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APPLICATIONS OF FERRITE MAGNET

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ABSTRACT

This work explained in details the Ferrite magnet form the structure, and the properties. It is found that it's consisting of non metallic material such as ceramic, and it is a compound of iron oxide with other different oxides. Also the applications of the two types soft/hard were presented.

I. INTRODUCTION

1. Historical Background

The term "ferrites"—from the Latin word for iron—means different things to different scientists. To metallurgists, ferrite means pure iron. To geologists, ferrites are a group of minerals based on iron oxide. To an electrical engineer, ferrites are also a group of materials based on iron oxide, but ones that have particular useful properties: magnetic properties and dielectric properties. Having magnetic properties means that a piece of ferrite will attract iron-based materials and will attract magnets of opposite polarity and repel magnets of like polarity. Magnetite, or lodestone, is a naturally occurring iron oxide that is considered a ferrite by both geologists and engineers. Over 2,000 years ago the ancient Greeks recognized the strange properties of lodestone, and almost 1,000 years ago the Chinese used it to invent the magnetic compass. Having dielectric properties means that even though electromagnetic waves can pass through ferrites, they do not readily conduct electricity. This gives them an advantage over iron, nickel, and other transition metals that have magnetic properties ("ferromagnetic") in many applications because these metals also conduct electricity. Materials can become magnetic because each of the molecules that make up the material function have a "magnetic moment" —that is they function like a very tiny magnet. When they all line up the overall material can produce a magnetic field. In the "ferrimagnetic" ferrites—as opposed to the "ferromagnetic" metals—there is not one alignment but a distinctive arrangement of parallel and perpendicular magnetic moments. This arrangement gives them their interesting properties[1,2]. This effect can be achieved through several different crystal structures. Different ferrites lend themselves to different applications, as we will see. Because their magnetism depends on an orderly crystal structure, both ferromagnetic and ferrimagnetic materials can lose their magnetism if they're heated too high or subjected to mechanical stresses Although theoretically an engineer's ferrite could be a single crystal or a collection of crystals grown together—like the geologist's ferrite—in practice ferrites are made from pressing together iron oxide powders under high heat. Because of this, ferrites can be put into a ceramic or rubber matrix and molded into an endless variety of sizes and shapes. Because there are different types of ferrites, different mixtures of iron oxides—with other materials added as well—can be produced with the exact desired combination electrical and magnetic properties. Ferrites, therefore, have many very important uses. Whenever a fixed magnet, as opposed to an electromagnet, is needed, ferrites are there. Certain types of electric generators and electric motors use fixed magnets, and ferrites are ideal for these applications. They are used as cores for inductors and transformers. Cassette and video tapes use ferrites coated onto the plastic base to record the signal. And many computers up to the 1970s used magnetic core memories where the cores were made of ferrite (in fact, because of their reliability, ferrite core memories were used in the Space Shuttle until 1990. Perhaps the most important use of ferrites in recent times is as a medium for transmitting microwaves. This is because some ferrites at very high frequencies (beginning above about 500 MHz, and very strongly in the microwave range of 1 to 30 GHz) exhibit a nonreciprocal effect. That means that electromagnetic waves passing through them behave differently traveling in different directions. This phenomenon allows the construction of one way transmission lines, junctions that can control the "traffic" of microwaves, and other microwave control devices. Our modern telecommunications system would not be possible without ferrites. Ferrites are a class of ferromagnetic ceramic chemical compounds consisting of mixtures of various metal oxides, usually including iron oxides. Their general chemical formula may be written as AB_2O_4, where A and B represent different metal cations. Ferrite is a ceramic-like material with magnetic properties, which is used in many types of electronic devices [3, 4, and 5].

2. Definition of Ferrite

Ferrites are explained as any of a group of nonmetallic, ceramic-like, usually ferromagnetic compounds of ferric oxide with other oxides, especially a compound characterized by extremely high electrical resistivity. A ferrite is usually described by the formula $M(Fe_xO_y)$, where M represents any metal that forms divalent bonds, such as nickel ferrite ($NiFe_2O_4$).Ferrite may refer to[6]:

- Ferrite (iron) - iron or iron alloys with a body-centered cubic crystal structure
- Ferrite (magnet) - ferromagnetic ceramic materials used in magnetic applications
- Ferrite bead - components placed on the end of data cables to reduce interference
- Calcium aluminoferrite - a mineral found in cements
- Ferrite core - a structure on which the windings of electric transformers and other wound components are formed

3. Crystal Structure

Ferrites are a class of spinels. They adopt a crystal motif consisting of cubic close-packed (FCC) oxides (O^{2-}) with a cations occupying one-eighth of the octahedral holes and B cations occupying half of the octahedral holes. The magnetic material known as "ZnFe" has the formula $ZnFe_2O_4$, with Fe^{3+} occupying the octahedral sites and half of the tetrahedral sites. The remaining tetrahedral sites in this Spinel are occupied by Zn^{2+}.

4. Preparation of Ferrites

Ferrites were first prepared by ceramic methods, involving milling, mixing, pressing, sintering, and finishing as basic operations, to obtain bulk materials with grains in the micrometric scale. However, as a result of the general current tendency to circuit integration and miniaturization, ferrites are prepared in the form of thick and thin films and, more recently, as nano structured materials. Ferrite thin films can be polycrystalline or epitaxial films. Major methods to obtain ferrite thin films are electroplating (or ferrite plating) [7], magnetron sputtering (single and multi target) [8], pulsed laser deposition , and molecular beam epitaxial [9]. A detailed account of epitaxial ferrite films can be found in [10]. An additional route to tuning ferrite properties for specific applications is the production of hetero structures, that is, the artificial layering of ferrites with isostructural and non-isostructural materials, such as Fe_3O_4/NiO (53), Fe_3O_4/C_oO (56), and $(Mn,Zn)Fe_2O_4/C_o$ Fe_2O_4 and incorporating them into planar devices. The combination of ferrite layers with piezoelectric layers is leading to new and exciting applications. By reducing the scale to the nanometric size, new and technologically interesting properties have been obtained. Nanocrystalline magnetic materials have been obtained by a variety of methods, such as co precipitation, hydrothermal , sonochemical , citrate precursor , sol-gel , mechanical alloying ,shock wave reverse micelle , forced hydrolysis in a polyol , and even by using egg white as an aqueous medium [11].

5. Production

Ferrites are produced by heating an intimate mixture of powdered precursors (which are often carbonates of the metals chosen) and then pressed in a mold. During the heating process, calcinations (thermal decomposition) of carbonates occur. The general reaction of a metal carbonate (where M is the metal ion) may be written as follows:

$$MCO_3 \rightarrow MO + CO_2$$

For example, barium carbonate ($BaCO_3$) and strontium carbonate ($SrCO_3$) are converted to their oxides, BaO and SrO, respectively. The resultant mixture of oxides undergoes sintering (in which the solid particles adhere to one another). The cooled product is then milled to tiny particles (smaller than two micrometers (μm)), the powder is pressed into a shape, dried, and re-sintered. The shaping may be performed in an external magnetic field, to achieve a preferred orientation of the particles (anisotropy).Small and geometrically easy shapes may be produced with dry pressing. However, in such a process small particles may agglomerate and lead to poorer magnetic properties compared to the wet pressing process. Direct calcinations and sintering without re-milling is possible as well but leads to poor magnetic properties. Electromagnets are pre-sintered as well (pre-reaction), milled, and pressed [12]. However, the sintering takes place in a specific atmosphere, such as that is low in oxygen. The chemical composition and especially the structure vary strongly between the precursor and the sintered product.

6. General Properties

Ferrites are electrically non-conductive ferromagnetic ceramics. They are usually mixtures of iron oxides, such as hematite (Fe_2O_3) or magnetite (Fe_3O_4), and oxides of other metals. Like most other ceramics, they are hard and brittle. In terms of their magnetic properties, they are often classified as "soft" or "hard," referring to low or high coercivity of their magnetism, respectively. Ferrites are often classified as "soft" or "hard" in terms of their magnetic properties [13]:

- Soft ferrites - used in transformer or electromagnetic cores. They have a low coercivity (manganese-zinc ferrite, nickel-zinc ferrite).
- Hard ferrites- have a high coercivity. They are cheap, and are widely used in household products such as refrigerator magnets (strontium ferrite, barium ferrite).

Soft ferrite does not retain significant magnetization, whereas hard ferrite magnetization is considered permanent. Ferrite components are pressed from a powdered precursor and then sintered (fired) in a kiln. The mechanical and electromagnetic properties of the ferrite are heavily affected by the sintering process which is time-temperature-atmosphere dependent. Ferrite shrinks when sintered. Depending on the specific ferrite, this shrinkage can range from 10% to 17% in each dimension. Maintaining correct dimensional tolerances as well as the prevention of cracking and war page related to this shrinkage are fundamental concerns of the manufacturing process.

II. APPLICATIONS OF SOFT/HARD FERRITE

1. Classifications

Soft ferrite applications fall into three major areas [14]:

- Low signal ferrites.
- Power handling ferrites.
- Interference suppression ferrites.

There are other uses for ferrites, such as memory storage systems, microwave gyro rotational devices, and thermal switching devices, but most of the materials produced today focus on these three classifications.

2. Low Signal Level

Low signal level ferrites may be grouped into four sub classifications [15]:

- High Q inductors.
- Common mode inductors.
- Wideband and matching transformers.
- Pulse transformers.

In all of these, the core windings excite the core to low levels of operating flux density. Each of the subclasses requires unique features in the ferrite core. Some of these are common, but there are preferred shapes and material types for each.

3. High Q Inductors

The majority of High Q Inductors are used in analog devices, particularly in telecommunications applications. A component must resonate at the desired frequency, be stable over time and temperature range, and have high permeability combined with negligible energy loss. Finally, the inductor should occupy the smallest possible volume and be cost effective[16].Although telecommunications is the largest and most critical segment, High Q Inductors are also used in many other electronic areas. These include communications, entertainment, controls. and other industries. Ferrite manufacturers provide standard inductor geometries, influenced by IEC standards. These are in the configurations of pot cores, RM cores, and in some cases, toroids. Manufacturers' literature describes the magnetic and physical parameters of the cores[17].

4. Common Mode Inductors

The most frequent use of common mode inductors is in power conditioning or power supply components. Although this is a relatively narrow application segment of the soft ferrite market, large quantities of cores are utilized. Their function is to insure that the power being supplied to an electronic device is "clean". Additionally, they prevent common mode noise generated by the equipment from escaping into other circuitry. The common mode inductor forms the heart of the low pass power filter[18].The core may operate at moderate flux densities, but is generally designed to function at low amplitudes. Many of the characteristics desired in materials for High Q Inductors are also needed for these filters Demands on temperature stability, high quality factor, and precision inductance are not as stringent. Most common mode inductors utilize toroids, but in some cases un gapped pot cores or PQ cores may be employed. When using toroids, the core must be insulated from the winding with high resistance barrier.

5. Wide Band and Matching Transformers

Although some energy is transferred in wideband transformers, they are used primarily to match impedances, provide precise current or voltage ratios and serve as interfaces between balanced and unbalanced circuits. Wideband transformers are designed to operate over a wide frequency range with low insertion loss in the mid-band area[19].Communications systems employ the largest number of wideband transformers. The materials utilized depend upon the frequency where low and high end cut-offs occur and the width of the pass band. Material requirements are high initial permeability (compatible with the frequency used), low loss, and magnetic stability.

6. Pulse Transformers

While pulse transformers are required to function over a wide frequency band, the fact that their signal wave shape is not sinusoidal makes them unique, both in their function as well as their ferrite requirements. The effect of the ferrite on the generally rectangular pulse shape is an important measure of their performance. The transformer, to function effectively, should transfer the pulse shape without appreciable distortion. Ferrites are utilized as low-power pulse transformer cores in

Data circuits involving[19,20]:

- Impedance matching.
- Balanced to unbalanced circuits.
- Isolation.
- Precise voltage or current transformation.

Core properties impact all three areas. The two significant pulse ferrite parameters are the pulse permeability (l +). And a measure of the non-linearity of the magnetizing current commonly referred to as the voltage-time product (ET). The Ferrite types used in pulse applications exhibit [21]:

- High permeability.
- Low core loss
- High saturation flux density.
- Good magnetic stability.

7. Hard Ferrite Applications

Barium Ferrite is used in tape drives and floppy disks, among other things. Barium ferrite is a very applicable material used in many industry fields in today's day and age. The material is seen around the world in applications such as recording items such as tapes and other media devices, permanent magnets, and also magnetic stripe cards (credit cards, hotel keys, ID cards). Due to the stability of the material, it is able to be greatly reduced in size, making the packing density much greater. In the late media devices, acicular oxides were used which produced the coercivity values necessary to record. Although in the past few decades barium ferrite has replaced the acicular oxides; without any dopants, the acicular oxides produce very low coercivity values, making the material very magnetically soft. The barium ferrite which has recently taken the oxide's place produces much higher coercivity levels which make the material magnetically hard, therefore making the ferrite better for recording materials [22].The rate of growth in the production of RE-Magnets has continued unabated, despite fluctuations in the world economy. Thus, sintered NdFeB magnets are exhibiting a current growth rate of ~12% whereas the growth rate for bonded NdFeB magnets is in excess of 20%.The total value of hard magnets now exceeds that of soft magnets and the gap is widening. The reason for this spectacular growth has been due partially to the booming global PC market, as around 60% of NdFeB magnet production goes into disc-drive applications, primarily voice-coilmotors (VCMs).This is by no means the whole story however and a summary of the very wide range of applications for RE-magnets is given below, with many of these being capable of substantial further growth.In general terms, permanent magnets are far more important than is generally realized and this is perhaps, best illustrated by their use in the motor car. In the early fifties a car would have one magnet (the speedometer) whereas some modern cars can have over a hundred permanent magnet motors. Currently these are almost exclusively based on Sr-ferrite (SrFe12019) and the penetration of NdFeB magnets into this area requires a significant cost reduction, an increase in the maximum operating temperature and improvement in corrosion resistance[23].The potential benefits of using NdFeB magnets would be a significant reduction in volume and weight and an improved efficiency[24]. This will probably be a major influence in the use of these magnets in the future. Growing concern about global warming has scientific and technological implications and many of these impinge on the use of NdFeB magnets. Future uses could include their more widespread use in "white goods" such as washing machines, refrigerators etc, in order to improve energy efficiency and hence reduce CO_2 emissions. Another large use could be in generators for domestic combined heat and power units and in clean energy production such as windmills. The biggest potential however is in electric vehicles (EVs) which could be hybrid vehicles or totally driven by electricity in the form of batteries or a fuel cell There has been an enormous increase of interest and activity in this area over the past 5 years and the Japanese have been the first to commercialize these vehicles

8. Examples of Applications for Permanent Magnetic Materials

Automotive: Starter motors, Anti-lock braking systems (ABS), Motor drives for wipers, Injection pumps, Fans and controls for windows, seats etc, Loudspeakers, Eddy current brakes, Alternators.

Telecommunications: Loudspeakers, Microphones, Telephone ringers, Electro-acoustic pick-ups, Switches and relays.
Data Processing: Disc drives and actuators, Stepping motors, Printers.

Consumer Electronics: DC motors for showers, Washing machines, Drills, Low voltage DC drives for cordless appliances, Loudspeakers for TV and Audio, TV beam correction and focusing device, Compact-disc drives, Home computers, Video Recorders, Clocks.

Electronic and Instrumentation: Sensors, Contactless switches, NMR spectrometer, Energy meter disc, Electro-mechanical transducers, Crossed field tubes, Flux-transfer trip device, Dampers.

Industrial: DC motors for magnetic tools, Robotics, Magnetic separators for extracting metals and ores, Magnetic bearings, Servo-motor drives, Lifting apparatus, Brakes and clutches, Meters and measuring equipment.

Astro and Aerospace: Frictionless bearings, Stepping motors, Couplings, Instrumentation, Travelling wave tubes, Auto-compass.

Biosurgical: Dentures, Orthodontics, Orthopedics, Wound closures, Stomach seals, Repulsion collars, Ferromagnetic probes, Cancer cell separators, Magneto motive artificial hearts, NMR / MRI body scanner[24].

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III. CONCLUSION

The basic properties and applications of magnetic materials were studies, and properties and applications of type of Ferrite magnetic (soft and hard) was investigated. Ferrites are ferromagnetic compounds of ferric oxide with other oxides, especially a compound characterized by extremely high electrical Resistivity. Uses of Ferrite e.g. Permanent magnets, Ferrite cores for transformers and toroidal inductors, Computer memory elements, Solid-state devices. Soft ferrites are Ferrites that are used in transformer or electromagnetic cores contain nickel, zinc, or manganese compounds. They have a low coercivity. Hard ferrites are permanent ferrite magnets (or hard ferrites) which have a high remanence after magnetizations are composed of iron and barium or strontium oxides. In a magnetically saturated state, they conduct magnetic flux well and have a high magnetic permeability. Ferrite cores are used in electronic inductors, transformers, and electromagnets, where the high electrical resistance of the ferrite leads to very low eddy current losses. They are commonly seen as a lump in a computer cable, called a ferrite bead, which helps prevent high-frequency electrical noise (radio frequency interference) from exiting or entering the equipment.It is that there is not a problem with the price of iron oxidation raw materials at low cost. In addition, it also has excellent corrosion resistance and oxidation resistance. It is very stable and difficult to demagnetize the magnetic properties are not inferior to the rare-earth magnet, but the coercive force is large.

1. Advantages of Ferrites

Ferrites have a paramount advantage over other types of magnetic materials: high electrical resistivity and resultant low eddy current losses over a wide frequency range. Additional characteristics such as high permeability and time/temperature stability have expanded ferrite uses into quality filter circuits, high frequency transformers, wide band transformers, adjustable inductors, delay lines, and other high frequency electronic circuitry. As the high frequency performance of other circuit components continues to be improved, ferrites are routinely designed into magnetic circuits for both low level and power applications. Another factor in choosing ferrites is the higher cost of magnetic metals. For the most favorable combination of low cost, high Q, high stability, and lowest volume, ferrites are the best core material choice for frequencies from 10 KHz to 50 MHz. Ferrites offer an unmatched flexibility in magnetic and mechanical parameters.

2. Summary of Ferrite Advantages

- Low cost
- Large selection of materials
- Shape versatility
- Economical assembly
- Temperature and time stability
- High resistivity
- Wide frequency range (10 KHz to 50 MHz)
- High Q/small package

3. Disadvantages

It is easy to crack as pottery mechanical strength is low. In addition, it is less expensive quantity is gathered, but the response to the prototype can be difficult because it becomes the mold required for production

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