Annealing Temperature Effect on Structural and Magnetic Properties of Nano Crystalline $Ni_{0.6}Co_{0.2}Cu_{0.2}Fe_2O_4$ (NCCFO) Thin Film

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Abstract. In the present work we prepared NCCFO thin films by metallo-organic decomposition (MOD) technique and studied the effect of different annealing temperature on structural and magnetic properties. The prepared thin film samples are annealed at four different temperatures (550^0C, 650^0C, 750^0C, 850^0C) for two hours. The XRD results confirmed the cubic spinel structure at different temperature with the sharpening of (311) peaks. The crystallite size was found to increase with annealing temperature and was further confirmed from AFM images. All samples show distinct hysteresis curves and improved ferromagnetic properties. The saturation magnetization increases with increase in annealing temperatures, while coercivity shows anomalous behavior which could be due to transformation from single to multi domain system. The ferrite thin films with distinct magnetic properties can find applications in many technological advanced nano devices.

INTRODUCTION

Ferrites are an important class of magnetic materials which find applications in many technologically advanced devices such as magnetic storage devices, electronic devices (microwave radio frequency and optoelectronic devices), sensors (humidity, gas sensing etc.), ferrofluids, technology, data processing devices and drug delivery system [1-2]. The ferrite thin films are more interesting because there is drastic change in properties such as structural and magnetic properties of ferrite materials as we moves from bulk to nano world. Ferrite thin films exhibit relatively high resistivity at carrier frequency, low loss for microwave applications as compare to other metal oxide thin films [2]. Among ferrite, the inverse ferrites are more significant due to its high magneto crystalline anisotropy, high magnetic saturation magnetization and unique magnetic structure. The properties of ferrite thin film are greatly influence by the composition, size, shape and annealing temperature etc. Recently cobalt doped nickel ferrite; copper doped and cobalt-copper doped nickel ferrite attracts many researcher attentions because co-cu brings significant changes in the properties of ferrite thin films [3]. This motivates us to synthesize co-cu doped nickel ferrite thin films by a new methodological approach and to study the effect different annealing temperature on their structural and magnetic properties.

EXPERIMENTAL METHOD

For the synthesis of $Ni_{0.6}Co_{0.2}Cu_{0.2}Fe_20_4$ thin films by Metallo-organic decomposition technique (MOD). The appropriate stiochiometry ratio of Fe-3ehylhexanoate, Ni-2-ehylhexonoate, Co-2-ethylhexonate and Cu 2-ethylhexonate were mixed properly and stirred for 3-4 hrs. After mixing, the solution was heat for an hour and 4-5 drops of polyethylene glycol (PEG) were also added in the mixture to act as binder. The solution was then filter to avoid any contamination of foreign material. The solution was kept as coating solution to deposit thin films. $Ni_{0.6}Co_{0.2}Cu_{0.2}Fe204$ thin films were prepared by spin coating technique. As such films are amorphous in nature and the post deposition annealing at different temperatures 550°C, 650°C, 750°C and 850°C for 2 h is normally required for the crystallization of the films. All the annealed samples were then furnace cooled. The deposited thin film samples were characterized by X-ray diffraction (XRD), atomic force microscopy

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(NTEGRA AFM) and Vibrating sample magnetometer (VSM) to understand the influence of annealing temperature effect on the films structural and magnetic properties.

RESULTS AND DISCUSSION

Structural Analysis

The XRD patterns of $Ni_{0.6}Co_{0.2}Cu_{0.2}Fe_2O_4$ (NCCFO) thin films annealed at different temperature 550^0C, 650^0C, 750^0C and 850^0C for 2hours are shown in Fig. 1. The well defined peaks namely: (111), (220), (311), (400), (422) and (511) correspond to cubic spinel ferrite $NiFe_2O_4$ [4-5]. The XRD patterns also show polycrystalline nature of deposited films with no preferential orientation appeared for films annealed in temperature range 550^0C to 850^0C. In XRD patterns of NCCFO thin film annealed at 850^0C, one can easily see all the ferrite peaks together with an impurity peaks (represent by * symbol) which indicate that 750^0C is best annealing temperature for synthesis of pure phase $Ni_{0.6}Co_{0.2}Cu_{0.2}Fe_2O_4$ thin film. The XRD patterns also show that the peaks become narrower as annealing temperature increases, indicating the increase in the crystallite size of thin film samples from 19 nm to 47nm.

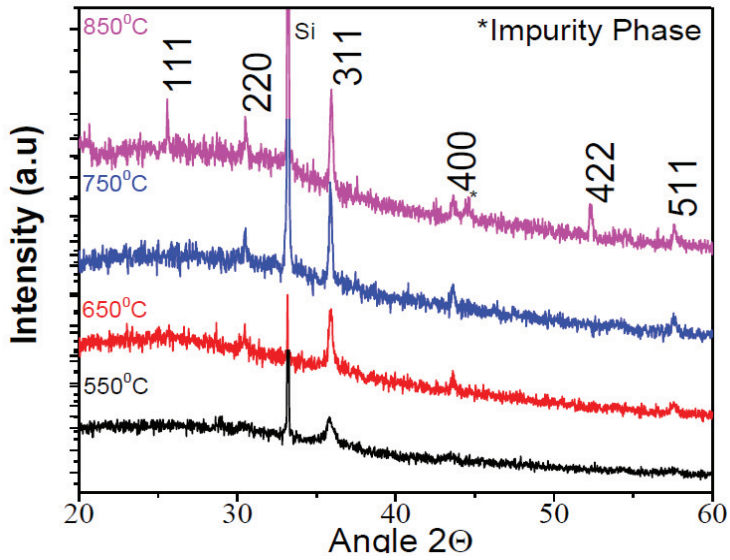

FIGURE 1. XRD pattern of NCCFO thin film different temperatures.

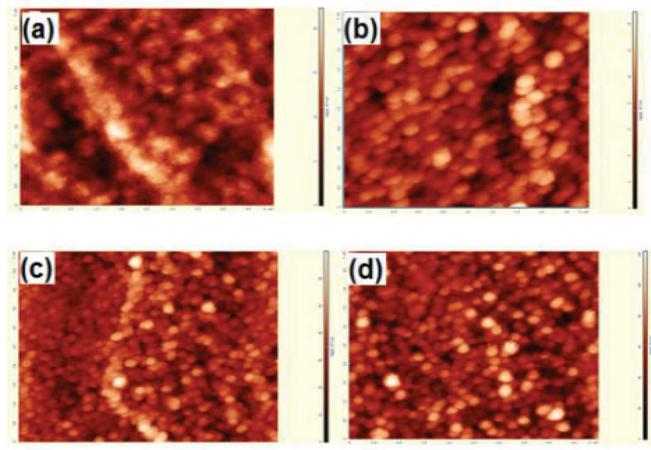

FIGURE 2. AFM images of NCCFO thin films annealed at annealed at different temperatures.

Figure 2(a) - (d) shows the AFM images of NCCFO thin film annealed at 550^0C, 650^0C, 750^0C and 850^0C. The surface morphology become homogeneous, smooth and grain size increases with increasing annealing temperature. The average grain size varies from 62 nm to 151 nm as the annealing temperature from 550^0C to 850^0C.The enhancement of grain size may results from the growth of grains due to high annealing temperature.

Magnetic Properties

The magnetic hysteresis loops were recorded at room temperature in order to see the effect of annealing temperatures on the NCCFO thin films deposited on Pt coated Silicon substrate. The M-H loops of the NCCFO thin films annealed at 550^0C – 850^0C for 2 hrs are shown in Figs. 3. All loops are well saturated at above 3.2 kOe and saturation magnetization increases with increasing annealing temperature. The maximum value of saturation magnetization is observed at 850^0C (168.3emu/cc). The values of saturation magnetization are higher than that for NCCFO ferrite pallets synthesized by double sintered ceramic reaction technique reported by others [6]. The coercivity initially increases up to 750^0C (1007.12 Oe) and then show sudden decrease for 850^0C (701.52 Oe). The anomalous behaviour in the coercivity may be attributed to the transition from single-domain to multi-domain system [7-8].

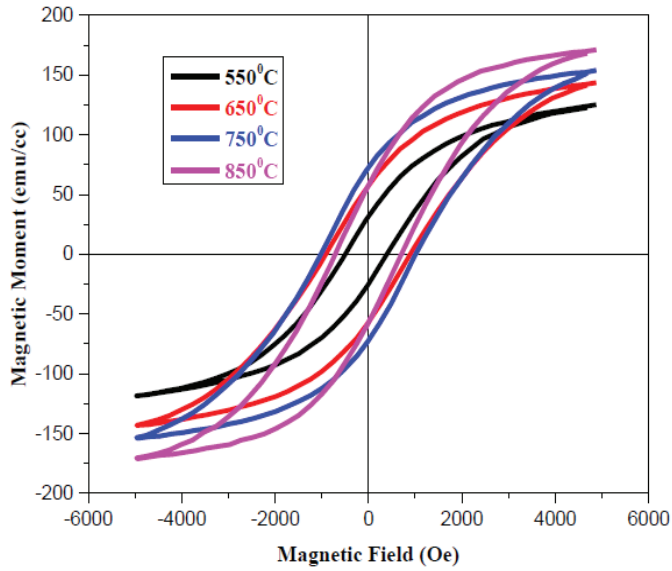

FIGURE 3. MH loops for thin film annealed at different temperatures.

CONCLUSION

The effects of annealing temperature on structural, micro-structural and magnetic properties of $Ni_{0.6}Co_{0.2}Cu_{0.2}Fe_2O_4$ (NCCFO) thin film have been investigated. The major findings include increase in crystallite size/average grain size and good magnetic properties as a result of increasing annealing temperature for the simultaneous substitution of Co-Cu substituent in the nickel ferrite thin films.

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