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## Effect of Oxidation Temperature on Structural and Magnetic Properties of Al-doped Iron Oxide Thin Films

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### Abstract

Spinel ferrites have attracted worldwide attraction due to technological applications in spintronic and data storage devices. Among spinel structures of the form  $XAl_2O_4$  (where  $X = Fe, Al, Mg$  etc.) very little attention has been given to  $FeAl_2O_4$ .  $FeAl_2O_4$  is a normal spinel oxide in which  $Fe^{2+}$  cations occupy 1/8th of the tetrahedral sites and  $Al^{3+}$  occupy 1/2 of the octahedral sites. The distribution of charges on octahedral and tetrahedral depends on the synthesis conditions as octahedral sites can also be occupied by  $Fe^{2+}$  cations. We here report the preparation of  $FeAl_2O_4$  thin films using thermal evaporation method. The metallic films are oxidized at  $250^\circ C$  and  $450^\circ C$  under oxygen flow rate of 10sccm. XRD results indicate that at  $250^\circ C$  pure  $FeAl_2O_4$  phase is formed. With increase in oxidation temperature to  $450^\circ C$  diffraction peaks corresponding to  $Fe_2O_3$  phase emerge. The presence of  $Fe_2O_3$  phase in  $FeAl_2O_4$  thin films leads to degradation in magnetic properties.

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## 1. Introduction

During the past few years, controlled growth of spinel nanostructures with desired morphology has been of technological interest due to properties like Giant Magneto Resistance (GMR) tunneling and electric field effects [1]. These properties have found wide applications in spintronic devices, e.g. Magnetic Tunnel Junctions (MTJ's), humidity sensors, in Magnetic Resonance Imaging, targeted drug delivery, magnetic recording etc. Spinel oxides appear flexible due to their complex structure and resulting high degrees of freedom [2, 3]. In spinel ferrites divalent metal cations are surrounded by four oxygen anions whereas trivalent metal cations are surrounded by six oxygen anions. Two sites are present namely octahedral and tetrahedral sites.

Spinel structures are classified as inverse, normal or partially spinel structures depending on the arrangement of divalent and trivalent cations on octahedral and tetrahedral sites. In case of normal spinel ferrites, divalent cations occupy tetrahedral sites while trivalent cations are only present on octahedral sites. In partial spinel ferrites there is an arbitrary distribution of trivalent and divalent cations on octahedral and tetrahedral sites. On the other hand in inverse spinel ferrites trivalent cations are present both on octahedral and tetrahedral sites while divalent cations are present only on octahedral sites.

To date various spinel structures have been reported including  $\text{CoFe}_2\text{O}_4$ ,  $\text{MgFe}_2\text{O}_4$ ,  $\text{MnFe}_2\text{O}_4$ , and  $\text{NiFe}_2\text{O}_4$  [5-8]. Among the inverse spinel structures of the form  $\text{FeX}_2\text{O}_4$  (where X= Co, Mg, Mn, Ni etc.) very little attention has been given to  $\text{FeAl}_2\text{O}_4$ .  $\text{FeAl}_2\text{O}_4$  is a normal spinel oxide in which  $\text{Fe}^{2+}$  cations occupy 1/8th of the tetrahedral sites and  $\text{Al}^{3+}$  occupy 1/2 of the octahedral sites. The distribution of charges on octahedral and tetrahedral changes depend on the synthesis conditions as octahedral sites can also be occupied by  $\text{Fe}^{2+}$  cations [7-12].

We here report preparation of iron aluminum oxide thin films via oxidation of thermally evaporated aluminum and iron metallic thin films. Films were oxidized at 250°C and 450°C under oxygen flow rate of 10sccm. It can be seen conclusively that low oxidation temperature resulted in pure phase while high oxidation temperature resulted in formation of  $\text{Fe}_2\text{O}_3$  phase along with  $\text{FeAl}_2\text{O}_4$  that strongly depreciates the magnetic properties.

## 2. Experimental Details

Preparation of  $\text{FeAl}_2\text{O}_4$  was done using thermal evaporation method in Edwards 306 coating unit. Before deposition of thin films glass substrates were placed in acetone in ultrasonic bath for 10 minutes followed by ultrasonication in Isopropyl Alcohol (IPA) for 15mins. Base pressure of  $10^{-6}$  torr and working pressure of  $1.5 \times 10^{-5}$  torr was maintained in the coating unit. Samples were oxidized in the presence of oxygen flow of 10sccm at 250°C and 450°C for 60min. Flow rate of oxygen was chosen on the basis of our previous work [10]. Structural characterization was done by XRD (Bruker D8 Advance X-ray Diffractometer) and magnetic properties were studied by VSM (Lake Shore 7407 Vibrating Sample Magnetometer).

## 3. Results and Discussion

Fig. 1 shows XRD pattern for iron aluminum oxide thin films oxidized under oxygen flow rate of 10sccm at 250°C and 450°C. Presence of diffraction peaks corresponding to (222) and (400) planes indicate the formation of  $\text{FeAl}_2\text{O}_4$  phase. With increase in oxidation temperature to 450°C the diffraction peaks corresponding to  $\text{Fe}_2\text{O}_3$  phase also exist indicating that higher oxidation temperature results in phase separation of iron oxide in iron aluminum oxide. Therefore, low temperature is effective in complete oxidation and compound formation of multilayered films while high temperature resulted in incomplete compound formation/oxidation of films.

Crystallite size, crystallinity and lattice parameters were calculated using Eqs. 1-4 and are listed in table 1.

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