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Synthesis and Characterization of Magnesium Zinc Ferrite Nanoparticles by Sol Gel (Auto Combustion) Method

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Abstract: Zinc Magnesium Ferrite is a magnetic substance of a very high permeability. The amount of magnesium and zinc used in the ferrite material's synthesis determines its permeability. The current study examines the amounts of magnesium, zinc, and ferrite in order to determine variations in magnetization. Also, in the present work Zinc nitrate and Ferric nitrate are used as precursor. A series of $Mg_xZn_{1-x}Fe_2O_4$ (x= 0.0, 0.6, 1.0) ferrite nanoparticles have been synthesized followed by annealing at a temperature of 1050 ^{0}c . FTIR spectra presents the characteristics peaks of spinel structure. VSM measures the magnetic behavior of the present magnetic sample.
Keywords: Sol-Gel, VSM, FTIR

I. INTRODUCTION

The use of matter on an atomic, molecular, and supramolecular scale for industrial applications is known as nanotechnology. The oldest and most commonly accepted concept of nanotechnology applied to the basic technical aim of specifically modifying atoms and molecules for the fabrication of macro-scale objects, which is now known as molecular nanotechnology. The National Nanotechnology Initiative later developed a more abstract definition of nanotechnology, defining it as the modification of matter with at least one dimension scaled between 1 and 100 nanometers[1].

Since quantum mechanical effects are significant at this quantum-realm scale, the concept has changed from a specific technical target to a science category that encompasses all forms of research and technologies concerned with the special properties of matter that exist below the specified size threshold[2]. As a result, the plural form "nanotechnologies" as well as "nanoscale technologies" are often used to refer to a wide variety of experiments and applications with a general characteristic of dimension. Surface science, organic chemistry, molecular biology, semiconductor physics, energy conservation, robotics, microfabrication, and molecular engineering are only a few examples of nanotechnology as characterised by scale. Nanotechnology has the ability to produce a broad variety of novel materials and products with applications in nanomedicine, nanoelectronics, biomaterials, energy processing, and consumer goods[3]. Nanotechnology, on the other hand, poses many of the same questions as every emerging technology does, such as worries over nanomaterials' toxicity and environmental consequences, as well as their possible impacts on global economies and theories about multiple doomsday scenarios.

These issues have sparked a debate among activist groups and governments about whether nanotechnology needs special regulation[4].

II. SOL-GEL METHOD

“The sol-gel process is a wet-chemical technique that uses either a chemical solution (sol short for solution) or colloidal particles (sol for nanoscale particle) to produce an integrated network (gel).

Metal alkoxides and metal chlorides are typical precursors. They undergo hydrolysis and polycondensation reactions to form a colloid, a system composed of nanoparticles dispersed in a solvent. The sol evolves then towards the formation of an inorganic continuous network containing a liquid phase (gel).

Formation of a metal oxide involves connecting the metal centers with oxo (M-O-M) or hydroxo (M-OH-M) bridges, therefore generating metal-oxo or metal-hydroxo polymers in solution. After a drying process, the liquid phase is removed from the gel. Then, a thermal treatment (calcination) may be performed in order to favor further polycondensation and enhance mechanical properties”[3].

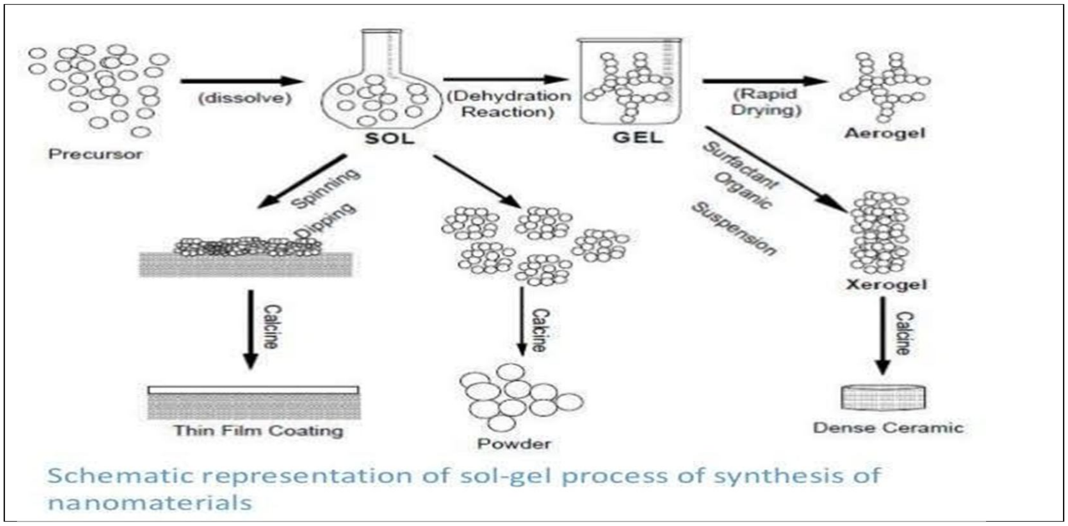

Fig.1.schematic Diagram of sol-gel process of synthesis of nanomaterials

III. EXPERIMENTAL SECTION

Table 1. Composition of Magnesium Zinc Ferrite

Composition	Magnesium nitrate	Zinc nitrate	Ferric nitrate	Citric acid
$ZnFe_2O_4$	---------	14.8740	40.40	28.5184
$Mg_{0.2}Zn_{0.8}Fe_2O_4$	2.5641	11.8992	40.40	28.5184
$Mg_{0.4}Zn_{0.6}Fe_2O_4$	5.1282	8.9244	40.40	28.5184
$Mg_{0.6}Zn_{0.4}Fe_2O_4$	7.6923	5.9496	40.40	28.5184
$Mg_{0.8}Zn_{0.2}Fe_2O_4$	10.2564	2.9748	40.40	28.5184
$MgFe_2O_4$	12.8205	--------	40.40	28.5184

IV. PREPARATION

The desired quantities of Magnesium nitrate, Zinc nitrate & ferric nitrate were dissolved in distilled water under magnetic stiiring. The required amount of citric acid were added as a fuel & taken as of the ratio 1:3 and all this solution mixed up in beaker . This mixed solution was heated up to 100 ^{0}c and ammonia was added into it by dropwise to set PH value neutral i.e.7. Now increasing the temperature upto 150 ^{0}c.After 4 hours we got dry gel. By futher continuously heating dry gel self combustion occurs & after that we got ferrite powder. This powder was grinded for 2-3 hours. Then this ferrite powder was sintered at 500˚C for 4 hours. Then this powder was again grinded & we got homogeneous single phase ferrite

V. CHARACTERIZATION TECHNIQUES

A. Fourier Transform Infrared Spectroscopy (FTIR)

"FTIR analysis is used for the identification of organic, inorganic, and polymeric materials utilizing infrared light for scanning the samples. Alterations in the characteristic pattern of absorption bands clearly indicate a change in the material composition. FTIR is useful in identifying and characterizing unknown materials, detecting contaminants in a material, finding additives, and identifying decomposition and oxidation. A schematic diagram of FTIR is depicted in Fig.2. A typical FTIR spectrometer includes a source, sample cell, detector, amplifier, A/D convertor, and a computer. Radiation from the sources reach the detector after it passes through the interferometer. The signal is amplified and converted to a digital signal by the A/D convertor and amplifier, after which the signal is transferred to the computer where the Fourier transform is carried out. Fig.2. shows the schematic diagram of FTIR spectrometer. Infrared radiation of about 10,000–100 cm^{-1} is sent through the sample with part of the radiation absorbed and some passing through. The radiation that is absorbed is converted by the sample to vibrational or rotational energy. The resultant signal obtained at the detector is a spectrum generally from 4000 to 400 cm^{-1}, which represents the samples' molecular fingerprint. Every molecule has a unique fingerprint, which makes FTIR an invaluable tool for chemical identification" [2].

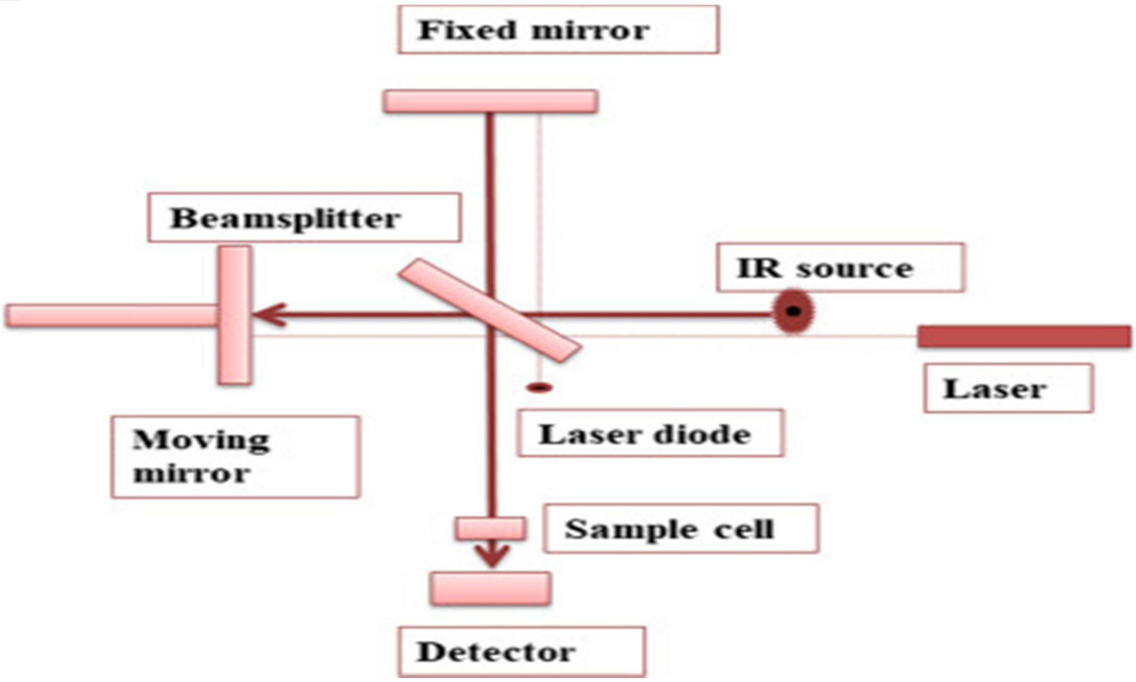

Fig.2.Fourier Transform Infrared Spectrometer

B. Results and Discussion

FTIR has been employed to observe the structural variations and spinel phase of ferrite systems. The characteristic bands of cubic spinel configuration are two vibrational bands, one with a higher vibrational frequency in the range of 600-500 cm-1 and the other with a lower vibrational frequency in the range of 450-350 cm-1. The FTIR spectra of $Mg_xZn_{1-x}Fe_2O_4$ (x= 0.00, 0.6,0.1) are shown in below fig. The tetrahedral and octahedral vibrational frequencies along with tetrahedral and octahedral force constants. In the sintered samples, the transmittance plots are very sharped as shown in graph. It was determined that the both tetrahedral and octahedral vibrational frequencies are shifted towards the higher frequencies with change in Mg^{2+} ions concentration, which are ascribed to increase in the force constants and contraction of Fe^{3+} - O^{2-} bond lengths. In sintering graph shown sharp peak for three different compositions.

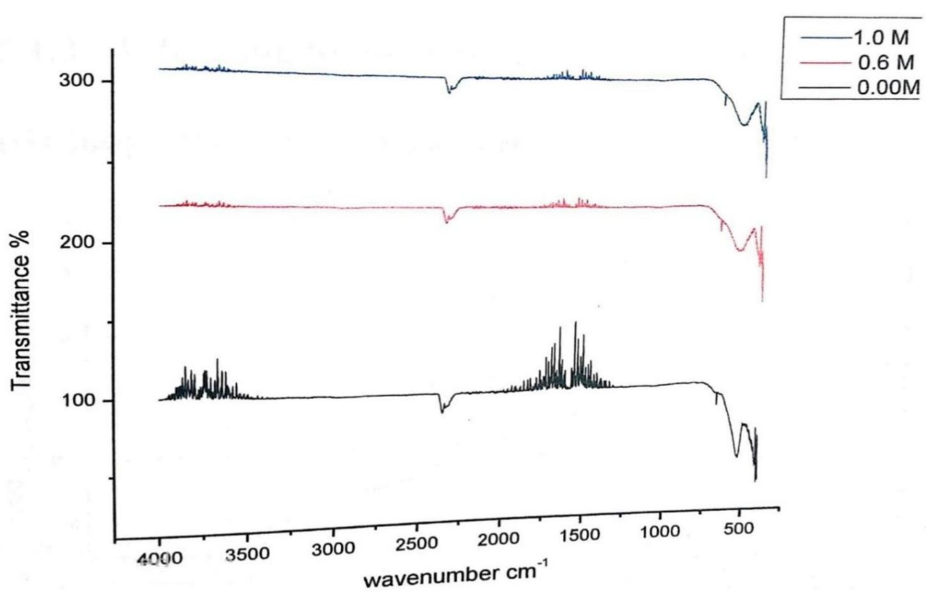

Fig. 3.FTIR plot of the sintering magnesium zinc ferrite (x = 0.00,0.6,1.0)

C. Vibrating Sample Magnetometer (VSM)

A vibrating sample magnetometer (VSM) is a scientific instrument that detects magnetic properties. It is also known as a Foner magnetometer. A uniform magnetic field is used to magnetise a sample first. It is then vibrated sinusoidally, usually with the aid of a piezoelectric material. Linear actuators of any kind are used in commercial devices. These devices were historically designed using adapted audio speakers, but this solution was abandoned due to interference induced by in-phase magnetic noise created by a nearby pickup coil that differs sinusoidally. The induced voltage in the pickup coil is relative to the magnetic instant of the sample, but it is independent of the applied magnetic field power. The induced voltage is usually determined with a lock-in amplifier using the piezoelectric signal as a frequency guide in a standard configuration. Sweeping the magnetic field may also be used to record the material's hysteresis curve.

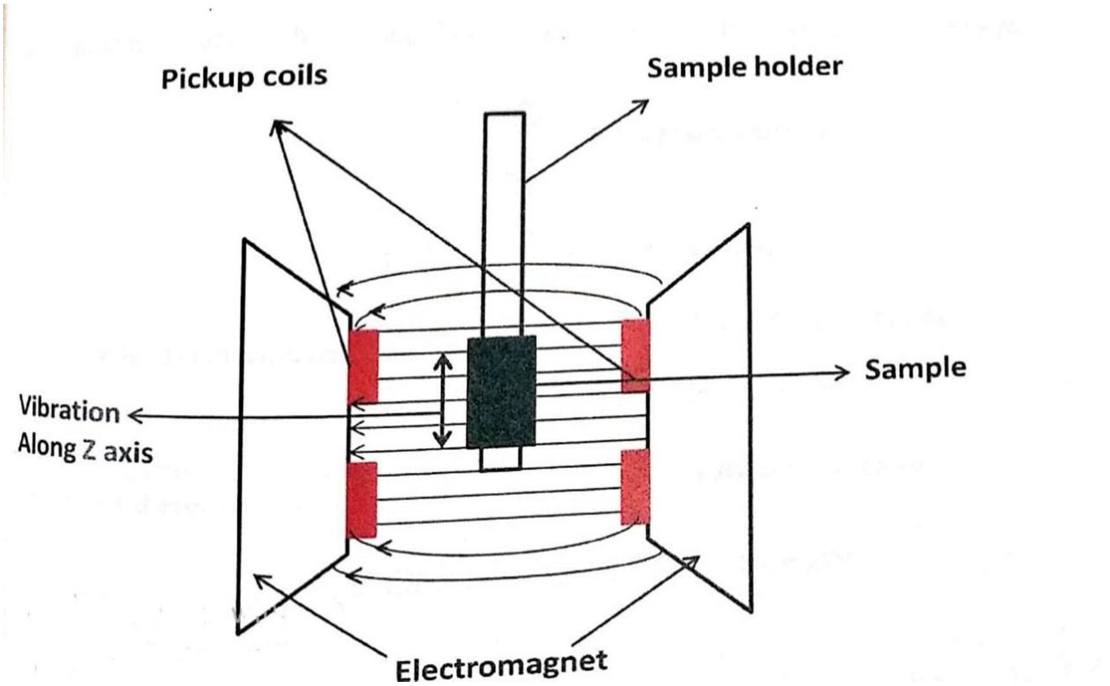

Fig.4.Vibrating Sample Magnetometer (VSM)

D. Results and Discussion

The VSM studies shows that sintered MgZn ferrite with the composition of x = 0.6 Show higher magnetic saturation (Ms). It confirm that the higher temperature sintering enhances the magnetic saturation. Also VSM studies shows that sintered MgZn ferrite with the composition of x = 0.6 show lower magnetization retentivity (Mr). It confirm that the higher temperature sintering decreases the magnetic retentivity (Mr). The coercivity (Hc) of the sintered MgZn ferrite with the composition of x = 0.6 show lower coercivity.

Table 2**:** Value of Magnetic Saturation (Ms), Magnetic Retentivity (Mr), Magnetic Coercivity (Hc),

Composition	Ms (emu/gm	Mr (emu/gm)	Hc (Oe)
$ZnFe_2O_4$	031.6085	1.6950	30402.2872
$Mg_{0.6}Zn_{0.4}Fe_2O_4$	108.1974	13.9426	4011.9413
$MgFe_2O_4$	064.1249	1.0925	471.6981

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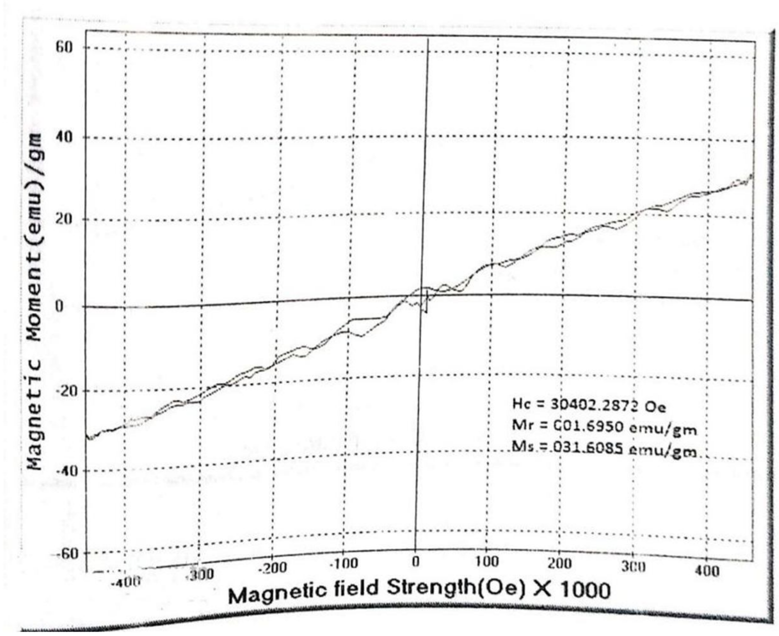

Fig.5. BH loop of the $ZnFe_2O_4$ Sintering (x= 0.00)

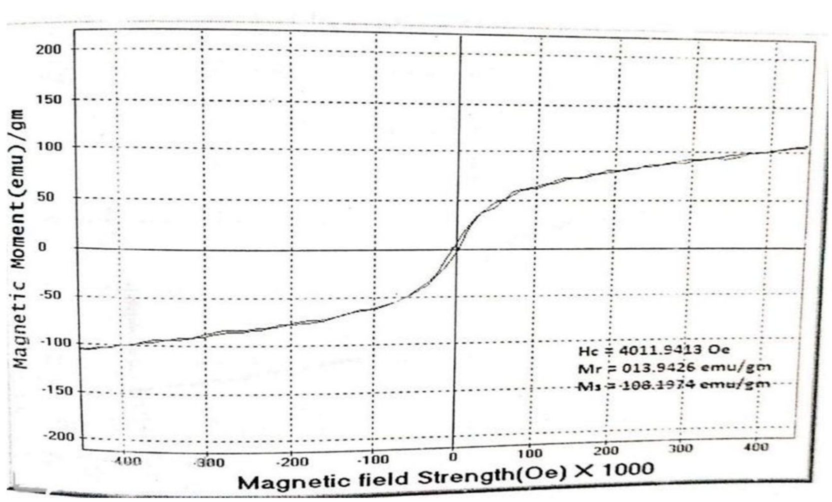

Fig.6. BH loop of the $MgZnFe_2O_4$ Sintering (x= 0.6)

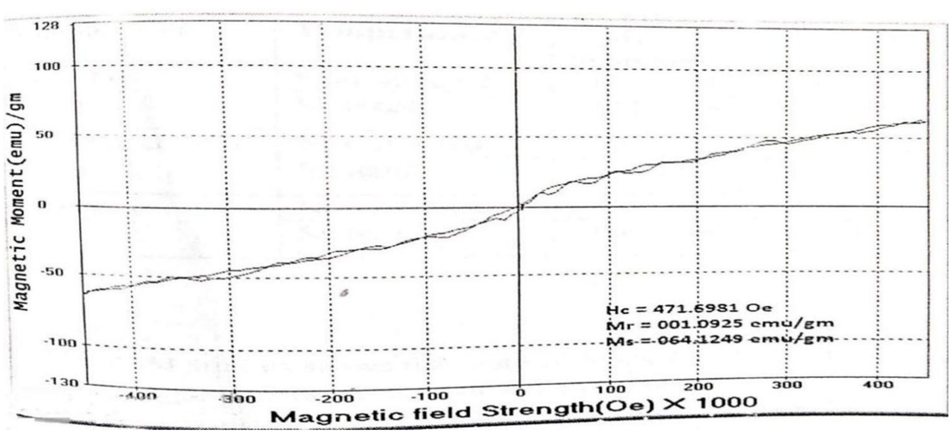

Fig.7. BH loop of the $MgFe_2O_4$ Sintering (x= 1.0)

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VI. CONCLUSION

The present study was carried out to synthesis nano sized Mg-Zn mixed metal ferrite material with formula $Mg_xZn_{1-x}Fe_2O_4$. The samples were prepared using a wet chemical autocombustion Sol-Gel method. The ferrite powder was sintered at high temperature were confirmed by different methods of characterization techniques such as FTIR, VSM.etc. The FTIR has been employed to observe the structural variations and spinel phase of ferrite systems. The characteristic bands of cubic spinel configuration are two vibrational bands, one with a higher vibrational frequency in the range of 600-500 cm-1 and the other with a lower vibrational frequency in the range of 450-350 cm-1. The FTIR spectra of $Mg_xZn_{1-x}Fe_2O_4$ (x= 0.00, 0.6,0.1) composition shows, The tetrahedral and octahedral vibrational frequencies along with tetrahedral and octahedral force constants. In sintering graph shown sharp peak for three different compositions. The VSM studies shows that sintered MgZn ferrite with the composition of x = 0.6 Show higher magnetic saturation (Ms). It confirm that the higher temperature sintering enhances the magnetic saturation. Also VSM studies shows that sintered MgZn ferrite with the composition of x = 0.6 show lower magnetization retentivity (Mr). It confirm that the higher temperature sintering decreases the magnetic retentivity (Mr). The coercivity (Hc) of the sintered MgZn ferrite with the composition of x = 0.6 show lower coercivity. The BH curve shows that the Magnesium zinc ferrite nanoparticles exihibits good ferromagnetic behavior. The BH curve shows that the Magnesium zinc ferrite nanoparticles exihibits good ferromagnetic behavior. This ferrite powder shows Soft magnetic characteristics.

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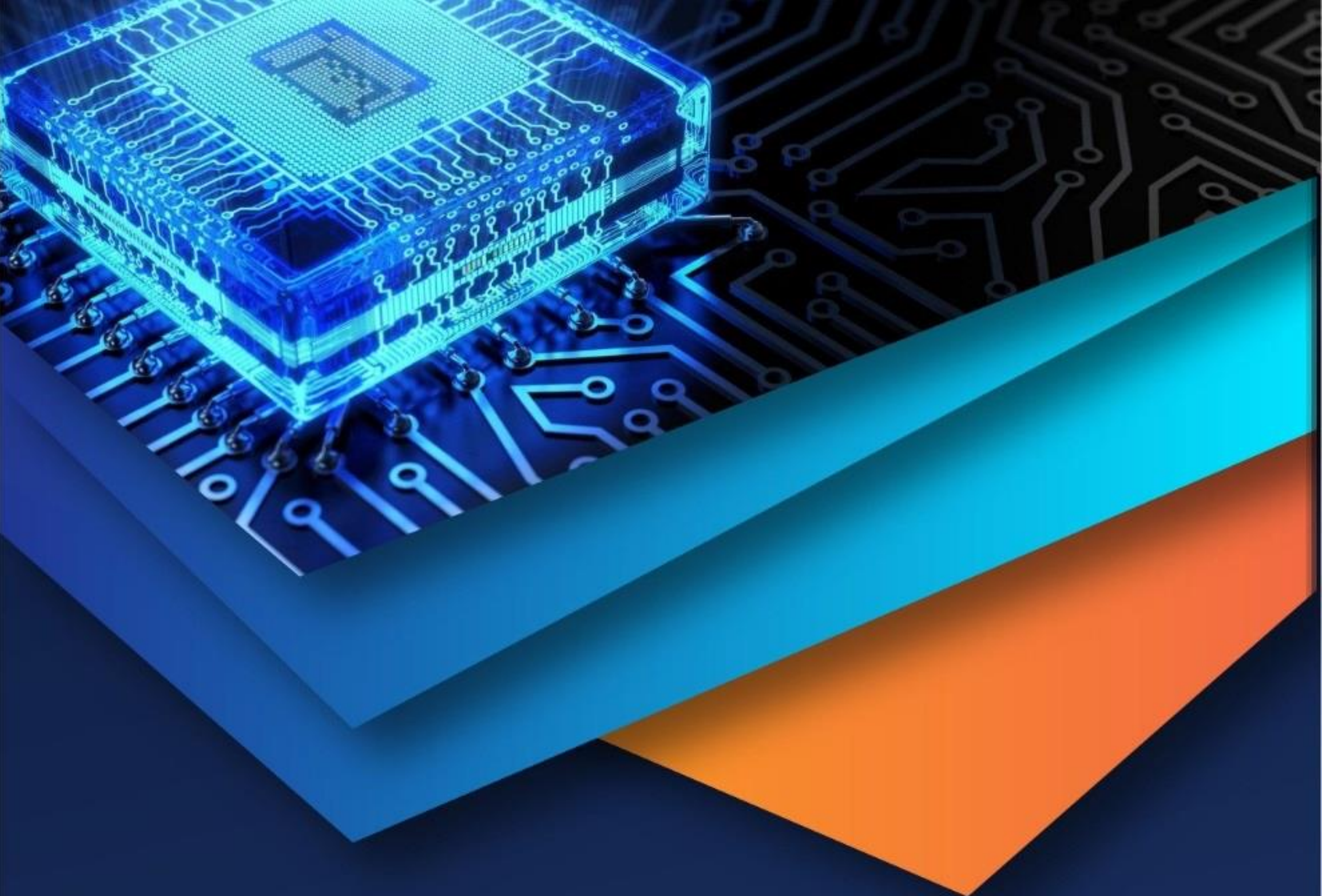

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