IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 8, Issue 5 Ver. II (Sep - Oct. 2016), PP 80-82
www.iosrjournals.org

Study The Electrical Properties of Co/TiO_2 Multilayer Thin Films

Md. Sarwar Pervez[1], M. A. I Nahid[2], Md. Faruk Hossain[3]
[1]*(Department of Natural Science, Varendra University, Bangladesh)*
[2]*(Department of Applied Physics and Electronic Engineering, University of Rajshahi, Bangladesh)*
[3]*(Department of Physics, Rajshahi University of Engineering and Technology, Bangladesh)*

Abstract: *The Co/TiO_2 multilayer thin films were prepared by e-beam evaporation on glass substrate. Each film was consisting of three alternative bi-layer of Co and TiO_2 and the top layer of the films were TiO_2. Films were annealed in open air at different temperatures. Temperature dependence of conductivity was measured for all the samples. It was observed that conductivity was found to increase with temperature. The conductivity of as-deposited film was higher than the conductivity of annealed film. Thickness dependence of conductivity was also studied. It was also found that, as the film thickness increased, conductivity decreased. The conductivity of the annealed film was of the order of $10^2(\Omega m)^{-1}$. The T.C.R of Co/TiO_2 multilayer thin films was negative for both as deposited and annealed films. All those results suggest that Co/ TiO_2 multilayer annealed thin films are semiconducting in nature.*
Keywords - *Transparent magnetic oxides, Diluted magnetic semiconductor, Co, TiO_2, Interdiffusion.*

I. Introduction

Transparent magnetic oxides have a high potentiality for fabricating future multifunctional spintronic devices according to the various technological reports and roadmaps [1-5]. One of the approaches in achieving this goal is the doping of transition magnetic (TM) material into transparent oxide [4-6]. In several cases, TM doped oxide such as Co doped ZnO, TiO_2 and SnO_2 etc. shows ferromagnetism at room temperature [5-12]. The mechanism and origin of ferromagnetism and its reproducibility is still studied. Among the various oxides, Co doped TiO_2 is very attractive and one of the most prominent material [3, 7]. This material shows ferromagnetism at room temperature, and it has a higher Curie temperature [3]. The requisite property of transparent magnetic oxides to use it as multifunctional is to obtain larger magnetization, higher optical transmittance as well as semiconducting behavior. Although, there are some works in Co doped TiO_2, there are few works on the electrical properties of Co/TiO_2 multilayer thin films. The conduction mechanism is quite complex in the metal doped oxide materials [13]. In this paper, we would like to investigate how annealing plays a role in the electrical properties of Co/TiO_2 multilayer thin films. After the preparation of the Co/TiO_2 multilayer, the samples were annealed at high temperature and the electrical properties were compared of Co/TiO_2 multilayer thin films of as-deposited with the annealed films.

II. Experimental Process

The Co/TiO_2 multilayer thin films were prepared by e-beam evaporation method (Edward-306) in a vacuum better than 10^{-5} Torr on glass substrate. The thickness of Co and TiO_2 was kept same. Optical interference method is used to measure the thickness of Co and TiO_2 films. Each layer thickness was varied from 2 nm to 4 nm and repeated three times. The sample size was 5 mm × 5 mm. There were three types of films. S1: $[Co(2nm)/TiO_2(2nm)]_{\times 3}$, S2: $[Co(3\ nm)/TiO_2(3\ nm)]_{\times 3}$, and S3: $[Co(4\ nm)/TiO_2(4\ nm)]_{\times 3}$. The deposition rate of the Co and TiO_2 thin films were about 1.33 nm/sec &.1.25 nm/sec respectively. The films were annealed in an oven in open air in the temperature range of 473K-673K.

III. Result And Discussion

Electrical measurements were carried out using Vander-pauw technique. The conductivity was calculated from the measured data. Fig. 1 shows the conductivity of as-deposited and annealed Co/TiO_2 (S2) thin films and Fig. 2 shows the conductivity of as-deposited and annealed Co/TiO_2 (S3) thin films. For both case, the conductivity is in the order of $10^2(\Omega\text{-m})^{-1}$ which is in the semiconductor range

The conductivity is found to increase with temperature because the number of carriers available for electrical conduction is increased with temperature. It is noteworthy to mention that Co/TiO_2 multilayer thin films were post annealed at different temperatures in open air for one hour. It shows that the post annealing decreases the electrical conductivity of the films. Although there is no direct evidence, however, there is a possibility that annealing cause interdiffusion of Co and TiO_2. The interdiffusion might reduce the effective conductive channel width.

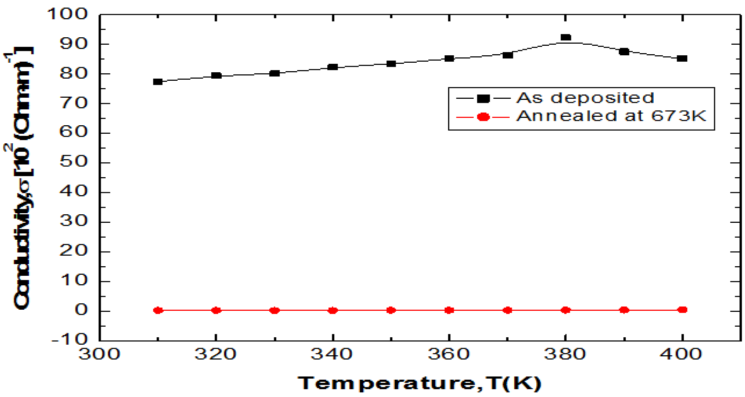

Fig. 1: Variation of conductivity with temperature of S2 film

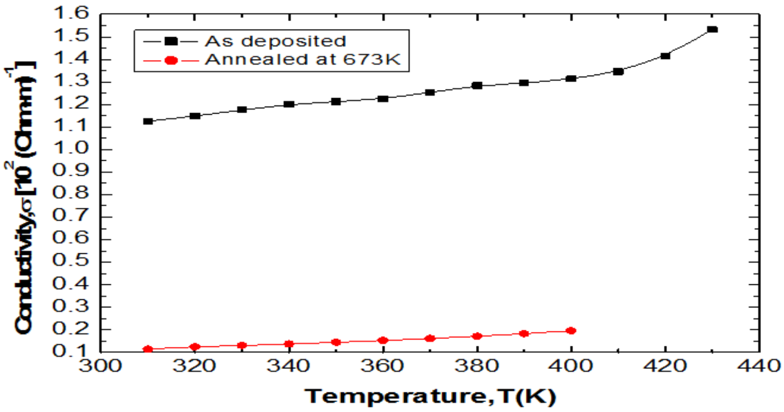

Fig. 2: Variation of conductivity with temperature of S3 film

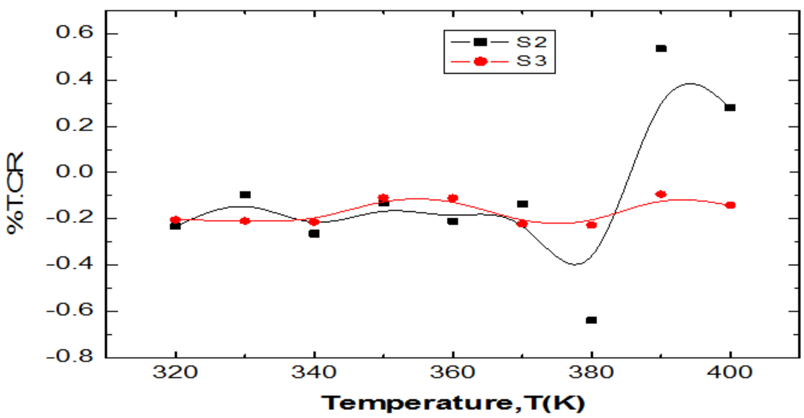

Fig. 3: Variation of T.C.R with temperature of as deposited films of different thickness.

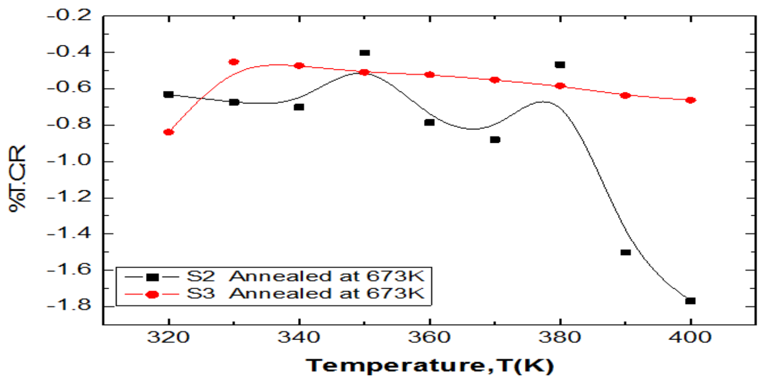

Fig. 4: Variation of T.C.R with temperature of annealed [673K] films of different thickness.

This results the decrement of conductivity. It is also observed that higher thickness Co/TiO_2 thin films show lower conductivity compare to the lower thickness one for both as-deposited and annealed. The room temperature conductivity of as-deposited S2 film was $77.5\times10^2(\Omega m)^{-1}$ while the room temperature conductivity of as-deposited S3 film was $1.125\times10^2(\Omega m)^{-1}$. For annealed film, the conductivity of S2 film was $0.1915\times10^2(\Omega m)^{-1}$ while the conductivity of S3 film was $0.119\times10^2(\Omega m)^{-1}$. In Fig. 1, for annealed film, the increase of conductivity with temperature is very small and because of this the curve looks like a straight line.

The temperature dependent transport plays an important role in thin film characterization. The temperature coefficient of resistance (TCR) is estimated from the measured data according to the formula reported elsewhere [13]. Fig. 3 and 4 depict the TCR of as-deposited and annealed Co/TiO_2 thin films of various thicknesses annealed at 673K. It is observed that TCR is negative in all cases. This indicates that the film are semiconducting in nature. However, TCR does not change systematically which is difficult to explain. The interdiffusion of the metal Co particles in insulating TiO_2 layers can make complex hopping transport mechanism. Ionized impurities are the important source of scattering in doped semiconductor and if this dominates the TCR can become negative.

It is noted that the S1: $[Co(2nm)/TiO_2(2nm)]_{\times3}$ film was very thin and oxidation may result discontinuity of the film. The result of S1 film is not included as we were not able to measure correctly the electrical conductivity of the films using Van-der-Pauw technique.

IV. Conclusion

The temperature dependent electrical properties of Co/TiO_2 thin films have been studied. It is concluded from the experimental result that the effect of annealing plays an important role in the electrical properties of the films. The as-deposited Co/TiO_2 thin films show higher conductivity. The post annealing at moderate temperature (473K) can give semiconducting behavior. The room temperature conductivity of Co/TiO_2 films annealed at 473K grown on glass substrate is obtained in the order of $10^2(\Omega\text{-m})^{-1}$ .The annealing at higher temperature reduces the conductivity. The key property for obtaining transparent magnetic oxides material for future multifunctional material is that it should exhibit magnetic, semiconducting property and at the same time it should be highly transparent. The role of annealing in Co/TiO_2 multilayer thin films gives the path to control the electrical properties.

Acknowledgement

The author greatly acknowledges the discussion with the faculty members and Thin Film Laboratory of the Dept. of Applied Physics & Electronic engineering, University of Rajshahi. The author also acknowledges the support from University Grant Commission (UGC) project

References

[1] M.BaghaieYazdi, M.-L. Goyallon,T.Bitsch, A. Kastner, M. Schlott, L. Alff, *Thin Solid Films*, **519**, 2531 (2011).
[2] J. Philip, A. Punnoose, B. I. Kim , K. M. Reddy, S. Layne, J. O. Holmes, B. Satpati, P. R. Leclair, T. S. Santos, and J. S. Moodera, *Nat. Mater.*, **5**, 298 (2006).
[3] Y. Matsumoto, M. Murakami, T. Shono, T. Hasegawa, T. Fukumura, M. Kawasaki, P. Ahmet, T. Chikyow, S. Koshihara, *Science*, **291**, 854 (2001)
[4] K.M. Krishnan, A. B. Pakhomov, Y. Bao, P. Blomqvist. Y. Chun, M. Gonzales, K. Griffin, X. Ji and B. K. Roberts, *J. Mater. Sci.*,**41**, 793 (2006).
[5] N. H. Hong, J. Sakai, N. Poirot, and V. Brize, *Phy. Rev.B*.**73**.132404 (2006).
[6] S.J. Pearton,W. H. Heo, M. Ivill, D. P.Norton, and T.Steiner, *Semicond. Sci.Technol.***19** R59 (2004).
[7] M. Subramanian, S. Vijayalakshmi, S. Venkataraj, R. Jayavel, *Thin Solid Films*, **516**, 3776 (2008).
[8] Y. Matsumoto, M. Murakami, T. Shono, T. Hasegawa, T. Fukumura, M. Kawasaki, P. Ahmet, T. Chickyow, S. Koshihara, and H. Koinuma, *Science*, **291**, 854 (2001).
[9] N. Hoa Hong, J. Sakai, W. Prellier, A. Hassini, A. Ruyter, and F. Gervais, *Phys. Rev. B*, **70**, 195204 (2004).
[10] M. Venkatesan, C. B. Fitzgerald, J. G. Lunney, and J. M. D. Coey, *Phys. Rev. Lett*., **93**, 177206 (2004).
[11] S. B. Ogale, R. J. Choudhary, J. P. Buban, S. E. Lofland, S. R.Shinde, S. N. Kale, V. N. Kulkarni, J. Higgins, C. Lanci, J. R. Simpson, N. D. Browning, S. Das Sarma, H. D. Drew, R. L.Greene, and T. Venkatesan, *Phys. Rev. Lett*., **91**, 077205 (2003).
[12] J. M. D. Coey, A. P. Douvalis, C. B. Fitzgerald, and M. Venkate-san, *Appl. Phys. Lett.*, **84**, 1332 (2004).
[13] J. Ederth, P. Johnsson, G. A. Niklasson, A. Hoel, A. Hultåker, P. Heszler, C. G. Granqvist, A. R. van Doorn and M. J. Jongerius, and D. Burgard, *Phy. Rev.B*, **68**.155410(2003).
[14] S. M. Sze, Semiconductor Devices: Physics and Technology. New York: Wiley. pp.53.(2001).