International Journal of Trendy Research in Engineering and Technology
(IJTRET) Volume 1 Issue 2 Aug- 2017

INVESTIGATIONS ON THE ELECTRICAL AND MAGNETIC PROPERTIES OF MgO NANOPARTICLES

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ABSTRACT

In the present work, we have synthesized MgO nanoparticles using Magnesium acetate tetrahydrate through a sol-gel method and studied its structural, electrical and magnetic characteristics in detail. This paper primarily focuses on the temperature dependence of dielectric constant and tangent loss in the temperature range 303 K to 573 K and frequency range of 100Hz -5MHz. Cole-Cole plot drawn from impedance spectra indicates the high resistive behavior of the synthesized MgO nanoparticles. Magnetic studies prove the presence of weak ferromagnetic behavior of MgO nanoparticles due to the presence defects. This Defect Induced Magnetism (DIM) of MgO nanoparticles at room temperature is highly useful for spintronic devices.

Key words: MgO nanoparticles, XRD, Dielectric constant, Tangent loss, Cole-Cole plot, VSM

I.INTRODUCTION

MgO is a typical wide band gap insulator (7.3 eV-7.8 eV) and it is widely used for high-Tc Superconductor (HTSC) thin-film coating applications worldwide. The incorporation of MgO nanorods into HTSCs led to improved performances at an elevated temperature or in intensive magnetic fields [1]. MgO has a space group of Fm3m with cubic structure (a=4.212 Å). MgO nanoparticles show excellent activity against bacteria, spores and viruses after adsorption of halogen gases because of its large surface area [2-3]. Researchers showed the room temperature behavior of MgO nanomaterial and it is usefulness for spintronic applications. In a bulk state, MgO is not magnetic, but in nanoscale range it shows a small magnetic behavior. Ben M. Maoz et al [4] have investigated the magnetism in highly defective MgO nanosheets. The mirror surface of single mode optical fiber deposited by the MgO would act as an effective low field magnetic sensor. The magnetic behavior obtained on the MgO nanoparticles is due to the defects and good magneto optic Kerr effect [5]

We ave successfully synthesized MgO nanoparticles using simple sol-gel method. The structural, electrical and magnetic properties of the synthesized sample were analyzed using powder XRD, Impedance and VSM spectra.

II.EXPERIMENT

1.Materials

Analytical grade (AR) Magnesium acetate tetra hydrate (CH3COO)2Mg.4H2O was used as starting material; double distilled water was used as solvent and acetic acid was used as the complexing agent.

2. Preparation of MgO nanoparticles

For the synthesis of MgO nanoparticles, 1mole of Magnesium acetate tetrahydrate was dissolved with 50ml double distilled water, and the solution was stirred well to get homogeneous solutions. After that, 0.5 mole of acetic acid was added drop wise to the above solution at room temperature. This solution was maintained in the temperature range 50-60°C for 4h. A gel formed in this process was then allowed to dry at room temperature. A white powder product obtained was dried at a temperature of 90°C for 6 hours. The sample was further annealed at 500°C for 2 hours in a muffle furnace. The final powder product was well grind and characterized using XRD, electrical and magnetic studies.

III.CHARACTERIZATION STUDIES

1.Phase analysis

The phase analyses of the samples were carriedout using powder (XRD) using Rigaku D/max-A diffractometer fitted with CuKα radiation (λ = 1.5406Å) at a scan rate of 0.01degree per second at room temperature. XRD pattern of pure MgO nanoparticle is shown in Figure1. From figure1 the major peaks with (hkl) planes (111), (200) and (220) at around 37.04o, 42.96o and 62.24o can be well indexed to the cubic MgO structure (JCPDS: 04-0829) and the lattice constant was found to be 4.2Å. The sharpness of the peak shows the well crystalline nature of synthesized MgO powder. The broadness of the peak is due to size and micro-strain of the particle. The crystallite size of MgO nanoparticle was calculated using Scherer formula [6].

$$t = K\lambda/B\cos\theta$$

Where t is the grain size, λ is the wavelength of Cukα radiation [λ=1.54056Å]. B is the full width at half maxima (FWHM) and θ is the angle of diffraction. The crystallite size is found to be 16 nm.

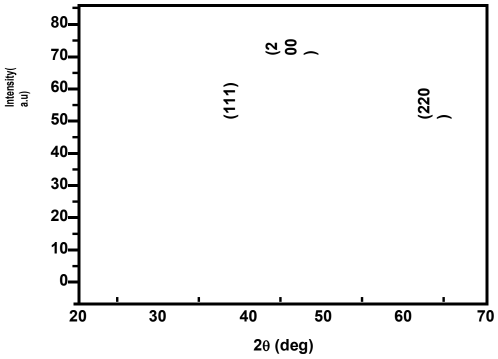

Figure 1. XRD pattern of MgO nanoparticles

2. Dielectric studies

The frequency and temperature dependence of dielectric constant (εr) and tangent loss (tanδ) was studied for MgO nanomaterial in the temperature range 303K to 573K at selected frequencies (100Hz, 1KHz, 10KHz, 100KHz and are shown in Fig. 2 and Fig. 3. The relative dielectric constant εr of the sample can be obtained following the formula:

$$\varepsilon r = Cd/\varepsilon 0S$$

Where, C, d, $\varepsilon 0$, and S are the measured capacitance, the thickness of the sample, the dielectric constant in vacuum ($\varepsilon 0$ =8.854 × 10−12 F/m) and the area of the samples respectively. From Fig. 2 it is observed that the dielectric constant decreases with increasing frequency. The dielectric constant found to decrease slowly with increasing frequency above Curie temperature (Tc). Curie temperature for the MgO nanomaterial is 373 K and it can be due to the constrained grains. Curie temperature value changes with the internal stresses developed in the constrained grains [7]. If the grain size is larger, the internal stress shifts the Tc to a higher temperature.

Variation of tangent loss with temperature is shown in Fig.3, which is similar to behavior of dielectric constant with temperature. That is tangent loss decreases with increasing temperature above a Tc. This behaviour of MgO nanoparticles is potentially useful for microwave devices to improve their temperature and frequency stabilities.

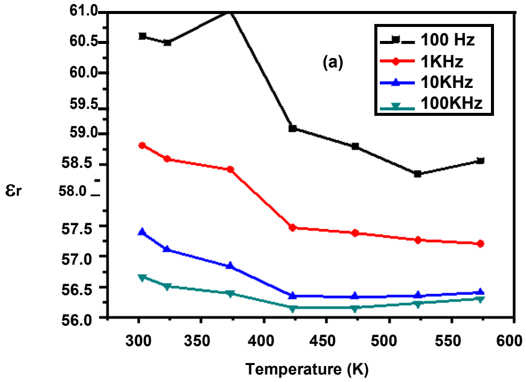

Figure 2. Temperature (K) vs. εr

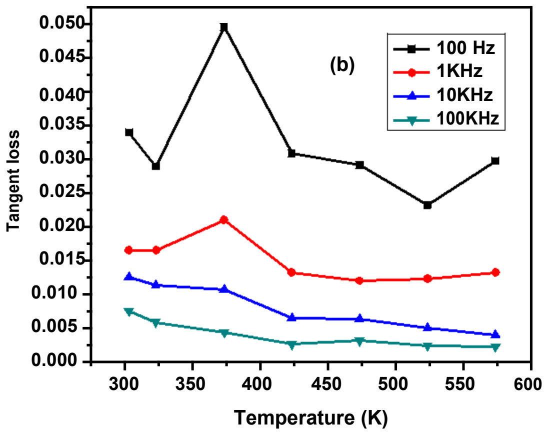

Figure 3. Temperature vs. tangent loss

3.Impedance Analysis

Figure (4&5) shows the variation of real and imaginary part of the impedance as a function of frequency at different temperatures (303 K – 573 K) for MgO nanoparticles. It is observed that the magnitude of Z' decreases with the increase in temperature at low frequency. This behavior suggests that the material possesses a Negative Temperature Coefficient of Resistance (NTCR). It is also found that all curves merge into a single curve at high frequencies independent of the temperature, showing the space charge dependent behavior of the material [8].

The variation of imaginary part of the impedance with frequency at different temperatures is shown in Figure 5. The curve shows that the value of Z″ decreases with increase in temperature and value of Z″ merges in the high frequency region with increase in temperature. Fig.6 shows the Cole-Cole plot of MgO nanoparticles. The semicircular arc (high frequency) in the Cole-Cole plot is attributed to bulk (grain) effect and the curve becomes almost straight line in the low frequency region, which shows the insulating properties of the nanoparticles.

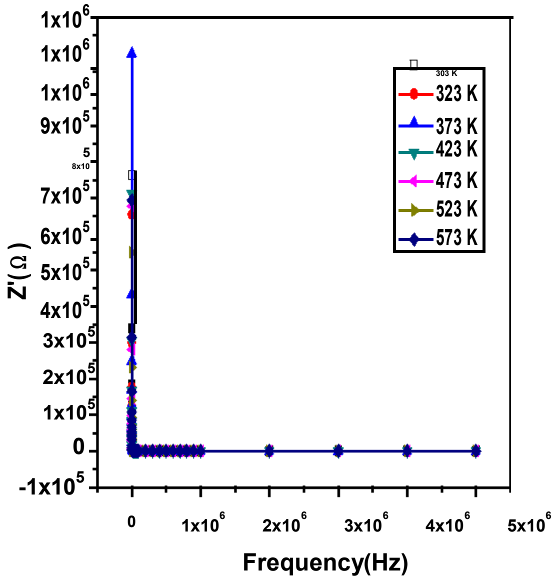

Figure 4. Real part of impedance (Z′) as a function of frequency for different temperatures

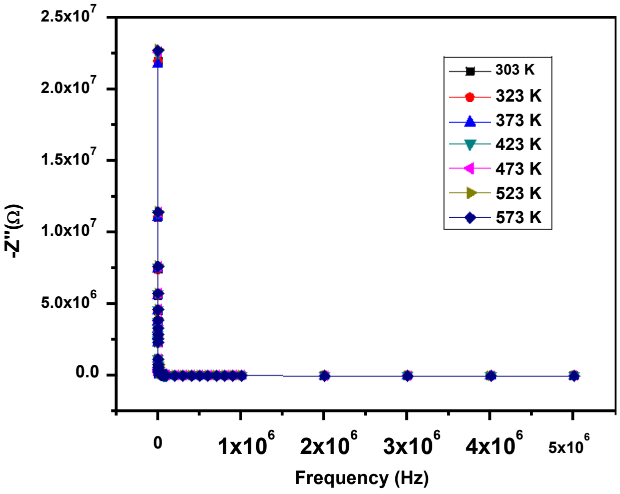

Figure 5. Imaginary part of impedance (Z″) as a function of frequency for different temperatures

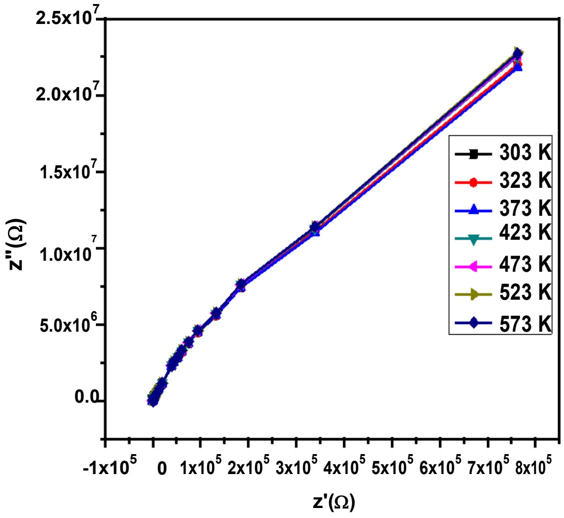

Figure 6. Cole-Cole plot of MgO

4.Magnetic studies

The MgO nanoparticles were further characterized by Vibrating Sample Magnetometer (VSM). The magnetization curve at room temperature is shown in Fig. 7 (a&b). The M-H hysteresis loop for MgO nanoparticle is obtained from Lakeshore VSM7410 magnetometer. The studies of magnetic properties of the materials are very important because they gives the knowledge about the defects, imperfections, structural changes and electron configuration observed in the synthesized composites [9].

The magnetism in solid materials originates mainly due to the orbital and spin motion of electron within its atoms.From the graph, it is observed that the synthesized MgO nanoparticless exhibits diamagnetism and it shows small ferromagnetic like behavior for low range applied magnetic field. The magnetization curve of MgO nanoparticles after subtracting the diamagnetic background signal is shown in fig. 7(b). The MgO nanoparticle appears ferromagnetic in the low frequency range. It known that the ferromagnetism of the MgO nanoparticles is due to the defects such as oxygen vacancies, Mg vacancies and dangling bonds. This Defect Induced Magnetism (DIM) has been studied by many research groups. Ben M. Maoz et al [4] has observed the room temperature ferromagnetism in highly defective MgO nanosheets. MgO is non-magnetic in bulk form but is shows the room temperature ferromagnetism in nanostructure. This is because of the loss of oxygen atoms (donor charge) which creates 2p holes at the nanograin surface. Gao et al [10] revealed that DIM in MgO nanoparticle is due to the spin polarization of 2p electrons of oxygen atoms near the Mg vacancies. MgO nanoparticles contain high cation vacancy and interfacial defects or grain boundaries. When the strength of the applied field increases, the material chnges from ferromagnetic to diamagnetic.

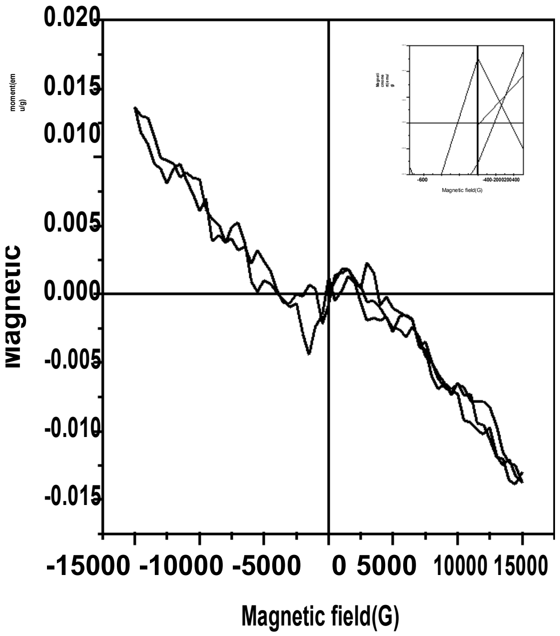

Figure 7(a). M-H hysteresis loop observed at Room temperature

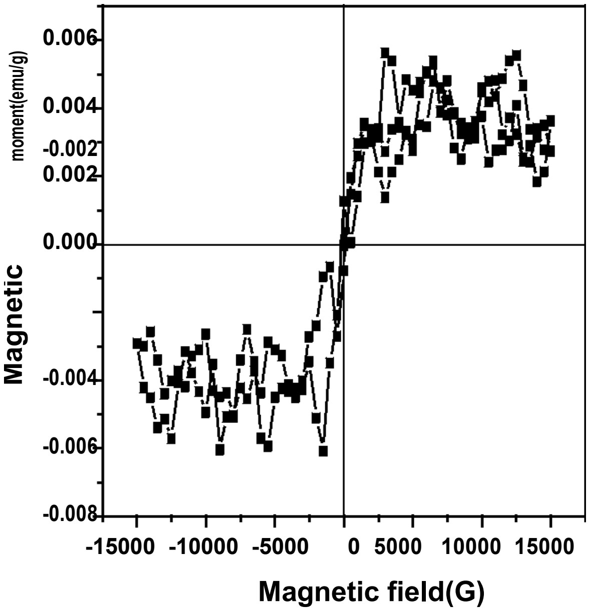

Figure 7(b) M-H hysteresis loop observed at Room temperature.(After subtracting the diamagnetic signal)

IV.CONCLUSION

In this work, the MgO nanoparticle was synthesized using simple sol-gel route. XRD report confirms that the synthesized MgO is in cubic phase and the crystallite size was calculated to be 16 nm using Scherer formula. The VSM results show that defects are responsible for the weak ferromagnetic behavior of the MgO nanoparticles .At high applied field the ferromagnetic like behavior changes to diamagnetic behavior. Dielectric studies show that dielectric constant and tangent loss increases with increasing temperature and decreases with increasing frequency and has been attributed due to space-charge polarization of thermally generated charge carriers. Cole-Cole plot in the impedance spectra indicates the high resistive behavior of the synthesized MgO nanoparticles. The results show that the synthesized MgO nanomaterial is a promising candidate for storage device applications.

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