrite)* representing their significance [1]. The structure, physicochemical properties, and applications of these ferrites significantly differ from each other behaving like a family member with certain similarities. Preferably, ferrite materials have a low gap semiconductor behavior and as low- temperature insulators deserve the leader place in the industrial, research, biomedicalapplications compared to the other competent materials [2, 3].

Specifically, spinel ferrite nanoparticles were more enthusiastically studied by numerous physicists, chemists, scientists, biologists, bacteriologists, researchers, engineers, etc. the materiologist has always kept the 'iron' to be connected with the human world. Ferrites are nothing but the 'iron oxide' formed of Fe_2O_3 and FeO as their main component. The usual and interesting properties like desirable chemical, tunable physical, excellent electrical, dynamic magnetic, and fascinating optical properties are taken as an outcome of extensive research and technological development. Magnetic nanoparticles (MNPs) have attracted incremental attention in the magnetic world over the past few decades, due to their excellent, easily tunable properties useful in a wide range of potential applications.

II FERRITE GEOMETRY:

The spinel ferrites have the general formula

$$(Me^{2+}_{1-x}Fe^{3+}_{x})[Me^{2+}_{x}Fe^{3+}_{2-x}]O_4;$$

where Me belongs to the divalent cations; taken from the

transmission group on the periodic table of the elements; like Cu^{2+}, Zn^{2+}, Co^{2+}, Mg^{2+}, Mn^{2+}, Ni^{2+},etc., and Fe is trivalent ferrous (Fe^{3+}) respectively [4]. These ferrites can be described as a cubic closed–pack arrangement of oxygen ions with an equal distribution of cations at tetrahedral (A)- site and octahedral [B]-sites in the lattice structure [5]. In one unit cell of the cubic spinel structure ferrite materials, there are 8 FCC cells, and 1 FCC cell has a there are 4 lattice points; contributing 32 lattice points for the occupancy of oxide anions. The divalent metal ion in this structure occupies $1/8^{TH}$ of the tetrahedral (A) voids contributing occupancy of 8 lattice points [6]. The trivalent cations occupy 1/2 of the octahedral [B] voids contributing occupancy of 16 lattice points [7, 8].

Physical Properties of spinels

Spinel ferrite possesses interesting physicochemical properties like high permeability [9], low eddy current losses [10] high saturation magnetization [11], High electrical resistivity [12], dielectric properties [13], etc. The various technological importance of the magnetic nano spinel ferrite materials has attained due to various properties viz. magnetic anisotropy, diamagnetism, paramagnetism, ferromagnetic property, anti-ferromagnetic and ferrimagnetic properties associated with the spin of electrons [14, 15]; high resistivity, high permeability and comparatively low magnetic losses [16, 17].

Applications of spinel ferrite

The applications of spinel ferrite involved a huge list that can be considered as the beginning of the future scope of magnetic nanomaterials. They are more suitable for various applications like biotechnology [18], telecommunication [19] and electrical switching applications [20], magnetic recording heads [21], antenna rods [22], microwave devices [23], MLCI [24], power switches, resonators, computer devices [25], TV sets etc. [16], pharmaceutical [26], data storage [27], magnetic fluid [28], photocatalysis [29], hyperthermia [30], gas sensors [3], electronic devices [31], energy storage [32], antibacterial activity [33]. magneticrefrigeration, magnetic resonance imaging[34], catalyst [35], transformer core [36], memory chip[37], etc. O.Mounkachi et al [38] has studied the magnetic and structural properties of Nd-doped Cobalt nano-ferrite for permanent magnet applications. M. B. Tahir, T. Iqbal, A. Hassan & Snobia Ghazal [39] have employed a wet chemical co-precipitation method for the synthesis of pure and doped nickel ferrite nanoparticles at low temperature with the concentration of nickel varies from 2, 4, 6, and 8%. Molongnenla Jamir et. al [40] have reported the effect of surface functionalization on Fe_3O_4 assembled nanoclusters with biopolymers, like chitosan and dextran using the solvothermal route. The surface functionalization significantly enhanced the SAR value up to 40% i.e., from 144.08 W/g for FO to 233.28 W/g for DFO at 1 mg/ml concentration. Anuvansh Sharma et al [41] have synthesized DNA-based tracers having a magnetic coreencapsulated in a protective silica shell and reported for the first time about the encapsulation of three different types of DNA using three different magnetic cores, thereby showing the uniqueness of the tracers. **Figure 1** depicts the Major applications of ferrite in diverse fields.

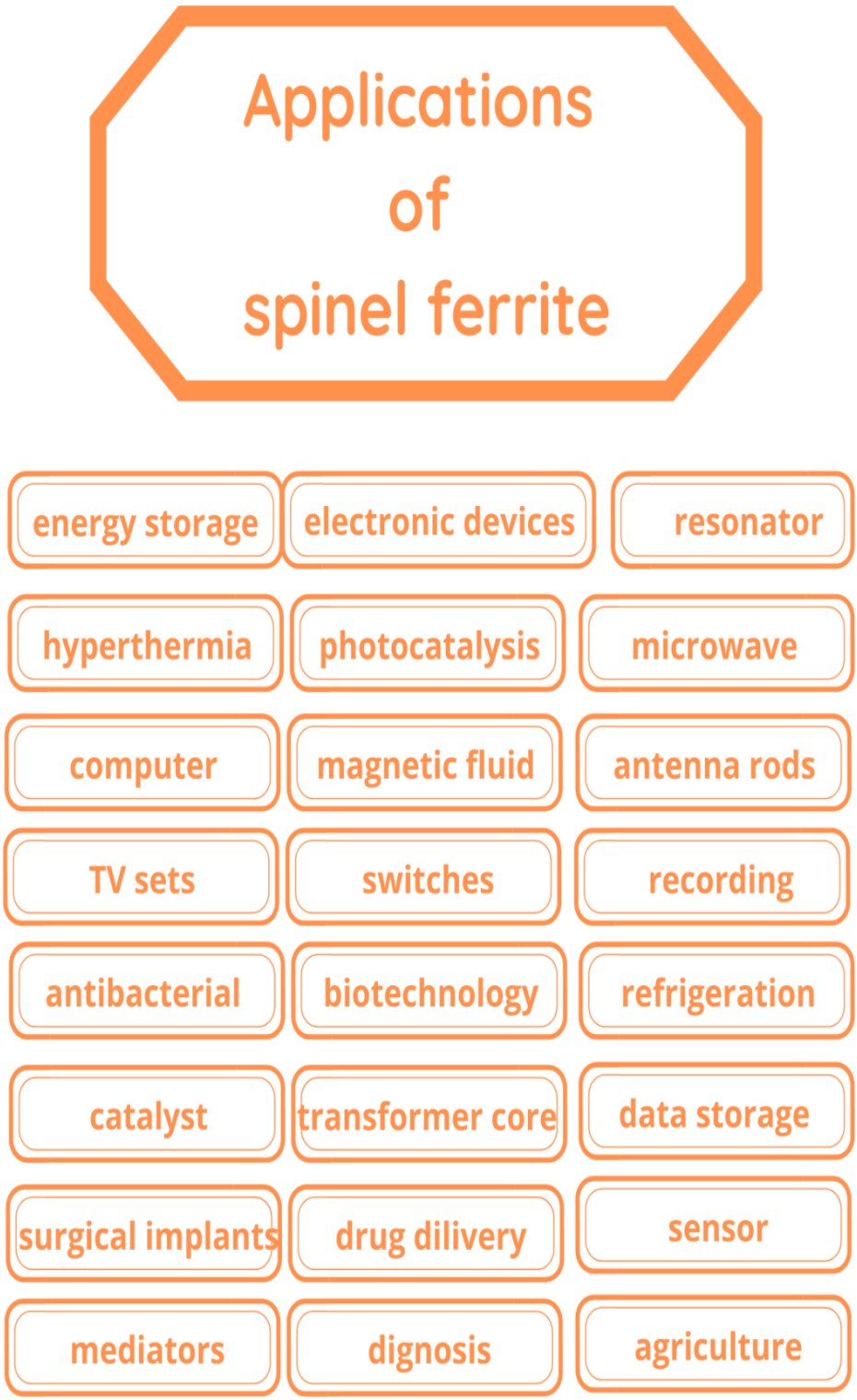


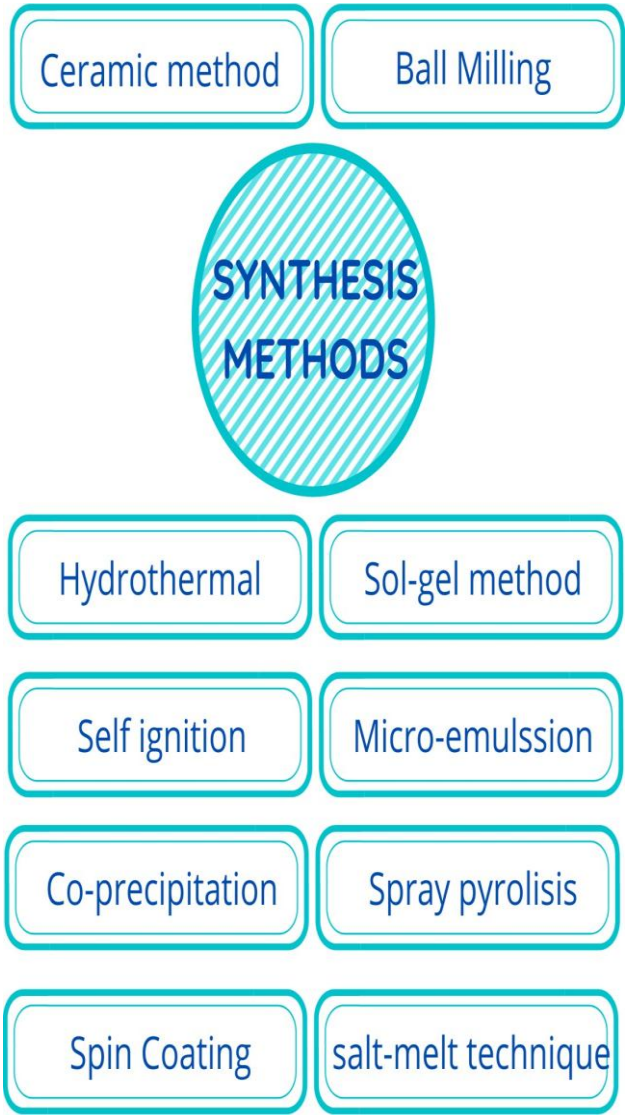
Figure 1. Major applications of ferrite in the diverse fields

Mirza Mahmood Baig et.al [42] have prepared single-phase manganese ferrite ($MnFe_2O_4$) nanoparticles using a low cost micro-emulsion method. Gnana Praveena Nethala et. al [43] have studied the influence of Cr on the structural, spectroscopic, Mössbauer Spectroscopy, and magnetic properties on the $CoFe_2O_4$ ferrite nanoparticles grown by the wet chemical method. S.Sharma, Deepak Kumar, Sanjay Kumar, M.S.Goyat, P.Mandal et.al [44] has prepared $Zn_{1-x}Cu_xFe_2O_4$ ferrite nanoparticles synthesized via cost effective wet chemical route. XRD revealed the formation of mixed phases of normal spinel zinc ferrite and hematite (α-Fe_2O_3) structure and the characterizations were followed by UV-Vis and Raman analysis. Mahnaz Amiri Khalil Eskandari and Masoud Salavati-Niasari et. al [45] have employed the green chemistry method to produce magnetically retrievable Co, Ni, Mg, Cu, and Zn ferrite nanoparticles and use in catalysis applications. Ala Manohar et. al [46] has effectively established that the Zn-doped Fe_3O_4 NPs prepared by a simple technique could be used in MH and photocatalytic applications. Sneha Singh et al [47] has reported the Ru doped cobalt ferrite nanoparticles with varying composition prepared using sol-gel method; and the photocatalytic degradation of Remazol deep red was observed and $CoRu_{0.06}Fe_{1.94}O_4$ gave the best results.

III SYNTHESIS METHODS

Among the diversified portfolio of synthesis methods, some of the good popular synthesis methods are the ceramic method [48], wet-chemical method [43], hydrothermal method [49], spray pyrolysis technique, a salt-melt technique [50], auto-clave method [51], micro-emulsion method [52], etc. A. Shebl et. al. [53] have reported that zinc-doped manganeseferrite nanoparticles prepared via. simple template-free microwave-assisted hydrothermal green synthesis technique at different temperatures and studied the structural, morphological, andelemental properties were studied by using different characterization tools. Figure 2 depicts various synthesis methods: B. G. Manju et. al. [54] has synthesized nickel-substituted copper ferrite nanoparticles [$Cu_{1-x}Ni_xFe_2O_4$ (x = 0, 0.5, 1)] using lime juice as a reducing agent by sol– gel method, showed very high antibacterial activity against Gram-negative bacteria E. coli, growth inhibitory ability against microbes can contribute to their possible use as antimicrobials in the field of medicine. Thus, the literature survey revealed the need, development of diverse synthesis methodologies, and the urgency of studying spinel ferrite nanoparticles at a glance for the future scope of the applications. Diverse methodologies were deployed for the synthesis and characterization of these magnetic materials that can be assisted for novel applications.

Figure 2: Synthesis methods adopted worldwide for the preparation of spinel ferrite



IV SUMMARY

In the present review, shade light on the recent advances in the literature relevant to the synthesis, characterization, various physical properties, and the major applications of spinel ferrites. In this course, we have identified the importance of 'spinel ferrite nanoparticles in diverse fields viz. industrial, biomedical, home appliances, medical diagnosis, space technology, transformers, catalysts, transducers, and so on. Finally, the challenges, gaps and the future scope of the research needs to improve the quality of of the nanomaterials; satisfying the demand of the industries involving the spinel ferrite

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