**INTRODUCTION:-**

Ferrites are ferromagnetic material containing predominantly oxides iron along with other oxides of barium, strontium, manganese, nickel, zinc, lithium and cadmium. Ferrites are ideally suited for making device like inductor core, circulators, memory devices and also for various microwave application. Although the saturation magnetisation of ferrites less than that of ferromagnetic alloys, they have advantages such as applicability at higher frequency, lower price and greater electrical resistance.

Since 1950, soft ferrites have been widely studied and have become a field of interest of many researches because of their application potential in the modern electronics industry. The electrical and magnetic properties of these materials are structure sensitive and can be altered by doping or substitution. The substitution of aluminium in the inverse ferrites like nickel, copper and cobalt ferrites have proved to be useful by increasing their saturation, magnetization, resistivity, however, at the cost of decrease of Curie temperature.

Cadmium ferrite is a normal spinel; its magnetic moment per unit cell is zero. Low magnetic high resistive ferrite are so applicable in the high frequency transformer cores.

The addition of aluminium which has strong preference for the octahedral sites should exhibit the decrease of the magnetisation because aluminium is nonmagnetic. As aluminium content increases, the magnetic moment of unit cell decreases that means show triangular spin moment, their occurs a reduction in the sub lattice interaction. The removal of iron ions from magnetic sublattice and substitution of the nonmagnetic aluminium ion in its place weakens the magnetism. Due to this substitution improves catalytic, dielectric and magnetic properties, as they possess high resistivity and negligible eddy current losses.

1. **Classification of magnetic material**

Depending upon the magnetic properties like susceptibility, magnetic materials have been classified into five groups.

a) Diamagnetic
b) Paramagnetic
c) Ferromagnetic
d) Anti-ferromagnetic
e) Ferromagnetic / Ferrites

a) **Diamagnetic**

Diamagnetic materials have a small negative, temperature independent susceptibility of the order $\chi = -10^{-5}$ and it is negative, the induced moment is directed oppositely to the applied magnetic field.
Diamagnetism is a universal phenomenon, it occurs in all substances including paramagnetic and ferromagnetic substances.

b) Paramagnetic
The phenomenon of paramagnetic occurs only in materials in which individual atoms or molecules have permanent magnetic moments. The susceptibility is positive and temperature dependent. It is of the order of $10^3$ at room temperature and is proportional to $1/T$. This kind of magnetic behaviour can be explained as a consequence of two opposing effects; one the tendency of applied field to orient the moments in the direction of the field and the other, tendency of thermal agitation to preserve a random orientation of magnetic moments. These materials have permeability $\mu$ slightly greater than that of the free space i.e. $\mu > \mu_0$.

c) Ferromagnetic
Some materials become spontaneously magnetized at low temperatures because of the interaction between the magnetic atoms called ferromagnetic. The susceptibility is of the order of $\chi = 50-1000$. In a ferromagnetic material, the interaction between magnetic atoms favours a parallel alignment of the atomic magnetic moments. At absolute zero, the alignment is complete and spontaneous magnetization has its maximum value. As the temperature is increased the effect of thermal agitation which favours random orientation of the magnetic moments begins to be felt. The spontaneous magnetization decreases with increasing temperature.

Some examples of ferromagnetic materials are iron, nickel and cobalt. Their permeability are 1200, 1250, and 220 respectively.

d) Anti-ferromagnetic
Neel predicted the existence of another kind of co-operative magnetic phenomenon called anti-ferromagnetism in materials. In the simplest form of anti-ferromagnetic material, the lattice of magnetic atoms can be divided into two equivalent interpenetrating sublattices A and B such that A atoms have only B atoms as nearest neighbours and vice-versa. The magnetic interactions are such as to cause the sublattice magnetization to be antiparallel. At absolute zero each sublattice has its maximum saturation magnetization. As the temperature increases, thermal agitation reduces the sublattice spontaneous magnetization in much the same way as for a ferromagnetic material. However, the net magnetic moment of the spontaneously magnetized anti-ferromagnetism is zero at all temperatures because of the exact cancellation of the spontaneous magnetization of the two equivalent sublattices.

e) Ferrimagnetisms / ferrites
Ferrimagnetisms is a particular case of Antiferromagnetism in which the magnetic moments on the A and B lattices while still pointing in the opposite direction have different magnitudes. The magnetization on lattice site A is not completely balanced by the magnetization on lattice site B giving rise to resultant magnetization equal difference between them. It has a
critical temperature below which the magnetic moments on both lattice have an orderly arrangement while above the critical temperature the magnetic moments randomly oriented as in paramagnetic substances. Ferromagnetic order was first suggested by Neel to explain the behaviour of ferrites. The ferrimagnetics behave on a macroscopic scale very much like ferromagnetic.

Ferrite is a ceramic material formed by reacting metal oxides into a magnetic material. Soft magnetic material is one that can be both easily magnetized and demagnetized, so that it can store or transfer magnetic energy in alternating or other changing wave forms (sine, pulse, square, etc).

2. Classification of ferrites

Now a day the term ferrite is used for magnetic oxides whose main constituent is iron oxide. There are mainly three different types of ferrites based on the crystallographic structure.

Soft Ferrite
Hard Ferrite

Soft ferrites

Ferrites that are used in transformer or electromagnetic cores contain nickel, zinc, and/or manganese compounds. They have a low coercivity and are called soft ferrites. The low coercivity means the material's magnetization can easily reverse direction without dissipating much energy (hysteresis losses), while the material's high resistivity prevents eddy currents in the core, another source of energy loss. Because of their comparatively low losses at high frequencies, they are extensively used in the cores of RF transformers and inductors in applications such as switched mode power supplies.

The most common soft ferrites are:

a. Manganese-zinc ferrite (MnZn), with the formula \((\text{Mn}_{a}\text{Zn}_{1-a}\text{Fe}_2\text{O}_4)\). MnZn have higher permeability and saturation induction than NiZn.

b. Nickel-zinc ferrite (NiZn), with the formula \((\text{Ni}_{a}\text{Zn}_{1-a}\text{Fe}_2\text{O}_4)\). NiZn ferrites exhibit higher resistivity than MnZn, and are therefore more suitable for frequencies above 1 MHz.

Hard ferrites:

In contrast, permanent ferrite magnets are made of hard ferrites, which have a high coercivity and high remanence after magnetization. These are composed of iron and barium or strontium oxides. The high coercivity means the materials are very resistant to becoming demagnetized, an essential characteristic for a permanent magnet. They also conduct magnetic flux well and have a high magnetic permeability. This enables these so-called ceramic magnets to store stronger magnetic fields than iron itself. They are cheap, and are widely used in household products such as refrigerator magnets. The maximum magnetic field \(B\) is about 0.35 tesla and the magnetic field strength \(H\) is about 30 to 160 kiloampere turns per meter (400 to 2000 oersteds).\(^1\) The density of ferrite magnets is about 5g/cm\(^3\).
The most common hard ferrites are:
Strontium ferrite, SrFe$_{12}$O$_{19}$ (SrO$_6$Fe$_2$O$_3$), a common material for permanent magnet applications.
A). Barium ferrite, BaFe$_{12}$O$_{19}$ (BaO$_6$Fe$_2$O$_3$), a common material for permanent magnet applications. Barium ferrites are robust ceramics that are generally stable to moisture and corrosion-resistant. They are used in e.g. subwoofer magnets and as a medium for magnetic recording, e.g. on magnetic stripe cards.

b). Cobalt ferrite, CoFe$_2$O$_4$ (Co$_{O_6}$Fe$_2$O$_3$), used in some media for magnetic recording.

3. Orientation of the present work:
Ferrimagnetics materials, ferrites, have wide application potential in different fields such as telecommunication, electronic industries, due to their interesting electrical and magnetic properties. In the past few years, several researchers have studied the electric and magnetic properties of ferrite materials in view of their importance in the application within the range of frequency up to few GHz. This is due to low eddy current and dielectric loss. The simultaneous requirement of optical, electric and magnetic properties in the advanced electronics, Microwave and computer technologies have focused the attention of research works on ferrites. Ferrites have wide application in microwave devices and magnetic recording.

Ferrite shows high resistivity and negative temperature coefficient of resistance like semiconductors. They also show low magnetic loss at higher frequency and hence they found useful in microwave region, high resistivity and low power loss is the prime requirement of magnetic material to it as core. It was found that the electrical and magnetic properties are mostly sensitive to method of preparation, preparation condition, and chemical compositions. It was also observed that these properties are significantly be modified by substitution of divalent or trivalent cations, to suit the material for particular application. Therefore, investigations of structural, electrical and magnetic properties of the ferrites become a field of interest for many researchers.

4. History of ferrites:
1. The first type of magnetic material known to man was in the form of lodestone, consisting of the ore magnetite (Fe$_3$O$_4$). Magnets found their first application in compasses, which were used in the ninth century by the Vikings, or perhaps even earlier.

2. A milestone in the history of magnetism was the work done by William Gilbert in 1600.


4. At about the same time, in 1948, L. Neel announced his celebrated theoretical contribution on ferri-magnetism. This dealt with the basic phenomenon of "spin-spin interaction" taking place in the magnetic sublattices in ferrites. The stage was now set for the development of microwave ferrite devices.
5. In 1956, Neel, discovered the garnet ferrite class of materials. This type of ferrite material has three sub lattices, and is also referred to as rare-earth iron garnets. These materials, although having a magnetization lower than spinel ferrite.