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Effect of Magnesium doping on Structural and Magnetic Properties of Iron oxide thin films

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ABSTRACT

Preparation of thin films consisted of nano structures have been intensively pursued not only for their fundamental scientific interest but also for many technological applications. Spinel ferrites are very important magnetic materials because of their interesting magnetic properties combined with chemical and thermal stability. Apart from the applications of their magnetic properties in magnetic recording, sensors, and photomagnetics, some spinal ferrites especially magnesium ferrite, are used as a heterogeneous catalysts, adsorption and humidity sensors, oxygen sensors and for their photoelectrical properties.The present studies were undertaken with a view to developing a low-cost, efficient method for the preparation of Mg doped iron oxide thin films. X-ray diffraction patterns demonstrate the formation of magnesium iron oxide. The magnetic measurements are made from M-H hysteresis loops traced at room temperature using vibrating sample magnetometer (VSM). Ferrites in the nanoregime are found to behave as single domain.

1. INTRODUCTION

Spinel ferrites of the type XFe_2O_4 (X=Mg, Cu, Ni, Zn, etc.) have been well-thought-out to be the significant materials for progresses in magnetic storage devices, electronics, ferro-fluid technology, magneto caloric refrigeration and bio-medical applications. These materials in form of thin films show marvelous chemical stability and high corrosion resistivity. They have great electrical resistivity and low dielectric losses which are suitable in microwave devices, computer memories and magnetic recording. Amongst all the spinel ferrites, $MgFe_2O_4$ (MFO) has been thought as a vital material because of its “partially inverse spinel structure” (Lee 2006) and a soft magnetic n-type semiconducting properties (Kim 2010). MFO has been considered for many applications, including microwave devices and fuel cells (Sugimoto 1999).

Magnetic materials (such as ferrites and spinel ferrites) in the form of thin films are

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of excessive importance because these are necessary for electronics and spintronics devices. The growth of high quality single crystal ferrite films is very significant. Many intrinsic magnetic properties can be examined using single crystal. In last few years, spinel ferrites in form of thin films display exciting magnetic and electrical properties which are not the same as those of the bulk. The materials in form of thin films ease to reduce the attenuation of light, microwave and electrical current, in high frequency applications. The epitaxial growth of various spinel ferrites has been reported on $SrTiO_3$ (Huang 2007), MgO (Zimnol 1997), Si (Hassan 2007) substrate. The thin film growth of spinel ferrites on different substrates leads to strain between film and substrate because of the mismatch in lattice parameters. The magnetization is induced, due to the stress in ferrite thin films on numerous buffer layers and substrates (Wakiya 2004, Iwata 2009).

Most of the researchers have grown thin films of $MgFe_2O_4$ on cubic substrate such as $SrTiO_3$, $MgAl_2O_4$, and MgO. Investigation of thin films of $MgFe_2O_4$ on sapphire substrate proves that $MgFe_2O_4$ is ferromagnetic at room temperature when grown on cubic substrate (Gupta 2011). There is no report for growth of $MgFe_2O_4$ on non-cubic substrate. In this study, the MFO films were deposited on glass substrates via a vapor deposition in Edward coating unit (PVD) and then annealed under different temperatures. The structural and magnetic properties of MFO thin films were studied as a function of the temperature.

2. EXPERIMENTAL DETAILS

Pure iron (99.99%) and Mg (99.99%) were thermally evaporated in 306 Edward coating unit in presence of high vacuum and the films are deposited on glass substrate. The films were then stored in desiccator to prevent ambient oxidation of iron and magnesium. These samples were then oxidized at oxygen flow rate of 10sccm at four different temperatures (150˚C, 250˚C, 350˚C, 450˚C) in a tube furnace for 60mins. The flow rate of oxygen has been optimized earlier (Riaz 2013). Structural characterization was done by XRD (Rigaku D/MAX-IIA Diffractometer) and magnetic properties were investigated VSM (Lake Shore 7407 Magnetometer).

2. RESULTS AND DISCUSSION

Fig. 1 shows XRD pattern for MgFe2O4 deposited on glass substrate and annealed at 150˚C, 250˚C, 350˚C and 450˚C under oxygen flow rate of 10sccm. The presence of diffraction peak at 2θ˚= 69.5˚ corresponding to both FeO_x and MgO_x indicate the formation of highly crystalline $MgFe_2O_4$. As the annealing temperature is increased the crystallinity of the films increase indicated by increase in peak intensities. Also it can be seen that upon annealing at 150˚C very small diffraction peaks corresponding to FeO_x emerge but these peaks do not strengthened as the film is annealed further.

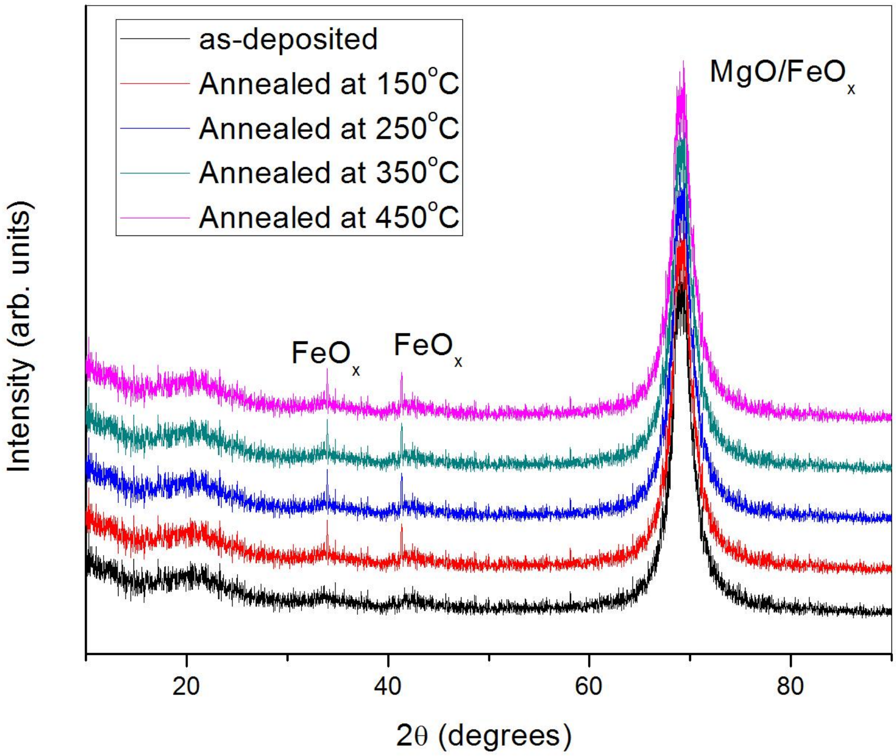

Fig. 1 XRD pattern of $MgFe_2O_4$ thin films under as-deposited and annealed conditions

Fig. 2 show room temperature M-H curves for $MgFe_2O_4$ thin films under as-deposited and annealed conditions. The film under as deposited conditions shows strong ferromagnetic behavior with relatively high value of coercivity.

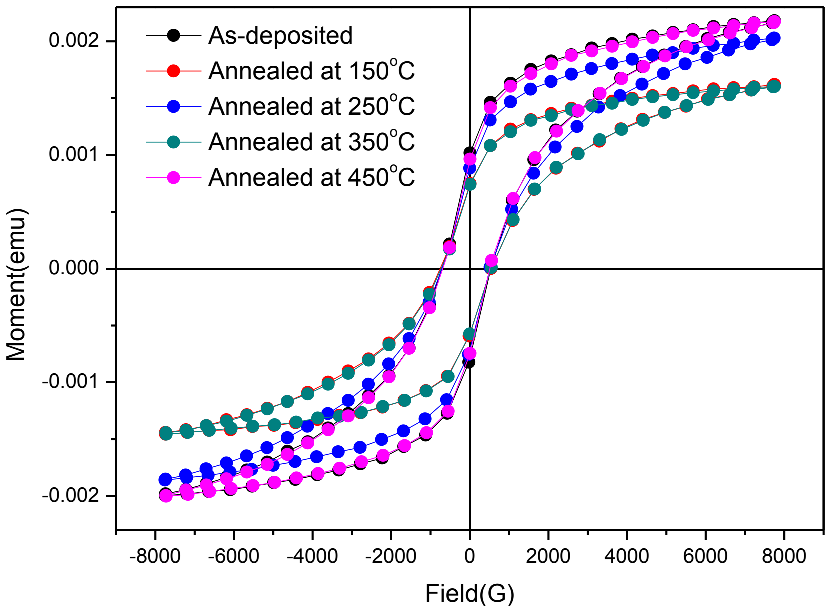

Fig. 2 Room temperature M-H curves for $MgFe_2O_4$ thin films

From these measurements coercivity and saturation magnetization is derived and is plotted as a function f annealing temperature in Fig. 3. It can be seen that saturation magnetization decreases as the films were annealed at 150˚C, where as annealing at 250˚C and 450˚C increases the saturation magnetization. The films show high value of coercivity. The coercivity of the films strongly depends on grain size, film microstructure and residual magnetic induction along with other complex factors. The coercivity of the films is also strongly dependent on magnetocrystalline anisotropy.

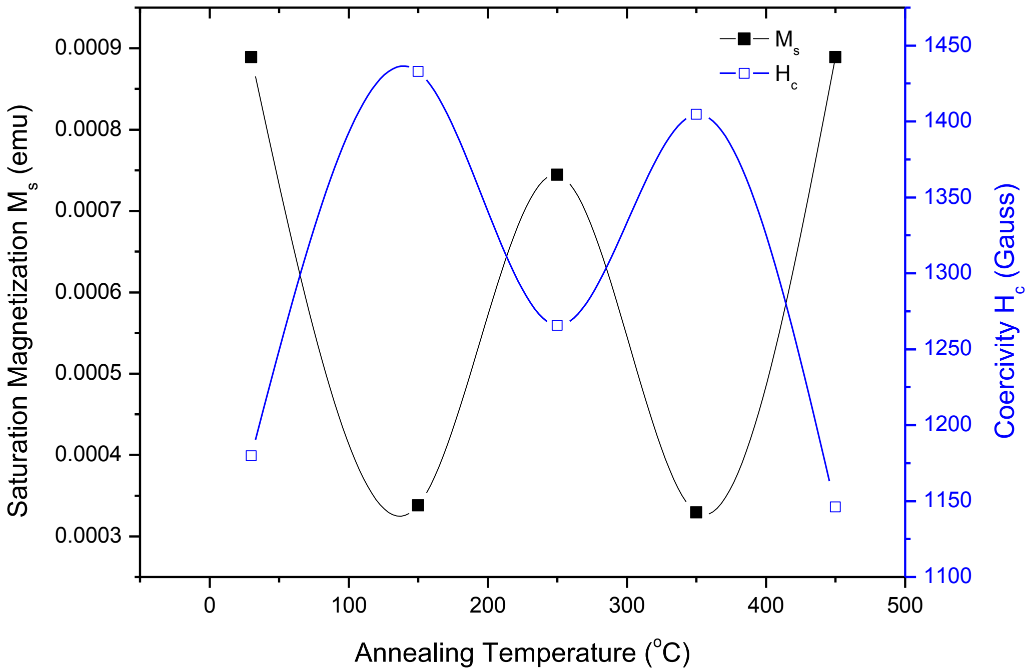

Fig. 3 Saturation Magnetization (M_s) and Coercivity (H_c) as a function of annealing temperature

3. CONCLUSIONS

Thin films of $MgFe_2O_4$ have been successfully deposited using thermal evaporation followed by oxidation at oxygen flow rate of 10sccm. The films are highly crystalline even under as deposited condition and the crystallinity of the films increases as the annealing temperature is increased. The films show ferromagnetic behavior with high value of coercivity.

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