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Enhanced Magnetic Properties of $YCr_{0.5}Mn_{0.5}O_3$ Thin films fabricated by RF Sputtering.

A. Rambabu
Department of Physics, GMRIT Deemed to be University, Rajam, Andhra Pradesh, India-532127

Abstract: Thin films of rare-earth orthochromites are successfully fabricated using radio frequency sputter technique. The processing parameters like substrate temperature, target-substrate distance, rf power, pressure inside the chamber etc. are optimized systematically. Crystallization of the $YCr_{0.5}Mn_{0.5}O_3$ bulk and thin films were characterized by X-ray diffractometer. Surface morphology was captured using scanning electron microscopy. Magnetic properties such as magnetic moment verse magnetic field and magnetic moment verses temperature of $YCr_{0.5}Mn_{0.5}O_3$ thin films were characterized by physical property measurement system. High magnetic moment and sharp magnetic transition observed at 85 K. These results are favorable to spintronic applications.
Keywords: Chromites, Thin films, Magnetic properties.

I. INTRODUCTION

Recently, there is a renewed interest in rare earth ferrites, manganites, and chromites due to the possible magneto electric coupling in these materials [1-3]. One of these compounds $YCrO_3$ belongs to the same family of compounds with general formula of $RCrO_3$ (rare earth and Y) and is reported to crystallize in a distorted perovskite structure. Rare earth orthochromites show extremely rich magnetic properties due to interaction between R^{+3} and Cr^{+3} ions leading to various types of magnetic ordering at low temperatures [4]. The isostructural rare earth orthochromites $RCrO_3$ with magnetic R-ion have been shown to exhibit ferroelectricity at the chromium ordering temperature due to magnetic interactions between rare- earth and Cr ions and it has been suggests that similar mechanism should be responsible to other magnetic rare-earth orthoferrites. The isostructural compounds, orthoferrites and orthochromites have a centrosymmetric orthorhombic structure and exhibit a weak ferromagnetism due to antisymmetric Dzyaloshinskii-Moriya (DM) interaction [5-6]. Upon substitution of Mn at the Fe site, the Yttrium orthoferrite shows interesting magnetic properties such as a first order spin-orientation and temperature induced magnetization reversal [7].
The investigations of these material properties have been studied in bulk form. However, properties of these materials in thin film form is still not been studied in large extend. The re-emergence of interest in multiferroics has been driven, in part, by the development of thin film growth techniques that allow for the production of non-equilibrium phases of materials and strain engineering of existing materials [8]. Thin films offer a pathway to the discovery and stabilization of a number of new multiferroics in conjunction with the availability of high quality materials that can be produced in larger lateral sizes than single crystal samples. Multiferroic thin films and nanostructures have been produced using a wide variety of growth techniques including sputtering, spin coating, pulsed laser deposition, sol–gel processes, metal-organic chemical vapor deposition, and molecular beam epitaxy.
The present study discusses the magnetic properties of $YCr_{0.5}Mn_{0.5}O_3$ thin films along with structural and morphological properties.

A. Experimental

The $YCr_{0.5}Mn_{0.5}O_3$ ceramic target used for rf magnetron sputtering was prepared by solid-state reaction method. For $YCr_{0.5}Mn_{0.5}O_3$ ceramic target, powders of Y_2O_3, Cr_2O_3, Mn_2O_3 of 99.8% purities were mixed in desired composition. The mixture was thoroughly grinded about 3-4 hours to get uniform mixing. The mixed powder was pre-calcinated at 1000°C for 12 h and then grinded it. Final calcination was done at 1100°C about 12 h to get homogenous and desired composition phase. The 2 inch dia of $YCr_{0.5}Mn_{0.5}O_3$ target, the calcinated powders were pressed into pellets and then finally sintered at 1170 °C for 12h.

B. Thin Film Preparation

The $YCr_{0.5}Mn_{0.5}O_3$ thin films were deposited on various substrates by RF magnetron sputtering at fixed gas pressure. The parameters such as the RF power, substrate temperature, sputter gas mixture i.e the Ar/O2 ratio, working/sputtering gas pressure and target to substrate distance can be controlled to influence the material properties of the sputtered films. It is important to note that the control over parameters that influence the physical properties of the growing film in general are greater during the deposition process.

Rf Power : 20,50W
Working pressure : 10mTorr
Oxygen mixing percentage : Ar: O_2 (50%: 50%)
Substrate temperature : 700, 725°C
Substrates used : LAO, Pt/Si,

Experimental conditions are varied in order to get uniform and homogeneous films. Above all conditions, we could able to grown the films with few conditions. However, still need to optimize the conditions.

II. RESULTS AND DISCUSSION

The structural properties of $YCr_{0.5}Mn_{0.5}O_3$ bulk and thin films compound was examined by X-ray diffractometer. The XRD pattern of $YCr_{0.5}Mn_{0.5}O_3$ powder after calcination indexed with (h k l) planes and these planes are matched with standard XRD pattern without any impurities. The bulk powder of $YCr_{0.5}Mn_{0.5}O_3$ XRD pattern was shown in figure 1(left).

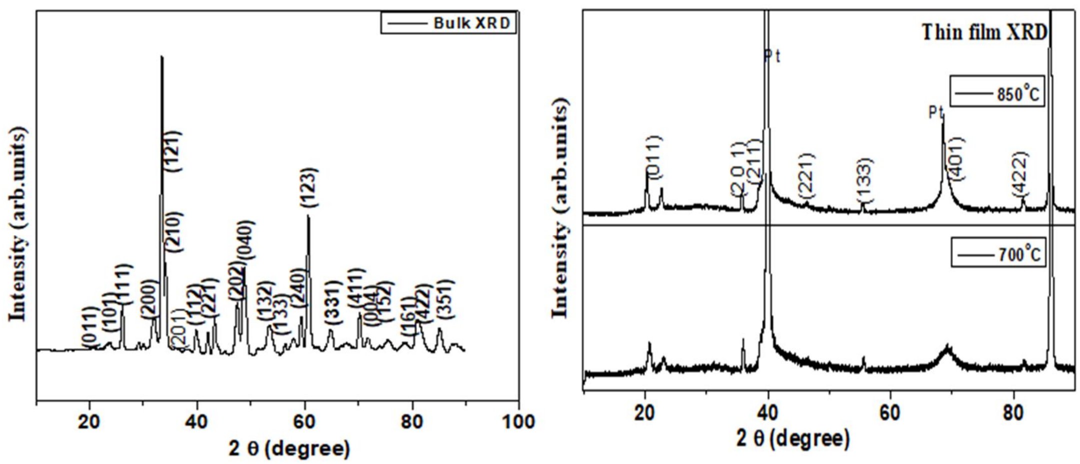

Figure 1: X-ray diffraction pattern (left) Powder form of $YCr_{0.5}Mn_{0.5}O_3$ (right) thin film form of $YCr_{0.5}Mn_{0.5}O_3$.

The XRD pattern of the $YCr_{0.5}Mn_{0.5}O_3$ thin film deposited on Pt/Si substrates shown in figure 1 (right). As deposited and low temperature deposited films were exhibited the amorphous nature (not shown here). As shown in figure 1(right), films deposited at lower temperature exhibited the less crystalline nature and films annealed at higher temperature showed good crystalline nature with orthorhombic structure.

$$D = \frac{k\lambda}{\beta\cos\theta} \qquad (1)$$

The crystallite size of the $YCr_{0.5}Mn_{0.5}O_3$ thin films was estimated by equation 1. Formula description was provided by A Rambabu et.al [9]. The crystallite values are estimated for films deposited at 700 °C, and 850 °C are 33 and 45 nm respectively.

C. Surface Morphological studies

The surface morphology images of the $YCr_{0.5}Mn_{0.5}O_3$ thin films deposited at 700 and 850 °C obtained from scanning electron microscopy shown in figure 2(a-b). Films deposited at 700 °C shows relatively less crystallization with randomly distributed grains and less densification. Films deposited at 850 °C exhibits the uniform distribution of grains and its grain size is around 100 nm with good packing density. It's clear that the temperature variation exhibits the effect on surface morphology.

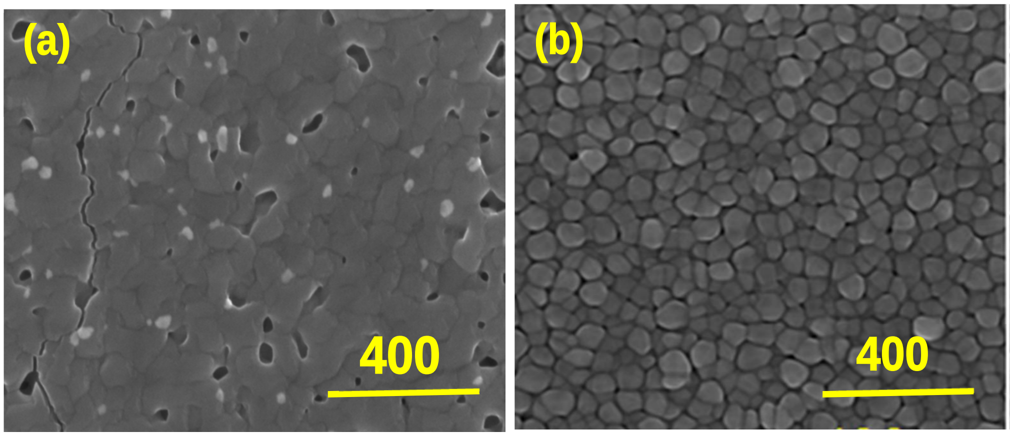

Figure 2(a-b): SEM images of the $YCr_{0.5}Mn_{0.5}O_3$ thin films deposited at (a) 700 ^oC, (b) 850 ^oC

III. MAGNETIC PROPERTIES

Magnetic properties of $YCr_{0.5}Mn_{0.5}O_3$ thin films deposited at 700 and 850^{o}C are shown in figure 3 (a-d). The applied magnetic field for the both samples around ±5T. Figure 3(a) indicates the hysteresis curve of $YCr_{0.5}Mn_{0.5}O_3$ thin films deposited at 700. The hysteresis curve showed inferred loop with well symmetric along the field axis and exhibited no proper saturation. This indicates that films deposited at 700 ^{o}C exhibits the weak ferromagnetism. Films deposited at 850 ^{o}C showed in Figure 2(b). From this graph, it's understood that magnetic properties are enhanced. In addition, as the magnetic field increases magnetic saturation also increases. These results revealed that the anti-ferromagnetism behavior decreases and exhibits the strong ferromagnetic behavior [10-12]. The $YCr_{0.5}Mn_{0.5}O_3$ films deposited at 700^{o}C exhibited less ferromagnetic properties due to poor crystallization, which supports the structural and morphological studies. Overall, films deposited at 850^{o}C, exhibited good magnetic properties compared with films deposited at 700^{o}C.

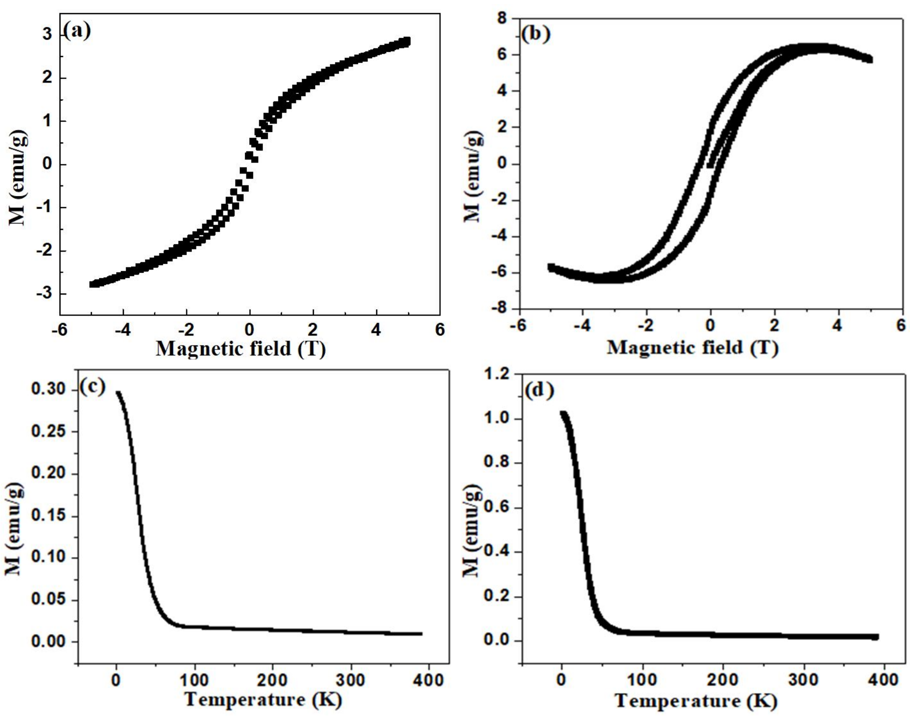

Figure 3(a-d): Magnetic moment Vs applied magnetic field at deposited at (a) 700^{o}C (b) 850^{o}C. Temperature variation of magnetic moment of $YCr_{0.5}Mn_{0.5}O_3$ thin films (c) 700^{o}C (d) 850^{o}C.

Figure 3 (c, d) reveals the temperature dependent magnetic properties m of $YCr_{0.5}Mn_{0.5}O_3$ thin films at an applied field of 100 Oe in a temperature range from 0 – 400 ^oK. The clear magnetization transition was observed for the $YCr_{0.5}Mn_{0.5}O_3$ thin films deposited at different temperatures. From the figure 3(c), it was observed that magnetic transition exhibits at 75K for this films deposited at 700 ^oC. On other hand, films deposited at 850 ^oC exhibits the magnetic transition at 85K which supports to the reported results. This is attributed due to ion exchange interaction between Cu^{3+}/Mn^{4+} [13-15]. Overall, the films deposited at 850^oC explored the favorable ferromagnetic properties with proper Neel temperature.

IV. CONCLUSION

Single phase $YCr_{0.5}Mn_{0.5}O_3$ target was prepared by solid state method. Crystalline form of $YCr_{0.5}Mn_{0.5}O_3$ thin film was successfully grown on Pt/Si substrates. XRD pattern of these films are well crystallized into orthorhombic structure as the temperature increases. Densified and uniformly distributed grains are grown for the films deposited at 850 ^oC. Excellent magnetic properties are exhibited for the films deposited at 850 ^oC which are useful for the spintronic devices.

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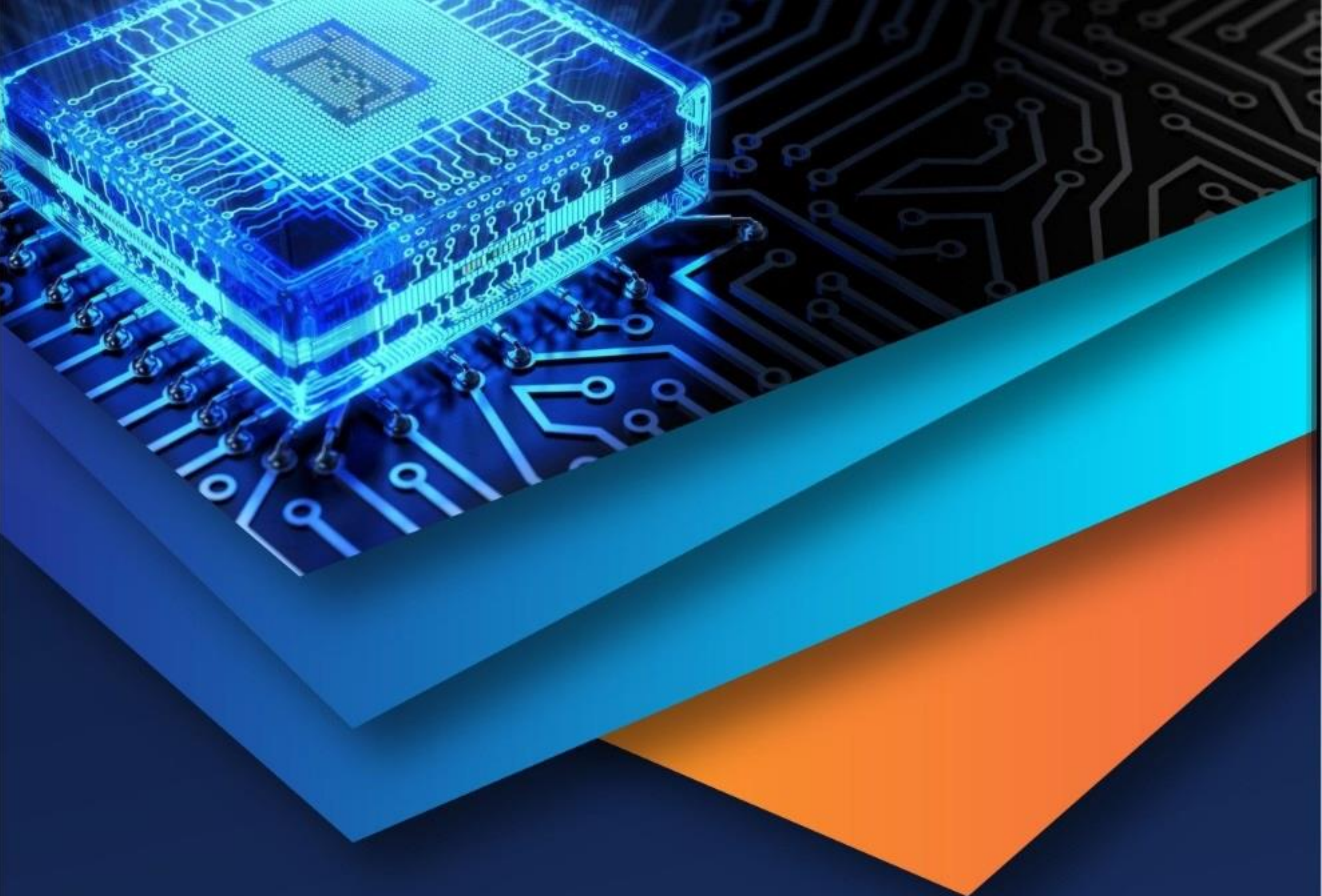

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