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Review Article

# Review Article: Ferrites in Wide Novel Medical Applications

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## Abstract

The magnetic nanoparticle materials of ferrites or ferromagnetic oxides; are enormously rapid growing and still developing due to the urgent need for their scientific importance in many applied uses, so it is not surprising that these materials are at the forefront of sales that achieve a good economic recourse for countries that depend on the strengthening industries that they directly enter, thus, it is a strong candidate for continuous scientific research and development. However, this article review will be focused on the most important field that have been used in recent years, the wide novel medical applications of biomaterials. Ferrite characteristics of the magnetic systems and crystal structure, besides the methods of preparation, will be discussed, lastly, the applications in the biomaterials including; diagnosis, therapeutics, control, enhanced MRI imaging, magnetic hyperthermia cancer treatment, targeted drug and gene delivery, bio-labeling & bio-sensing, antimicrobial agents, and treatment of diseases will be briefly discussed.

## Keywords

Ferrite, Magnetic Nanoparticle, Biomaterial, Medical Novel Applications

## 1. Introduction

Ferrite usages in the form of Nano-particles has open a new and exhilarating research fields, with innovatory applications not only in different sciences of contemporary technology but also in the biotechnology. In present Numerous routes were being used in synthesized different types of ferrites based on Nickel, Zinc, and Cobalt used in excessive magnetic anisotropy and biocompatibility, [1]. As an example the Nano technique applied on the cobalt ferrite due to its excellent features affected on hyperthermia, MRI: Magnetic Resonance Imaging, and, antibacterial activity [2, 3]. For, biological and medical applications, superparamagnetic iron oxide ($Fe_2O_3$), or ferric oxide, nanoparticles have single properties. The sort of hyperthermia cancer treatment known as restricted hyperthermia can advantage from this property of nanoparticles, [4]. Magnetic Nanoparticles offer single multimedia owing to their outstanding combination of optical and magnetic properties that is most desirable feature applicable in many biomedical and biological applications, such as separation methods, hyperthermia treatments, chemotherapy, drug delivery, magnetic resonance imaging, disease diagnostics, sorting and bio-labeling, [5]. The nanoparticles $MnFe_2O_4$ was developed to assist the sensitive MR imaging contrast agent for liver imaging, [6]. Excellent biocompatibility of manganese ferrite ($MnFe_2O_4$). When compare to hematite ($\gamma$-$Fe_2O_3$),

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magnetite ($Fe_3O_4$), cobalt ferrite ($CoFe_2O_4$), and nickel ferrite ($NiFe_2O_4$) be better and appropriate for magnetic resonance imaging (MRI) [7, 8]. This review article summarizes the overview, of ferrites nanoparticles as crystal structure, and their classifications. Furthermore, attention on the novel medical applications influenced by ferrites on the basis of the soft and hard nature of ferrite materials. Recently, ferrite has powerfully emerged in biomaterial applications, such as; diagnosis, therapeutics, control, enhanced MRI imaging, magnetic hyperthermia cancer treatment, in brief, ferrites has become an integral part of the materials that have become a scientific which are a potential candidate for widely spread applications.

## 2. Ferrites Structure

Ferrites with spinel crystal structure, also symmetric in different neighbor sides, have the chemical structure formula $[MF_2O_4]$ or $[AB_2O_4]$, anywhere the divalent metal [M=A], may be [Ca, Cd, Co, Cu, Fe, Mg, Mn, Ni, or Zn], while, the trivalent metal [$F_2 = B_2$] could be [Al, Cr, Fe, Ga, In, Mn, Rh, Ti, or V]. The cubic spinel structure of ferrite; Figure 1, has two sites: A (tetrahedral) and B (octahedral). [9, 10].

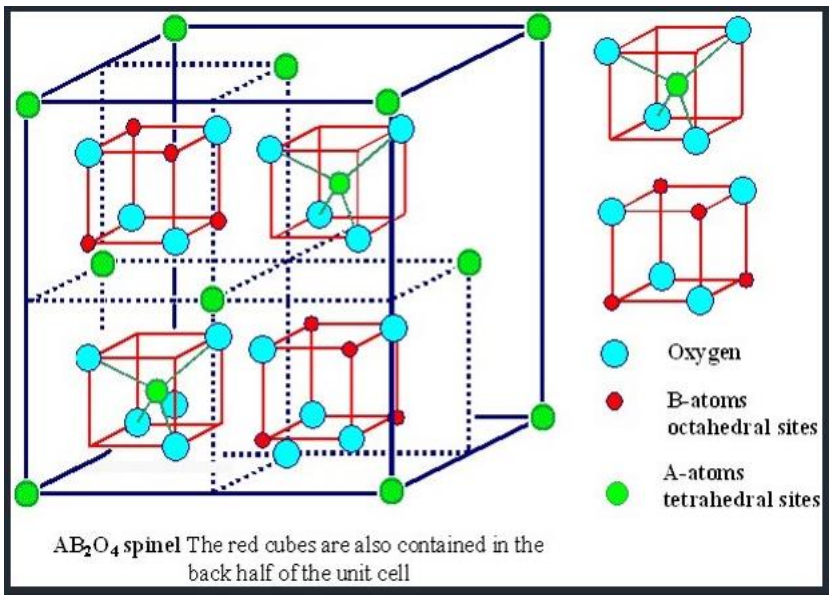


***Figure 1.*** *Structure of Spinel Ferrites.*

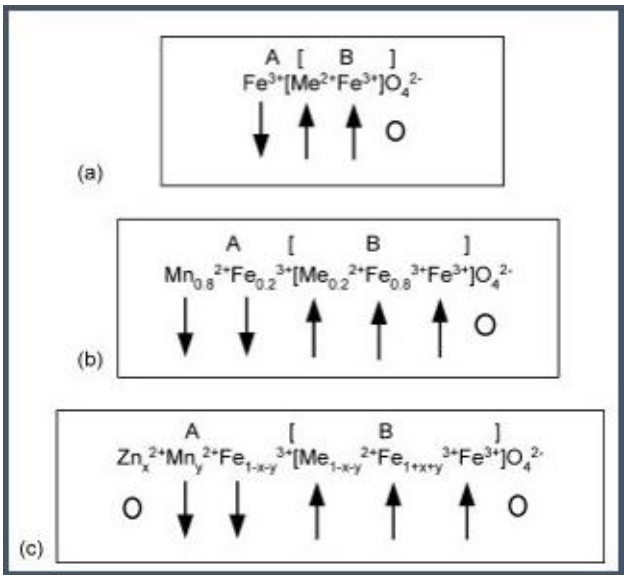


***Figure 2.*** *Cation distribution in spinel ferrites: (a) inverted ferrites, (b) manganese ferrites and (c) zinc manganese ferrites.*

According to site favorite of cations, they are divided into three groups, as shown in Figure 2, [10].

a. Normal spinel: When a tetrahedral site is occupied by divalent metal ions, and an octahedral site occupied by trivalent ions, then it is so-called normal spinel ferrite, examples of normal spinel's: $MgAl_2O_4$, $Mn_3O_4$, $ZnFe_2O_4$, $FeCr_2O_4$ (chromite). [11, 12].

b. Inverse spinel: When octahedral site is occupied by divalent metal ions, and a tetrahedral site is occupied by trivalent ions then it is known as inverse spinel ferrite, examples of Inverse spinel's: $Fe_3O_4$ (ferrite), $CoFe_2O_4$, $NiFe_2O_4$, [11, 12].

c. Mixed spinel: When the divalent cations are present on both tetrahedral and octahedral sites, the spinel is called as mixed spinel ferrite, example of mixed spinel's: $MnFe_2O_4$, [11, 12].

## 3. Methods of Preparation

Ferrite nanocrystal line magnetic materials have been synthesized by a wide variety of techniques for example; by

means of egg white in place of an aqueous medium [13], Sol-gel [14], citrate precursor [15], co-precipitation [16], hydrothermal [17], forced hydrolysis in a polyol [18], sono-chemical [19], micro-emulsion [20], thermal decomposition [21]. All preparation methods of ferrites above can be dependent for applications as required in various field in sciences of modern technology otherwise biotechnology.

## 4. Medical Novel Applications of Ferrites

Magnetic materials in the form of nanoparticles ferrites contributed to treatment with biomedicine including diagnosis, therapeutics, control, enhanced MRI imaging, magnetic hyperthermia cancer treatment, targeted drug and gene delivery, bio-labeling & bio-sensing, antimicrobial agents, and treatment of diseases, it will be addressed through what has been published of scientific research or review articles, whether have been reported on the in-vitro or in-vivo in the last two decades.

### 4.1. Cancer

Cancer is a disease resulting from unrestrained growth and partition of the strange cells, with highly symptoms variable such as weight loss or mysterious variations in the body or persistent knob, these symptoms caused by gene modifications that may result from exposure to chemicals, carcinogens, radiation or other reasons, and the treatment may include surgery, chemo or targeted therapy, radiotherapy and comforting care, just for reminder, here the common types of cancer are widespread now; Melanoma, Breast cancer, Osteoporosis, Prostate cancer, Colon cancer, Multiple myeloma, Lymphoma, Pancreatic cancer, Cervical cancer, and Leukemia, [22]. All published research on the application of magnetic nanoparticles used in the treatment of cancer recommended that this technique has moderately lesser side effects compared to the other existing treatment modalities for cancer.

### 4.2. Hyperthermia

Hyperthermia is a treatment for cancer organs or vague tissues, when the heating between 41-46 ℃. The superparamagnetic-ferrimagnetic $Fe_3O_4$ or γ-$Fe_2O_3$ particles have been widely studied as they are biocompatible in this field. Specimen, "M1-xZnx$Fe_2O_4$, M=Mn, Co, Fe" and "Fe1−xBx$Fe_2O_4$ (B=Mn)" have been taken more studies on this nanocomposite [23-25]. Also, cytotoxicity tests of Ferro fluids ($MnFe_2O_4$) were done using BHK 21 (Syrian Baby Hamster Kidney cell line) cell using BME (Basal Medium Eagle) as culture media. [26]. Dissimilar Ferro watery concentrations ($12x10^{-1}$ - $4x10^{-5}$ mg ferrite/ml) during time less than 100 h, were incubated for growing cells, and the result found that these materials useful for hyperthermia applications, [27]. One study suggested that γ-$Fe_2O_3$ nanoparticles could be used for local hyperthermia cancer therapy with a very short incubation time four hours as a hopeful experimental method for magnetic hyperthermia therapy, while more developments have to be achieved to reduction nanoparticles toxicity on healthy cells and to augmentation their targeted delivery [28, 29].

### 4.3. Drug Delivery

Three uncomplicated quantities are nanoparticles, drug, and targeting molecules Figure 3, were stand for the main types of drug delivery system. The nanoparticles are the basic nanostructures used to transport drugs, e.g., nanotubes, nanowires, quantum dots, mesostructures, polymers, dendrimers, liposomes and artificial DNA structures, etc.., with a simple option of nontoxicity, biodegradability, biocompatibility, and immunogenic properties [30, 31]. The drug may be loaded inside the nanostructure or can form a chemical bond with the surface leading to the creation of a drug-loaded structure.

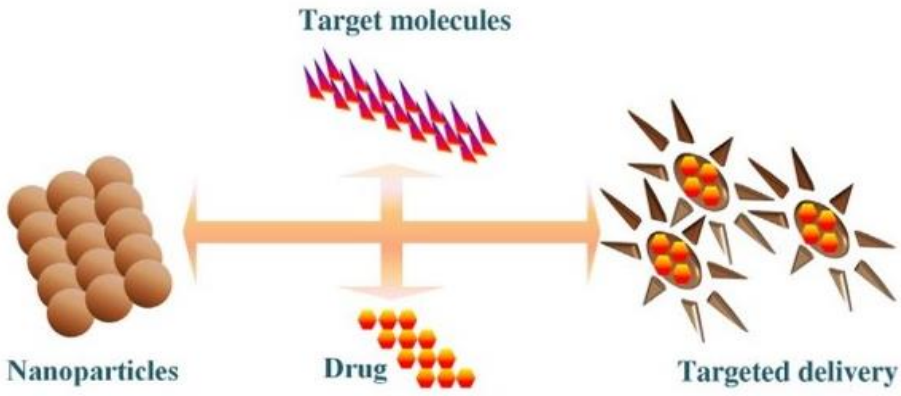


***Figure 3.*** *Main types of drug delivery system.*

Nanotechnology and its rapid development since the mid of the last century made the scientists consider about using it through many applied sciences, such as biomaterials, scaffolding, viruses, peptide/protein complexes, plasmids, lipo-

somes, and drug delivery systems to enhance the effective targeting of drugs, solubility, stability, and toxic side effects, [32]. The Manganese Ferrite ($MnFe_2O_4$) demonstrated higher biocompatibility in compare to hematite, cobalt ferrite, magnetite, and nickel ferrite; which make it an efficient candidate for various biomedical applications such as drug delivery, as well as, prepared $MnFe_2O_4$@$mSiO_2$ nanocomposite with suitable size, shape and magnetic property could be an appropriate magnetic Nano carrier for targeted drug deliver [33, 34].

### 4.4. Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) is a medical imaging technique that uses a magnetic field and computer-generated radio waves to create detailed images of the organs and tissues body. Most MRI machines are large, cylinder-formed magnets. When patient lie inside an MRI machine, the magnetic field temporarily rearranges water molecules in the body. Radio waves cause these aligned atoms to produce unclear signals, which are used to create cross-sectional MRI images like slices. The MRI machine can also produce 3D images that can be viewed from different angles. Contrast agents were used to improve the sensitivity of magnetic resonance imaging (MRI) to detect pathological structures with the help of modern technology possessed by Nano ferrite, where it was found in one study that it is possible to use dextrin-coated $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticles as a good negative contrast agent in MRI. In a second study of magnetic variation, ferrite nanoparticles [$Co_{0.3}Zn_{0.7}Fe_2O_4$] were found to play an essential and important role in medical and biological applications in temperature changes (sensors) with an accuracy of ±1.0 K at 310 K, which enhances the potential feasibility of this material. [35-37].

### 4.5. Antibacterial Activity

The cobalt ferrite $CoFe_2O_4$ at 400 ℃ and 600 ℃ nanoparticle, once mixed through chlorhexidine, provide the mean inhibition zone 8.5334 mm and 8.0667mm respectively, whereas the pure chlorhexidine was given that a mean inhibition zone of 3.1667 mm, then similarly the nanoparticles cobalt ferrite in individually cases of sintering without mixing, there was no antimicrobial effect [3]. Nanoparticles silver constructions have also been found to own a good capability for inhibiting the growth of microorganisms for example bacteria [38]. It was found that silver nanoparticles have a powerful antibacterial activity against both Gram-negative and Gram-positive bacteria [39, 40].

### 4.6. Bio-labeling

The labeling of individual cells, so called bio labeling, often used this technique was accomplished via the nanoparticles, one applied technological innovation for immunoassays based on functionalized $Y_2O_3$:$Nd^{3+}$ nanoparticle as bio label has been achieved that avoids interferences from biological background fluorescence. Although bio labelling has been carried out with gold Nano particles for almost a century, it is only over the last decade that colloidal nanoparticles have emerged as a truly generic tool for a variety of bio imaging and mark applications [41]. Polymer-coated nanoparticles have been developing into a standard platform for nanoparticles bio conjugation [42].

### 4.7. Photocatalytic

The active materials frequently used with their tunable properties such as conductive, magnetic, optical and catalyst be situated nanomaterials of ferrite when developing photocatalytic materials and these have dynamic rates, of charge separation, oxidation reaction and efficiency [43, 44].

## 5. Conclusions

This article review confirms the verified ferrite usages in the form of Nano-particles has open a new and exhilarating research fields, with innovatory applications not only in different sciences of contemporary technology but also in the biotechnology. Crystal structure of spinel ferrites and preparation method has been stated; and the uses the nanoparticles of ferrites in biomaterials as a high-tech material in medical novel applications thru modern and very useful advantages; such as; cancer, hyperthermia, drug delivery, magnetic resonance imaging (MRI), antibacterial activity, bio-labeling, and Photocatalytic.

## Abbreviations

MRI Magnetic Resonance Imaging

## Author Contributions

Jameel Mohammed Ameen Sulaiman is the sole author. The author read and approved the final manuscript.

## Conflicts of Interest

The author declares no conflicts of interest.

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