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A Review on Classification of Various Ferrite Particles on the Basis of Crystal Structure

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ABSTRACT

Ferrite basically is a compound composition of iron and metal oxides. The both oxides are electrically nonconductive and ferromagnetic, it signify that they can easily magnetize or attracted towards magnet. Based on their magnetic coercivity magnets are classified into hard and soft magnets. In this classification hard ferrites has high coercivity and soft ferrite has low coercivity. They also classified on the bases on crystal structure. Those ferrites are garnet, spinel, Ortho-ferrite and hexagonal ferrites. Theses ferrites are used in transformer and to make core in electronic industry. Ferrites are similar to ceramic materials and they are hard, brittle and poor conductors. Most of the ferrites contains structural site such as dodecahedral (c sites), tetrahedral, octahedral sites. Most of the ferrite has low cost, very stable and hard to demagnetize because of these properties they are found much suitable in microwave applications.

Key words: Ferrite, iron mad metal oxides, saturation magnetization, ferromagnetic

INTRODUCTION

Worldwide revolutionary development of nanoscience, chemistry, physics, and material science play a dominant role in recent years. At that time they are also pronounced as technology of next generation or micro technology. Similarly Ferrite particles and their applications are also familiar form many centuries ago. Ferrites particles are the composition of iron oxides and metal oxides. They are basically chemical compounds which obtained from the ferromagnetic properties of iron and metal oxides. Among the various ferrite and iron oxides, magnetite is the first particle which described in Greek writing about 800BC. First application of magnetite is invented in the form of 'Lodestones', which used by navigators to localize magnetic north. Magnetite (Fe_3O_4) and Maghemite ($y - Fe_2O_3$) are the main particles, which play important role in the terms of properties and its application in various fields. Oxygen ions with the iron ions in these ferrites are represented in two interstices such as tetrahedral sites and octahedral sites [1]. Chemical representation of Magnetite and maghemite are $Fe^{3+}[Fe^{2+}_{1-x}Fe^{3+}_{1-x}Fe^{3+}_{1.67x\Delta0.33x}]O_4$ here Δ symbol signify vacancies and x=0 is use for pure magnetite ferrite and x=1 is use for pure maghemite ferrite. If we increase the temperature from room temperature to the Curie temperature i.e. 860K, Most of the Fe^{3+} ions are occurred in tetrahedral sites and in octahedral sites Fe^{3+} and Fe^{2+} ions are placed equally. Ferrites contain large number of applications such as low level applications, power applications and electromagnetic interference suppression (EMI). This whole story of ferrite material is come into picture form the year of 1949, when ferromagnetic materials are searched to obtain high resistivity with minimum eddy current losses [2]. When a ferromagnetic material is submerged into Ac or alternative magnetic field, then eddy current losses are generated which dissipate more energy. These losses can be minimized using high resistive material. Ferrite has the property of high resistivity, low eddy current and dielectric losses, high permeability and high saturation magnetization. Due presence of several properties in ferrite make it very useful for large number of application in different areas. Ceramic technology is used to prepare high quality ferrite metal oxide. But it has disadvantage that it can only be used to produce bulk materials [3]. Many new synthetic methods have been generated to produce ferrites particles. Particle size and its morphology and crystallinity of any particle play important in its photocatalyst activity. Many researchers had been developing many techniques for the formation of the ferrites with taking certain precaution such that photocatalyst does not affect due to its size and all other parameters. These all ferrite are generated by ceramic method sol-gel method, co-precipitation, pulsed laser deposition, high energy ball milling, and hydrothermal technique [4].

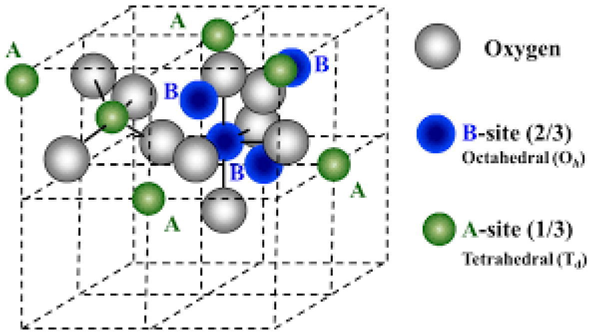


Fig. 1 Crystal Structure of Ferrite Particle

The cross-section view of ferrites is shown in figure 1 in which A and B is the tetrahedral and octahedral site respectively which present in ferrites structure.

Depending on their properties, commercial ferrites are classified into two parts which are soft ferrites and hard ferrites. In which soft ferrites have low hysteresis losses, low coercivity and high saturation magnetization whereas hard ferrites have large value of retentivity and coercivity. Some name has given in these ferrite based on their applications. Those are soft ferrite with garnet structure known as YIG, soft ferrites with cubic spinel structure known as NiZn, MnZn and MgMnZn ferrites [5]. Hard ferrite contains hexagonal structure.

CLASSIFICATION OF FERRITE PARTICLES BASED ON CRYSTAL STRUCTURE

On the basis of crystal structures, Ferrite particle can be classified into four parts, in which iron and metal oxides are employed as a main constituent. Based on crystal structure, ferrites have four classifications which describe below in detail:

Garnet Ferrite

Garnet contains cubic crystal structure. Garnet can be defined using formula $R_3^{3+}Fe_5^{3+}O_{12}$ Here R is known as rare earth ion for example yttrium (Y^{3+}),gadolium (Gd^{3+}) , samarium (Sm^{3+}) etc. chemical equation for ferromagnetic garnet is $Me_3Fe_5O_{12}$.In the chemical equation of ferromagnetic garnet Me_3 is a rare earth trivalent ion[4]. The unit cell of garnet is in cubic format and contains 160 atoms. Garnet particles occupy three structural site such as dodecahedral (c sites), tetrahedral, octahedral sites. Ions of iron oxides distributed over tetrahedral and octahedral sitesin the ratio of 3:2.There is various garnet materials which used to make garnet ferrites. Garnet ferrites are transparent in the presence of infrared waves [6]. Some iron garnets are defined based on their electrical properties in the table which shown below:

Table -1 Description of Various Properties of Yttrium Iron Garnet Ferrites Based on Different Parameters

Types	$4\pi J_s$ (Gauss error ±5%)	T_c (0_C) ±5%	x_{eff} ±5%	ΔF (Oe) ±20%	ΔF_{eff}(Oe) ±20%	ΔF_K(Oe) ±10%	$\in'$ ±5%	10^4 tanδ	$\propto.10^3$ ±0.2
Y10	1790	280	2.00	45	4	2	15.3	<2	2.2
Y101	1820	280	2.00	20	4	2	15.4	<2	2.2
Y102	1800	280	2.00	30	4	2	15.3	<2	2.2

Table -2 Description of Various Properties of Gadolium Iron Garnet Ferrites Based on Different Parameters

Types	$4\pi J_s$ (Gauss error ±5%)	T_c (0_C) ±5%	x_{eff} ±5%	ΔF (Oe) ±20%	ΔF_{eff}(Oe) ±20%	ΔF_K(Oe) ±10%	$\in'$ ±5%	10^4 tanδ	$\propto.10^3$ ±0.2
Y11	1600	280	2.00	60	5	3	15.3	<2	1.8
Y12	1420	280	2.00	65	6	6	15.3	<2	1.5
Y13	1250	280	2.00	75	8	8	15.3	<2	1.0
Y14	1100	280	2.00	95	12	9	15.4	<2	0.5
Y15	900	280	2.00	140	18	11	15.4	<2	0.7
Y16	750	280	2.00	200	25	15	15.4	<2	0.9

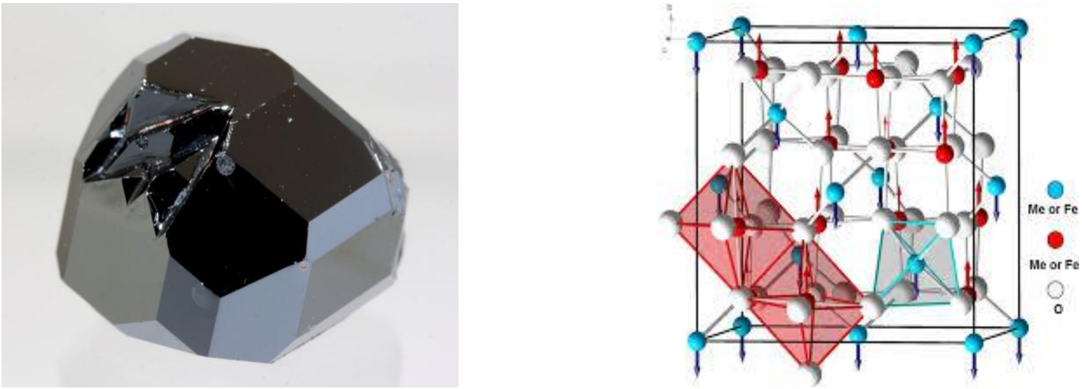
In the given table,J_s = saturation magnetization in C.G.S, whose flux is vary from -5% to +5%.

T_c = curie temperature.

x_{eff} = Effective line width

ΔF= Ferromagnetic resonance line width

ΔF_{eff} = Effective Land factor
ΔF_K = Spin wave line width
$\in'$ = Complex permittivity
∝.= Magnetization temperature coefficient, which lie in the range of -20 to +60 degree centigrade



(a) Iron garnet ferrite **(b) crystal structure of iron garnet ferrite**

Fig. 2 Different Structure of Garnet Ferrite

Spinel Ferrite

The General Chemical formula of spinel ferrite is MFe_2O_4. In chemical formula of spinel ferrite M is represented by divalent metal ions. M can be replaced by many other materials. The crystal structure of spinel ferrites have two interstitial sites named as octahedral and tetrahedral sites [7]. In the crystal structure of spinel ferrite particles, unit cells consist 32 oxygen,8 divalent metal ions, 16 trivalent metal ions. Spinel ferrite have large number of members, these members are Aluminum spinel, iron spinel, chromium spinel etc.

Table -3 Different Types of Spinel Ferrites

Types	General Formula
Normal	$(A^{2+})[B_2^{3+}]O_4$
Inverse	$(B^{3+})[A^{2+}B^{3+}]O_4$
Mixed	$(A_{1-x}^{2+}B_x^{3+})[A_x^{2+}B_{2-x}^{3+}]O_4$

In the table ( ) represent Tetrahedral site and [ ] represent Octahedral sites.

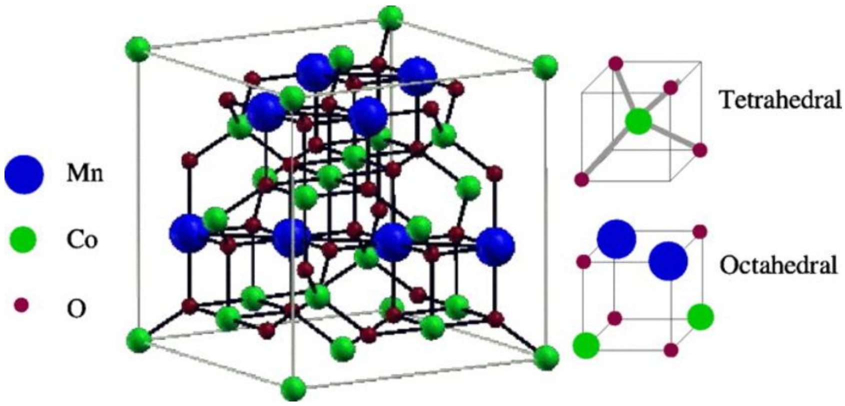


Fig. 3 Crystal Structure of Spinel Ferrite

Table -4 Description of Various Properties of Manganese-Magnesium Ferrites Based on Different Parameters

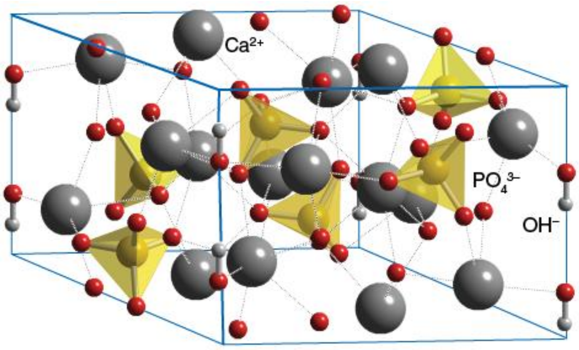
Types	$4\pi J_s$ (Gauss error ±5%)	T_c (0_C) ±5%	x_{eff} ±5%	ΔF (Oe) ±20%	ΔF_{eff}(Oe) ±20%	ΔF_K(Oe) ±10%	$\in'$ ±5%	10^4 tanδ	$\propto.10^3$ ±0.2
U21	2400	275	2.03	290	6.0	4	13.0	< 3	2.7
U20	2100	300	2.01	360	6.0	4	13.0	< 3	2.3
U19	1900	280	2.01	350	6.0	4	13.0	< 3	2.2
U33	1600	230	2.02	290	8.0	4	12.4	< 3	3.3

Spinel ferrites contain large number of application in many areas such as fuel cells, solar cells, sensors, batteries, memory devices transformer etc.

Ortho-Ferrites

Ortho-Ferrites the chemical compounds which have general formula in the form of $RFeO_3$. Here R is rare earth elements. They have orthorhombic crystal structure and weak ferromagnetic. In place of R in chemical formula of Ortho-ferrites M can also be used which stands for trivalent metal ions. Ortho –ferrites have small alignment in their anti-ferromagnetically coupled lattices. The material is a function of temperature and the net magnetization of this material is rotates by 90 degree. Ortho ferrite has anti ferromagnetic property below Neel temperature.

(a) Ortho-Ferrite Practical View



(b) Crystal Structure of Ortho- Ferrite

Fig. 4 Crystal Structure of Ortho-Ferrite

Table -5 Descriptions of Various Properties of Ortho- Ferrite Based on Different Parameters

X value	M_s	M_R	H_C
0.00	2.11	0.47	503.76
0.10	1.79	0.39	549.59
0.15	0.77	0.16	639.75
0.20	0.78	0.26	2336.70

These are some properties of $[(La)_{(1-X)}]$ $[(Ce)_X][(Fe)_{(1-X)}][(Cr)_X]$ O_3 in which M_s is known as saturation magnetization, M_R is called remanence magnetization and H_C referred as Critical field. These compounds are prepared by a well-known method which named as co-precipitation method [8]. Their susceptibility is depending on Neel temperature. Another ferrite which contains single crystal structure with magnetization temperature range 78-295 degree kelvin named as gadolinium ortho-ferrite and Yttrium ortho-ferrite operated at antiferromagnetic whose temperature approximately 602 degree kelvin. Ortho-ferrites have face centered cubic structure at 310 degree kelvin and body-centered cubic structure at 865 degree structure [9, 10].

Hexagonal (Magneto-plumbite) Ferrite

There are certain numbers of ferrites which come under the category of hexagonal ferrites. All these ferrites have hexagonal structure so that they know as hexagonal ferrites. These ferrites classified into some compounds named as M, Y, Z, U, W. The well Known Barium ferrite, which also known as hard ferrite is come under this category of ferrite. This Ferrite has general compound formula which is$MeFe_{12}O_{19}$. Here Me is divalent ion of Ba^{2+}, Sr^{2+}or Pb^{2+}. Hexagonal ferrites consist three interstitial sites such as tetrahedral, Octahedral and trigonal bi-pyramid [11]

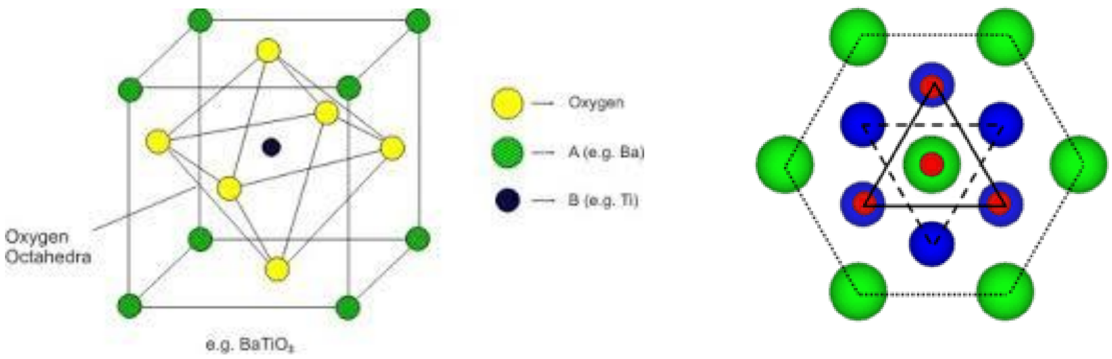


Fig. 5 Cross-Section View of Hexagonal Ferrite-Ferrite

There are large numbers of data set of hexagonal ferrite which totally depend on the crystal formula of ferrite; the data set is described as in table which is given below:

Table - 6 Data Set of Hexagonal Ferrite for M_2Y_n Structure

M: Y	Anion layers	Structure symbols	Space groups	Ideal formula
2:4	$(34)_1$	34H	$P6_3/mmc$	$Ba_{10}Zn_8Fe_{72}O_{126}$
2:5	$(40)_3$	120Rb	R3m	$Ba_{12}Zn_{10}Fe_{84}O_{148}$
2:6	$(46)_3$	138Rb	R3m	$Ba_{14}Zn_{12}Fe_{96}O_{170}$
2:7	$(52)_3$	156Rb	R3m	$Ba_{16}Zn_{14}Fe_{108}O_{192}$
2:8	$(58)_1$	58Ha	P3m1	$Ba_{18}Zn_{16}Fe_{120}O_{214}$
2:9	$(64)_3$	192Rb	R3m	$Ba_{20}Zn_{18}Fe_{132}O_{236}$
2:10	$(70)_3$	210Rd	R3m	$Ba_{22}Zn_{20}Fe_{144}O_{258}$

CONCLUSION

Ferrite particles are play a significant role in mechanical and electronics fields, where high electrical ferrite contains low eddy current losses. Due to containing less loses they are much suitable to use as a core of coils in microwave frequency devices. The all different types of ferrites which describe in this paper are playing very important role in engineering and technology. Ferrites are efficiently work on low field and low power applications but it does not work on high field and high power applications because of their low permeability and flux density in comparison to iron.

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