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IMPORTANCE OF MAGNETIC MATERIAL AND THIER CLASSIFICATION

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ABSTRACT:

It is in this article that you will learn about the fundamentals of magnetic materials. Classification. The need for electromagnetic equipment is rising along with the power industry's boom. When designing and improving electrical equipment, it's critical to precisely replicate magnetic characteristics of magnetic materials under a variety of external situations, such as changing frequencies or pressures. As a prelude, this study outlines the history of magnetism and its many classifications. Currently, materials scientists and nuclear magnetic resonance spectroscopists have simple access to high magnetic fields of around 10 T provided by superconducting magnets. Laboratory neodymium magnets may be found inexpensively, and they're also commonly employed in everyday items like cell phones and electric automobiles. These magnets create magnetic fields of around one tera Tesla. In the last 30 years, researchers have been able to find novel magnetic phenomena and use these phenomena to the processing of diamagnetic materials, which was previously unimaginable. Also included in our research are materials such as paramagnetic, ferromagnetic, and antiferromagnetic.

Keywords: Magnetic Materials, Paramagnetic, Ferromagnetic, Antiferromagnetic, Ferrimagnetic, Ferrites

1. INTRODUCTION

People in ancient Greece as well as ancient China first considered how magnets could attract iron. The Greek word "Magnesia" is the root of the English word "magnet" Magnetite (Fe_3O_4), the first magnetic substance discovered by humans around 2500 years ago, serves as the scientific starting point for the study of magnetism. Magnets were used in ancient times to find their way and were referred to as "Lode stones," which were made of the mineral magnetite (Fe_3O_4). This conclusion was made by Dr William Gilbert, a court physician, after he studied the Earth's magnetic field for decades [2, 3]. Compasses were once used to find their way in the past because they worked on the same principle. When it comes to magnetism, a number of historical contributions have been made since then.

2. Magnetic Materials

For thousands of years, materials that exert an attractive or repellent influence on other magnetic materials have been referred to as magnetic materials. Due to the increasing reliance on magnetism in our current technology, magnetic materials are becoming increasingly important in society's

growth and development [4]. A wide range of magnetic materials, including metals, ceramics, and polymers, are available in a variety of shapes and sizes. There are a variety of elements that influence the utilisation of magnetic materials, including their kind and characteristics, magnetization and form.
Since the 1950s, magnetic materials have been frequently employed. These materials have become increasingly popular in recent years. For high frequency applications such as in antennas, filters, resonators, phase shifters, and microwave anti-reflection coatings, only a small number of the most adaptable technical ceramics for high frequency applications are magnetic oxides.
By moving an electric charge (the foundation for electric current), the magnetic field is generated, like the gravitational and electrical fields, in material. There are two electronic movements connected with the electron, the orbital motion and the spin motion, which are responsible for magnetism in all materials. Tiny currents can be regarded as magnetic dipole moments because of their dynamics. Magnetization (M) is defined as the net magnetic dipole moment per unit volume of the magnetised material in response to an external magnetic field (H). The alignment of electron spins (M) is the source of magnetization (M). Additionally, the method in which M changes with H is an important part of a material's magnetic characteristics. Eq.1.1 expresses the relationship between these two values, known as magnetic susceptibility.

$$\chi = \frac{M}{H} \qquad (1.1)$$

Temperature, an external magnetic field, and atomic structure all have a role in magnetic susceptibility.

ferrimagnetic materials such as ferrites and magnetic ceramics are widely established. Ferrites have been the subject of a great deal of study in the last century. Because of their high resistivity, reduced cost, and better homogeneity compared to metals, ferrites are increasingly being used in place of metallic magnetic materials. They now play a significant role in nearly every aspect of modern life and may be found in a wide variety of settings. A variety of modern technologies rely on them as permanent magnets and/or bubble devices, including satellite communication and digital recording.

3. Classification of Magnetic Materials

Every substance contains variable magnetic behaviour under an applied magnetic field and so it is appropriate to categorise them into several categories. The magnetic materials may be divided into five basic categories on the basis of relative organisation and alignment of atoms or molecules under the applied external magnetic field.

3.1 Diamagnetic Materials

A pair of paired electrons in an orbital cancel each other out, resulting in dimagnetism. A extremely weak kind of diamagnetism is a trait shared by all matter. Because there are no unpaired electrons in diamagnetic material (Fig.1), there is no net magnetic moment (a).

Electrons in a material are aligned in the opposite direction of the applied magnetic field when it is put in the magnetic field. For diamagnetic materials, the value of susceptibility is tiny and negative (n0), which is independent of temperature, because of the obverse direction of the magnetic field. Example: Silver (Ag), SiO_2, Gold (Au), Quartz, Bismuth, Copper, Antimony (Sb), Hydrogen, Air, Mercury, etc.

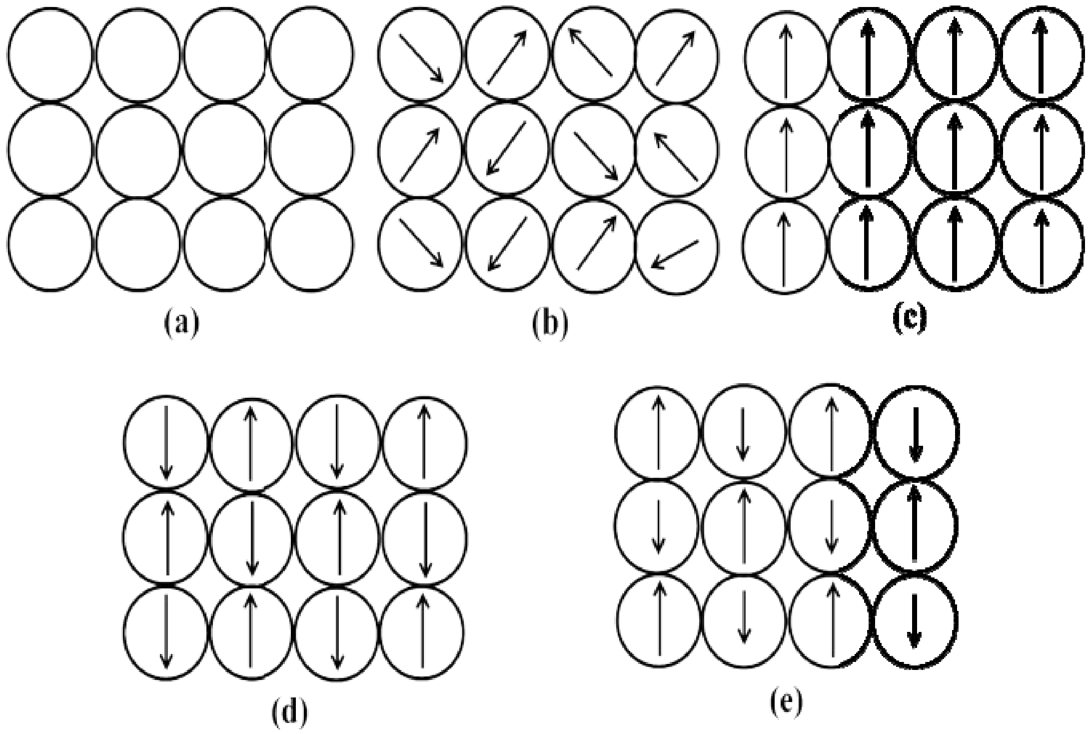

Figure 1: Magnetic moment ordering in (a) Diamagnetic, (b) Paramagnetic, (c) Ferromagnetic, (d) Antiferromagnetic and (e) Ferrimagnetic materials

3.2 Paramagnetic Materials

Thermal agitation randomly distributes atoms' and ions' permanent magnetic moments, resulting in paramagnetism. The magnetic moment aligns itself in the direction of an applied magnetic field in the presence of an applied magnetic field. When an external magnetic field is removed, these materials lose their magnetism; this is the case with all magnetic materials. These materials have a positive and temperature-dependent susceptibility. At room temperature, it is on the order of 10-3. The Curie's law governs paramagnetic materials. When I/T is equal to C/T, the susceptibility of a material increases as a function of the absolute temperature.

$$\chi = \frac{C}{T} \tag{1.2}$$

The magnetic materials adhere to this rule at high temperatures, but it breaks down at lower temperatures. The magnetic dipoles in paramagnetic materials are arranged in the manner seen in Fig.1.1 (b). Materials with odd numbers of electrons, such as transition metals, tend to exhibit paramagnetism in paramagnetic structures. Aluminum, platinum, iron, pyrite (sulphide), and siderite (carbonate) are a few examples of these elements).

3.3 Ferromagnetic Materials

The parallel alignment of magnetic moments (domains) results in ferromagnetism, which is identical in magnitude. In ferromagnetic materials, magnetic dipoles are aligned as seen in Fig.1.1 (c). Even in the absence of an externally imposed magnetic field, some materials demonstrate spontaneous magnetization. Weiss, a French physicist, proposed in 1907 that magnetic domains exist within materials, where the magnetic moments are aligned. The mobility of these domains affects the magnetic field response of materials. All domains in a material align in the direction of an applied magnetic field, resulting in a non-zero magnetic moment when applied externally. Magnets draw these materials to themselves.

Ferromagnetic materials are ferromagnetic up to a certain temperature, known as the Curie temperature (Tc), and become paramagnetic when the magnetic moments interaction is not strong enough to keep them aligned when subjected to thermal agitation. Because of the Curie-Weiss law, they have a high yet positive susceptibility.

$$\chi = \frac{C}{T-\theta} \tag{1.3}$$

Where θ is a temperature known as a Curie. Among the ferromagnetic metals are Fe, Co, and Ni, with permeabilities ranging from 1200 to 1250 gauss.

3.4 Antiferromagnetic Materials

Magnetic moments alternately align alternatively antiparallel in antiferromagnetic materials, as seen in Fig.1.1 (d). Their tiny but positive susceptibility is due to the antiparallel alignment of the spins, which is caused by an applied magnetic field tending to align the spins and this induced alignment is larger than the diamagnetism of electron orbitals. There is a particular critical temperature (TN) at which the magnetic alignment of a material is disrupted, and the substance becomes paramagnetic. Net magnetization is 0 at absolute zero in the antiferromagnetic condition. There are no magnetic moments in paramagnetic materials above the Neel temperature. They include transition metal oxides (CoO and NiO, as well as Hematite (Fe_2O_3) and Nickel Oxide (NiO)), as well as ironmanganelse (FeMn).

3.5 Ferrimagnetic Materials

There is a limited net magnetization in ferrimagnetic materials because the magnetic moments are oriented in an antiparallel direction and hence do not totally cancel out. In ferrimagnetic materials, magnetic moments align as seen in Fig.1.1 (e). Below a certain temperature known as the Neel temperature, these materials exhibit a spontaneous magnetization (TN). Only a few ferrimagnetic materials are also excellent insulators, which makes them ideal for reducing the amount of energy lost to transformer eddy currents. These materials include ferrites and magnetite, which are naturally occurring ferrimagnetic materials. In high-frequency electronics and electrical engineering, these materials are commonly utilised.

3.5.1 Ferrites

Metallic oxide mixtures called ferrites are typically nonconductive. Ferrite is a fascinating magnetic substance that has been used in several technological applications due to its unique combination of magnetic and electric characteristics. A variety of variables influence the magnetic and electric characteristics of ferrites, including the synthesis methods used, the synthesis conditions, the elemental composition and substituent amounts, as well as the sintering temperatures and times. Neel has explained that the ferrites' magnetic characteristics are determined by the arrangement of ions in the sublattice.

In addition to its high resistivity, low dielectric and magnetic loss, high Curie temperature, and high magnetic permeability, ferrites may be used in a variety of technical applications, including radar and satellite communication, memory cores in computers, and microwave devices.

4. CONCLUSION

Diamagnetic materials, particularly polymers, were examined for their magnetic properties. It is the force of magnetism that causes phenomena such as magnetic levitation, particle separation, and particle manipulation, whereas the torque of magnetism is responsible for phenomena such as crystal and fibre orientation. Magnetic energy is what generates the force and the torque in a motor. Because of this, we can plainly see the effects of these elements on the world. With regard to polymeric materials, magnetic orientation may be readily traced to the magnetic torque acting on the filler. The 'Cinderella materials' of the magnetic realm are today recognised as paramagnetic and diamagnetic materials. However, measurements of susceptibility done on these materials in the past have revealed several information regarding the molecular bonding and atomic structure of the so-called "transition" elements. Indeed, neodymium's magnetic capabilities have been known for decades, but only lately have they been put to use. There may be a relationship between the past and the present in the experiment on susceptibility presented in this article. EC NDE is heavily influenced by the ferromagnetic characteristics of materials. Understanding the magnetization (and demagnetization) processes that occur in ferromagnetic materials is necessary for the successful interpretation of EC measurements on a variety of steels and other types of ferromagnetic conductivity. When it came to high-frequency magnetic fields, the ferrites offered more 'effective permeability' than the metals, as well as reduced 'eddy-current' losses due to their higher d.c. electrical resistivities and lower magnetic saturation intensities. Non-metallic materials' ferromagnetic and antiferromagnetic behaviour has been studied in more depth thanks to these efforts, which have had mixed results thus far.

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