IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

New Trends In Magnetism And Magnetic Materials - An Overview

Madhvi Trivedi

(M.Sc., M.Phil.)

Assistant Professor

Department of Physics

Faculty of Science

S.P.U. PG College Falna

Pali Rajasthan India

ABSTRACT

The Magnets, reed switch magnetism decreases at higher temperature and increases at lower temperature. This is because high temperatures increase random atomic movement and misalignment of magnetic domains. As a result, more magnetism needs to be applied to the reed switch at high temperature.Excessive heat causes atoms to move more rapidly, disturbing the magnetic domains. As the atoms are sped up, the percentage of magnetic domains spinning in the same direction decreases. This lack of cohesion weakens the magnetic force and eventually demagnetises it entirely.around 80 °C, a magnet will lose its magnetic force and it will become demagnetized permanently if exposed to this temperature for a period, or if heated above its Curie temperature. Heat the magnet even more, and it will melt and eventually vaporize

Key Words : Backdrop, Current Trends, Types, Factor Affecting, Difference and Superheating Reduce the Magnetism

Backdrop

The history of magnetism dates back to earlier than 600 b.c., but it is only in the twentieth century that scientists have begun to understand it, and develop technologies based on this understanding. Magnetism was most probably first observed in a form of the mineral magnetite called lodestone, which consists of iron oxide-a chemical compound of iron and oxygen. The ancient Greeks were the first known to have used this mineral, which they called a magnet because of its ability to attract other pieces of the same material and iron.

The Englishman William Gilbert (1540-1603) was the first to investigate the phenomenon of magnetism systematically using scientific methods. He also discovered that the Earth is itself a weak magnet. Early theoretical investigations into the nature of the Earth's magnetism were carried out by the German Carl Friedrich Gauss (1777-1855). Quantitative studies of magnetic phenomena initiated in the eighteenth century by Frenchman Charles Coulomb (1736-1806), who established the inverse square law of force, which states that the attractive force between two magnetized objects is directly proportional to the product of their individual fields and inversely proportional to the square of the distance between them. Danish physicist Hans Christian Oersted(1777-1851) first suggested a link between electricity and magnetism.

Experiments involving the effects of magnetic and electric fields on one another were then conducted by Frenchman Andre Marie Ampere (1775-1836) and Englishman Michael Faraday (1791-1869), but it was the Scotsman, James Clerk Maxwell (1831-1879), who provided the theoretical foundation to the physics of electromagnetism in the nineteenth century by showing that electricity and magnetism represent different aspects of the same fundamental force field. Then, in the late 1960s American Steven Weinberg (1933-) and Pakistani Abdus Salam (1926-), performed yet another act of theoretical synthesis of the fundamental forces by showing that electromagnetism is one part of the electroweak force. The modern understanding of magnetic phenomena in condensed matter originates from the work of two Frenchmen: Pierre Curie (1859-1906), the husband and scientific collaborator of Madame Marie Curie (1867-1934), and Pierre Weiss (1865-1940). Curie examined the effect of temperature on magnetic materials and observed that magnetism disappeared suddenly above a certain critical temperature in materials like iron.

Weiss proposed a theory of magnetism based on an internal molecular field proportional to the average magnetization that spontaneously align the electronic micromagnets in magnetic matter. The present day understanding of magnetism based on the theory of the motion and interactions of electrons in atoms (called quantum electrodynamics) stems from the work and theoretical models of two Germans, Ernest Ising (1900-) and Werner Heisenberg (1901-1976). Werner Heisenberg was also one of the founding fathers of modern quantum mechanics.

Magnetic Moments: Magnetic moments are the inherent characteristics of atoms, ions, or molecules that determine their response to an applied magnetic field. Magnetic moments are a result of the orbital motion of electrons within atoms as well as the spin of electrons. The combination of orbital and spin angular momentum generates a net magnetic moment.

Current Research Trends in Magnetism

Ideally pure magnetic systems have provided the most extensively investigated models of the large scale collective behavior of atoms and electrons that occur in the vicinity of the critical point of phase transitions. More recent studies have unearthed fascinating effects caused by the intentional introduction of impurities and defects into random locations in the atomic lattice of a magnetic material. For example, these random magnetic systems display transitions to states of order that have no counterparts in pure systems, because pure systems are, by necessity, always close to thermodynamic equilibrium or stability. For these reasons there is now intense interest and research activity in disordered systems, and random magnets provide ideal model systems for such investigations.

An area of intense current activity centers around the search for a likely magnetic pairing force in the high temperature ceramic superconductors that were discovered in 1987 by the German-Swiss team of Georg Bednorz and Karl Alexander Muller. A superconductor achieves a zero resistance state by means of a force field that pairs up the conducting electrons within its atoms. The new ceramic materials are antiferromagnets in their undoped state, but on doping start to superconduct at temperatures that are over 182.F (83.C) warmer than conventional pure metal and alloy superconductors.

The effects of extremely high magnetic fields on the properties of condensed matter continues to be an area of high interest. New research areas, such as the search and study of magnetism in organic matter, and the study of diamagnetism and novel magnetic effects in the recently synthesized nanometer-sized (a nanometer is equal to 10-9 meter) carbon tubes, are of increasing interest to physicists and material scientists.

Types of Magnetic Materials

Diamagnetic Materials: Diamagnetic materials have no net magnetic moment and are weakly repelled by a magnetic field. This behavior arises due to the electron motion opposing the external magnetic field.

Paramagnetic Materials: Paramagnetic materials have unpaired electrons, leading to a weak attraction to a magnetic field. The unpaired electrons tend to align their magnetic moments with the external field, but thermal motion hinders full alignment.

Ferromagnetic Materials: Ferromagnetic materials exhibit strong and permanent magnetization even in the absence of an external magnetic field. This behavior arises from the alignment of atomic magnetic moments due to a phenomenon called exchange interaction. Examples include iron, nickel, and cobalt.

Antiferromagnetic Materials: In antiferromagnetic materials, neighboring magnetic moments align in opposite directions, resulting in a net magnetic moment of zero. The alignment is such that the magnetic forces cancel each other out.

Ferrimagnetic Materials: Ferrimagnetic materials are similar to ferromagnetic materials but have unequal magnetic moments on different sublattices, leading to a net magnetic moment. Ferrites are common examples of ferrimagnetic materials.

Magnetization Curves: Magnetization curves, also known as hysteresis loops, describe the relationship between the magnetic field strength (H) and the magnetic induction (B) of a material. These curves help characterize a material's response to changing external fields and provide insights into its magnetic behavior.

Curie Temperature (Tc): The Curie temperature is the temperature at which a ferromagnetic material transitions from being ferromagnetic to paramagnetic. At temperatures above the Curie temperature, thermal energy disrupts the ordered alignment of magnetic moments.

Magnetic Domains: Magnetic domains are microscopic regions within a magnetic material where the atomic magnetic moments are aligned. Within each domain, the moments are strongly aligned, but the orientations of different domains can be random. Domain walls are the boundaries between these regions.

Magnetic Anisotropy: Magnetic anisotropy refers to the directional dependence of a material's magnetic properties. Some materials have preferential directions along which their magnetic moments align more easily. This anisotropy can affect the material's behavior in different applications.

Factors Affecting Magnetic Strength

The factors affecting magnet strength are:

1.Steel Thickness

The steel thickness affects the absorption of magnetism. The magnet strength (performance and pull of magnet) can be impacted by the thickness of the steel surface on which the magnet applies the force. For example, if a magnet needs steel thickness to be 5 mm to apply its maximum magnet strength, then contacting the magnet to a higher thickness will result in a loss of magnetism.

2.Air Gaps

Air gaps affect the magnetic circuit. An air gap is a space or void that is non-magnetic. Air gaps are created between the material, preventing magnetism from applying force on other substances and reducing the magnet strength. The main causes of air gaps can be if the steel used is rusty, dirty, painted, or distorted in shape and size.

3.Material

The material used affects the determination of magnetic strength. When we are testing the pull strength of a magnet, mild steel is used as contact steel because its ability to conduct magnetism is higher than the other metals such as cast iron or alloy steel.

4.Sheer Force

Sheer force is another important factor affecting magnet strength. Magnets can be removed far more easily if we slide the magnet from the surface rather than trying to pull it away from the surface. When we slide the magnet vertically, the phenomenon is known as sheer force.

5.Temperature

Magnets depend on a particular temperature to work their best with maximum magnetic strength and force on the substance. If a magnet is heated beyond its operating temperature, its performance will decrease. In contrast, if a magnet is exposed to low temperatures, its magnetic strength and performance improve.

6.Heat

As discussed above, exposing a magnet to high temperatures that are more than its operating temperature reduces its magnetic strength and performance. Continuous exposure to heat reduces the magnet's strength to perform and pull. Some magnets designed to work in high temperatures are Samarium Cobalt, Ferrite, and Alnico.

7.Corrosion

Magnets are used in every kind of environment. Those usually used in industries are exposed to outer weather conditions. When the weather is more humid or rainy, or the magnet comes in contact with the water, it becomes rustier, which reduces the magnet strength.

Temperature Affect the Magnetism of Magnets

Magnets are used in daily life. They're used in manufacturing, automobiles, security systems and electronics devices. Even the earth itself is a magnet.

To understand temperature effects, we need to look at the atomic structure of the elements that make up the magnet. Temperature affects magnetism by either strengthening or weakening a magnet's attractive force. A magnet subjected to heat experiences a reduction in its magnetic field as the particles within the magnet are moving at an increasingly faster and more sporadic rate. This jumbling confuses and misaligns the magnetic domains, causing the magnetism to decrease. Conversely, when the same magnet is exposed to low temperatures, its magnetic property is enhanced and the strength increases.

In addition to the strength of the magnet, the ease at which it can be demagnetized also varies with temperature. Like magnet strength, demagnetization resistance generally decreases with increasing temperature. The one exception is ceramic (ferrite) magnets, which are easier to demagnetize at low temperature and harder to demagnetize at high temperature.

Different magnet materials react differently with temperature. Alnico magnets have the best strength stability followed by SmCo, NdFeB, and then ceramic. NdFeB magnets having the highest resistance to demagnetization (coercivity), but the largest change with temperature. Alnico magnets have the lowest resistance to demagnetization, but the smallest change with temperature. Alnico have the highest service temperature followed by SmCo, ceramic and then NdFeB.

Not everyone realizes that the shape of a magnet affects its maximum usable temperature. This is especially important for NdFeB magnets because they have the greatest change in demagnetization resistance with temperature. As the length of the magnetized axis increases, its resistance to demagnetization also increases.

Temperature Difference Leads to Magnetism

Heat field. Heating the right edge of an n-type semiconductor on top of a p-type semiconductor leads to loops of current in each material that generate a magnetic field pointing out of the screen, according to computer simulations.

Computer simulations suggest that creating hot and cold regions within a specific arrangement of semiconductors generates internal electric currents and magnetic fields. If borne out by experiments, the new effect, reported 8 July in Physical Review B, could lead to improvements in electronic devices that heat up in use. Experts are intrigued by the effect but remain cautious about its practical importance until they see experimental data.

Temperature differences, or “gradients,” can have important effects on the flow of current in a semiconductor because the electrons or holes tend to drift from hotter regions toward colder ones. Such thermal effects can also interact with electric and magnetic fields, as in the so-called thermoelectromagnetic effects. For instance, in the Nernst effect, when a semiconductor is exposed to a temperature gradient and a magnetic field at right angles to each other, a small electric field is produced in the third direction. Semiconductors in electronic devices often develop temperature gradients, so researchers need to understand their effects.

Junqiao Wu of the University of California, Berkeley, and his colleagues noticed that in the known thermoelectromagnetic effects, the magnetic field is never induced but always one of the “inputs,” or applied fields. They wondered whether a magnetic field would result if a semiconductor were subjected to an electric field and a temperature gradient.

The team ran computer simulations of a two-micron-wide sample consisting of an n-type semiconductor (electrons carry current) on top of a p-type semiconductor (positively-charged holes carry current). Near the interface, such a structure–which is common in electronics–generates a so-called depletion region, where electrons diffuse down into the p-type material and holes diffuse up into the n-type material. The fixed charges left behind create an electric field pointing down. Next, the team’s simulation assumed that the left edge was 10 millikelvin cooler than room temperature, and the right edge was 10 millikelvin hotter.

In the simulations, a current vortex developed in each material. In the n-type semiconductor, which was on top, electrons moved to the right at the top edge and to the left just above the interface, with the holes executing nearly a mirror image of this motion below the interface, in the p-type material. These vortices generated a magnetic field that pointed outward, toward the viewer.

The vortices are results of a complex simulation, and It’s difficult to explain them in physical terms. But part of the story is that half of each loop of current goes through the depletion region, the area within perhaps 100 nanometers of the p/n interface, where there are fewer charge carriers than in the rest of the material. This lack of charge carriers turns out to allow the temperature gradient to have a stronger effect on the mobile charges that remain there–pushing them from right to left–than it has on charges outside the depletion region. Away from this zone, near the upper and lower edges of the structure, there is much higher conductivity, which allows the charges to more easily flow left-to-right, against their usual thermal diffusion direction.

In addition, the vertical electric field effectively acts at the center of charge of the electron or hole “cloud,” whereas the temperature gradient acts at the center of mass, says Wu. He says that perpendicular forces acting at different places generate a torque on the charges, which partly explains the rotation, an effect described theoretically by others in 2005.

The magnitude of the effect can be large, and the eddy currents could soak up energy if the structure were part of a circuit, the researchers say. In fact, Wu says, similar arrangements of semiconductors in commercial devices that heat up may be running with slightly reduced efficiency because of this effect. The solution would be to minimize the vortices by aligning the direction of the temperature gradient with that of the electric field in future designs. The team believes that a better understanding of the relationships among temperature, currents, and electromagnetic fields may help engineers improve electronic designs in other ways as well.

Superheating Reduce the Magnetism of Magnets

To understand how temperature might affect a magnet, you need to look at the atomic structure of the elements it is made of. Magnets are made of atoms and, in normal conditions, these atoms align between poles and foster magnetism. There is a delicate balance between temperature and magnetic domains – that is the atom's inclination to 'spin' in a certain direction.

Temperature can either strengthen or weaken a magnet's attractive forces. Cooling or exposing the magnet to low temperatures will enhance and strengthen its magnetic properties, while heating will weaken them.

As you heat a magnet, you supply it with more thermal energy; this allows the individual charged particles to move around at an increasingly faster and more sporadic rate. Between the weakening of overall magnetism and the availability of extra thermal energy, the spin of individual electrons within the atom – which behaves like mini-magnets – are more likely to be in high energy states.

So, heating a magnet disrupts the domain walls, making it easy for the magnetic domains, which are ordinarily lined up, to rotate and become misaligned. They are now less aligned and point in the opposite direction to their neighbors, causing a decrease in the magnetic field and loss of magnetism.

As you heat a magnet further, the individual spins within the domains become even more likely to point in opposite directions to their neighbors, decreasing their average alignment seen by their neighbors, decreasing the effect which favors their initial lining up.

At a well-defined temperature – known as the Curie temperature – the entire tendency of atoms to align into domains collapses and the material stops being a magnet. Named after Pierre Curie, the French physicist, the Curie Temperature is the temperature at which the atoms are too frantic to preserve their aligned spins. As such, no magnetic domain can exist. Even if the magnet is then cooled, once it has become demagnetized, it will not become magnetized again.

If a magnet is exposed to high temperatures, the delicate balance between temperature and the domains in a magnet is destabilized. At around 80 °C, a magnet will lose its magnetic force and it will become demagnetized permanently if exposed to this temperature for a period, or if heated above its Curie temperature. Heat the magnet even more, and it will melt and eventually vaporize.

The ease with which a magnet becomes demagnetized decreases with increased temperature. Different materials react differently under heat, so what the magnet is made of is important; different magnetic materials have different Curie temperatures, the average being between 600 to 800 °C. Magnets consisting of Alnico – an iron alloy containing aluminum, nickel and cobalt – have the best strength resistance, then SmCo (Samarian cobalt) and NdFeB (neodymium-iron-boron), followed by ceramics.

Neodymium (NdFeB) magnets have the highest resistance to demagnetization but the largest change with temperature. To elaborate, NdFeB magnetics lose some of their performance for every degree of rise in temperature. Up to 150 °C neodymium magnets are considered to have the best magnetic performance of all permanent magnetic materials.

Samarium cobalt magnets are not as strong as neodymium magnets at room temperature but have better resistance to demagnetization than neodymium magnets.

Alnico magnets are second only to neodymium magnets in terms of magnetic strength but are significantly more susceptible to demagnetization by external magnetic fields and physical shock, although not by elevated temperature.

The shape of a magnet can also affect its maximum useable temperature as the length of the magnetized axis increases, and resistance to demagnetization also increases. Small, thin magnets are generally more susceptible than magnets greater in volume to rising temperatures.

Link Between Magnetic Field Strength and Temperature

In diamonds, nitrogen atoms can replace carbon atoms; when this occurs next to vacancies in the crystal lattice, it produces useful quantum properties. These vacancies can have a negative or neutral charge. Negatively charged vacancy centers are also photoluminescent and produce a detectable glow when exposed to certain wavelengths of light. Researchers can use a magnetic field to manipulate the spins of the electrons in the vacancies, which alters the intensity of the photoluminescence.

A team of Russian and German researchers created a system that can measure temperatures and magnetic fields at very small resolutions. The scientists produced crystals of silicon carbide with vacancies similar to the nitrogen-vacancy centers in diamonds. Then, they exposed the silicon carbide to infrared laser light in the presence of a constant magnetic field and recorded the resulting photoluminescence.

Stronger magnetic fields make it easier for electrons in these vacancies to transfer between energy spin states. At a specific field strength, the proportion of electrons with spin 3/2 quickly changes, in a process called anticrossing. The brightness of the photoluminescence depends on the proportion of electrons in various spin states, so the researchers could gauge the strength of the magnetic field by monitoring the change in brightness.

Additionally, the luminescence abruptly changes when electrons in these vacancies undergo cross-relaxation, a process where one excited quantum system shares energy with another system in its ground state, bringing both to an intermediate state. The strength of the field needed to induce cross-relaxation is directly tied to the temperature of the material. By varying the strength of the field, and recording when photoluminescence suddenly changed, the scientists could calculate the temperature of the region of the crystal under investigation. The team was surprised to discover that the quantum effects remained even at room temperature

Conclusion

A material's permeability is not constant but rather changes based on several factors. These factors include temperature, how it was processed, the intensity of the applied drive field, and humidity.If the object is heated, the magnetization is viewed to be inversely proportional to the temperature. The law was discovered by the French physicist, Pierre Curie. Curie point, also called Curie Temperature, temperature at which certain magnetic materials undergo a sharp change in their magnetic properties. In the case of rocks and minerals, remanent magnetism appears below the Curie point—about 570 °C (1,060 °F) for the common magnetic mineral magnetite. The Curie temperature is different depending on the metal, being about 770°C (1420°F) for iron, 1127°C (2060°F) for cobalt, and 354°C (670°F) for nickel. So heating up any of these metals to the Curie temperature means that it will spontaneously change from magnetic to non-magnetic.

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