American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-10, pp-48-53
www.ajer.org
Research Paper Open Access

Analysis The Electrical Properties of Co, TiO_2 and Co/TiO_2 Multilayer Thin Films of Different Thickness Deposited by E-Beam Technique.

Md. Faruk Hossain[1], Md. Abdullah Al Asad[2] , Md. Omar Faruk[3], Dr. Md. Ariful Islam Nahid[4]

[1](Department of Applied Physics & Electronic Engineering, University of Rajshahi, Rajshahi, Bangladesh)
[2](Department of Applied Physics, Electronics and Communication Engineering, Bangabandhu Sheikh Mujibur Rahman Science & Technology University, Bangladesh)
[3](Department of Information and Communication Engineering,Pabna University of Science and Technology,Bangladesh)
[4](Department of Applied Physics & Electronic Engineering,Rajshahi University,Bangladesh)

ABSTRACT : *This paper presents the fabrication of the Co doped TiO_2 film for studying the electrical properties. In this case, at first Co/TiO_2 multilayer films were prepared by e-beam evaporation in a vacuum better than 10^{-5} Torr. The electrical properties of the deposited Co, TiO_2, Co/TiO_2 films had been studied. The surface morphology had been studied by Atomic Force Microscopy. In the multilayer, the thickness of Co and TiO_2 was kept same. Each layer thickness was varied from 5nm to 15 nm and repeated three times. The deposition rate of the Co and TiO_2 thin films are about 1.33 nm/sec &.1.25 nm/sec respectively. Electrical conductivity for the deposited Co, TiO_2 and Co/TiO_2 multilayer thin films had been measured as a function of temperature ranging from 300K to 470K. The deposited Co thin film, conductivity is of the order of $10^6(\Omega\text{-m})^{-1}$ that decreases with increasing temperature and the value for deposited TiO_2 and Co/TiO_2 multilayer thin films is of the order of 10^2 $(\Omega\text{-m})^{-1}$ and $10^5(\Omega\text{-m})^{-1}$ respectively. Again, the conductivity of the deposited TiO_2 thin films decreases with film thickness where in the case of as deposited Co, Co/ TiO_2 multilayer thin films increases with increasing film thickness. The sheet resistance of the as deposited Co thin films increases with increasing temperature which is to be the order of 10^2 Ω/sheet. It is found that the sheet resistance of the as deposited TiO_2 and Co/TiO_2 multilayer thin films to be the order of 10^7 Ω/sheet and 10^2 Ω/sheet respectively which decreases with increasing temperature. Variation of temperature coefficient of resistance (T.C.R) for Co and TiO_2 thin films are metallic and insulating in nature respectively. The T.C.R. of deposited Co/TiO_2 multilayer thin films in all cases are semiconducting in nature.*

Keywords - *Co, e-beam, electrical properties, TiO_2, thickness.*

I. INTRODUCTION

Co-doped TiO_2 has been a promising candidate for dilute magnetic semiconductor (DMS). Many researchers are investigating this system to study and further manipulate their electrical, magnetic or semiconductor properties, The cobalt doped titanium dioxide which has received widespread interest since it was discovered to be ferromagnetic at room temperature by Y.Matsumoto et al[1].Newly discovered room-temperature ferromagnetic semiconductor cobalt-doped titanium dioxide (Co-doped TiO_2) is known as wide-bandgap diluted magnetic semiconductors(DMSs), it has a higher Tc (above room temperature), which makes it an extremely attractive material [2,3].The magnetic material is doped in transparent oxide in a motivation that the magnetic properties can be controlled by controlling the electrical interaction. The reason for choosing cobalt and titanium dioxide in this research is because cobalt is a well-known magnetic element while the titanium dioxide has been extensively studied for several decades since it has many technologically important properties. TiO_2 is soft solid and melts at 1800°C.It absorbs ultraviolet light and has a high stability which is suitable to act as a matrix layer in semiconductor. Meanwhile,Co-doped TiO_2 naturally has high value of Curie temperature (Tc) [4], very much well above room temperature. With all these properties and a doping with cobalt magnetic ions, it would be able to control its optical, magnetic and semiconductor characters for suitable applications. Therefore, it is interesting to investigate the electrical properties of Co /TiO_2 multilayer thin film.

II. EXPERIMENTAL PROCESS

Thin film specimens for all the experimental investigations (e.g. electrical) have been prepared by e-beam technique using Edwards E-306 vacuum coating unit. The unit consists of a deposition chamber, a pumping system and electrical sources. The deposition chamber is cylindrical and has a mechanically polished interior. A stainless steel substrate holder to hold four substrates is situated just above the source. A mechanical shutter operated from outside the chamber isolates the source from the substrate for desired times. A tungsten filament (W) is used for the electron beam. The accessory is comprised of six hearth turret with rotary drive. The source turret is rotated, raised and lowered by an external control mechanism.The deposition chamber is evacuated with oil diffusion pump, which is controlled by an automatic evacuation system. The coating unit is provided with Edwards, EBS power supply unit having high tension (HT) 0-6 kV and low tension (LT) 0-500 mA. For present work HT is fixed at 4 kV and LT is varied from 40mA to 50mA. Electron bombardment heating of an evaporation source has been used. Single crystal substrates of alkali halides, mica, MgO, Si, Ge etc. are used for epitaxial growth. In the present work the ordinary microscope slides glass has been used. For patterning thin films,physical masking has been used by author. The measurement of resistivity and Hall co-efficient of the samples has been carried out by Van-der-Pauw method [5]. To fabricate a planer thin film,firstly, a suitable mask and source turret (with source-hearth contained TiO_2 or Co material) are adjusted and then shutter is placed between the substrate holder and source hearth to protect the substrate from unwanted deposition. Then the HT and LT regulators on the EBS power supply unit are ensured in the zero position. After switching ON the power supply the LT control of this supply unit is then increased slowly in order to degas the filament and evaporant, it is kept at about 60% on the LT control, and it is continued to degas the filament until the system pressure is reached a steady level and then LT control is reduced to zero. Then HT control of the EBS power supply is increased to HT voltage of 4 kV indicates on the meter and then the LT control is slowly increased until an emission current of 40mA in the case of Co material and 50mA in the case of TiO_2 material indicates on the meter. The HT voltage drops slightly. The source turret is slowly raised and hearth height is adjusted as the previous relevant steps to obtain the best film conduction. The shutter is then removed to allow deposition onto the substrate through the mask windows. When the deposition of film is completed then the shutter is replaced at the proper time. The EBS power supply is switched OFF properly. The high vacuum valve is then closed. The vacuum chamber and the fabricated devices are allowed to cool down for about an hour before air is admitted. The films are then taken out and stored them into a desiccators for various measurements. During the deposition of Co, TiO_2 and Co/TiO_2 multilayer, two films are prepared in a single run. For the process optimization,the first set of films is deposited at various substrate heights (d_{ss}) with respect to evaporant source keeping all other deposition parameters constant at an arbitrary level. From this set of films, the optimum substrate height (d_{ss}) is selected with respect to the higher thickness as well as conductivity of films.In all sets, deposition time and thickness are monitored carefully. From these monitored data, the deposition rate has been calculated. For the present work the substrate temperature has been kept at room temperature. Optical interference method is adopted for film thickness measurement by which the thickness of the film can be measured accurately. To measure resistivity, varying temperature of Van-der-Pauw technique has been adopted. The voltage and current of the sample have been measured for different temperatures. After collected these data; the resistivity, conductivity, sheet resistance and T.C.R. of the films have been calculated for a particular temperature, respectively.

III. RESULT And DISCUSSION

Our main objective is to study the electrical properties of Co/TiO_2 multilayer thin film. In the multilayer, the thickness of Co and TiO_2 was kept same. Each layer thickness was varied from 5nm to 15 nm and repeated three times. There are six alternative layer of Co and TiO_2 in each film and the upper layer is TiO_2. S_1 denotes that each layer is 5nm and S_2, S_3 denotes that each layer is 10nm and 15nm respectively. Temperature effect on conductivity has been studied for thickness variation as deposited Co, TiO_2 and Co/TiO_2 multilayer thin films are depicted in Fig-3.1, 3.2 and 3.3 respectively.

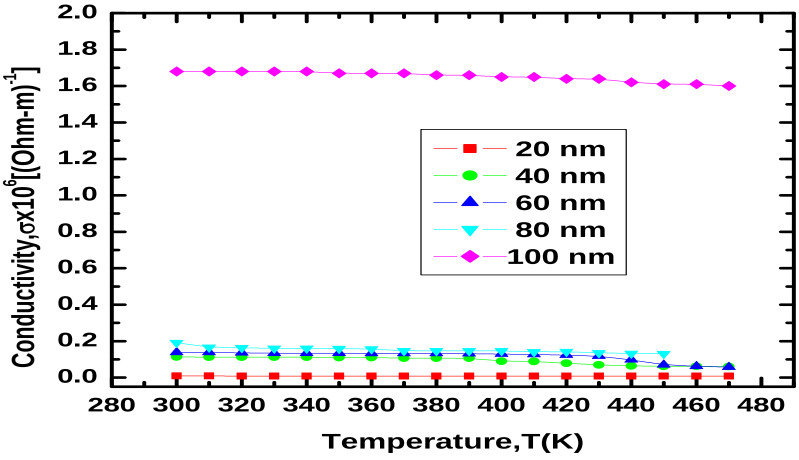

Fig-3.1: For deposited Co thin film of different thicknesses.

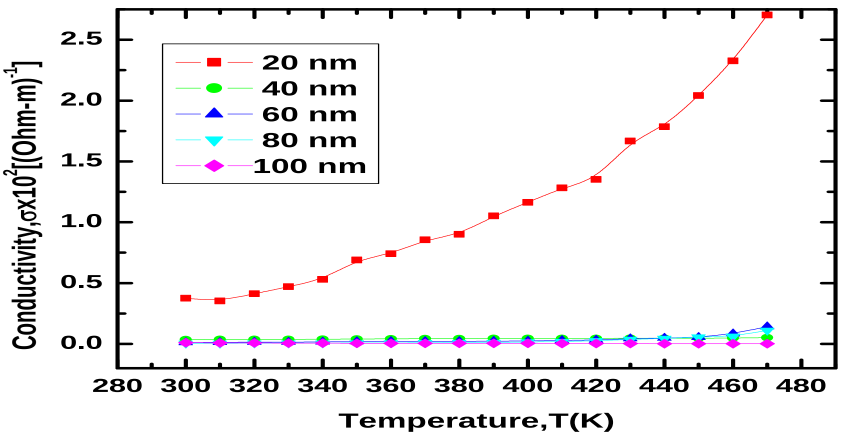

Fig-3.2: For deposited TiO_2 thin film of different thicknesses.

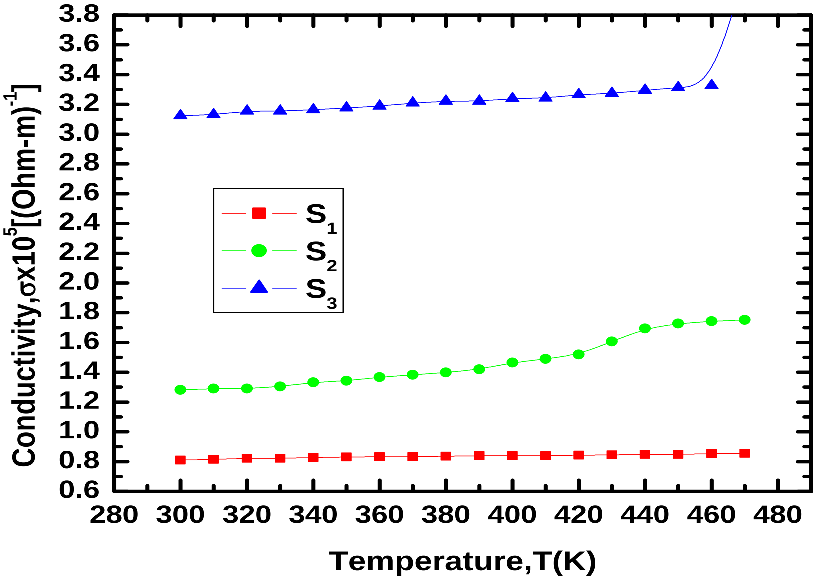

Fig-3.3: For deposited Co/TiO_2 multilayer thin film of different thicknesses.

The temperature dependence of sheet resistance has been studied for thickness variation as deposited Co, TiO_2 and Co/TiO_2 multilayer thin films are depicted in Fig. 3.4, 3.5 and 3.6 respectively..

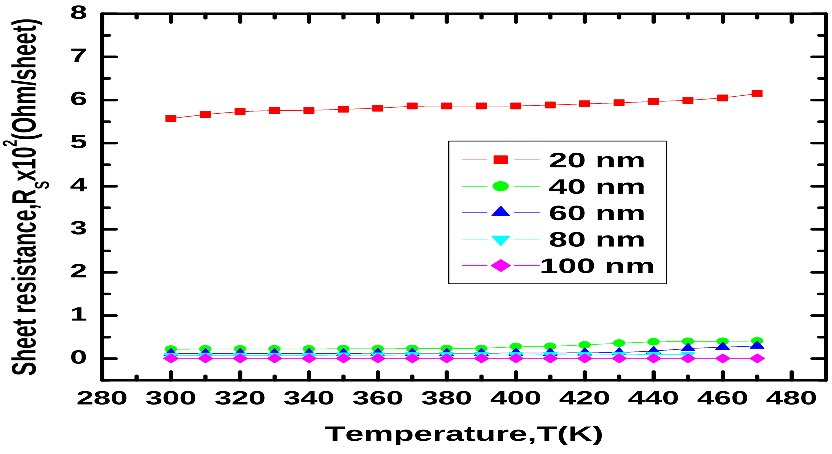

Fig-3.4: For deposited Co thin film of different thicknesses.

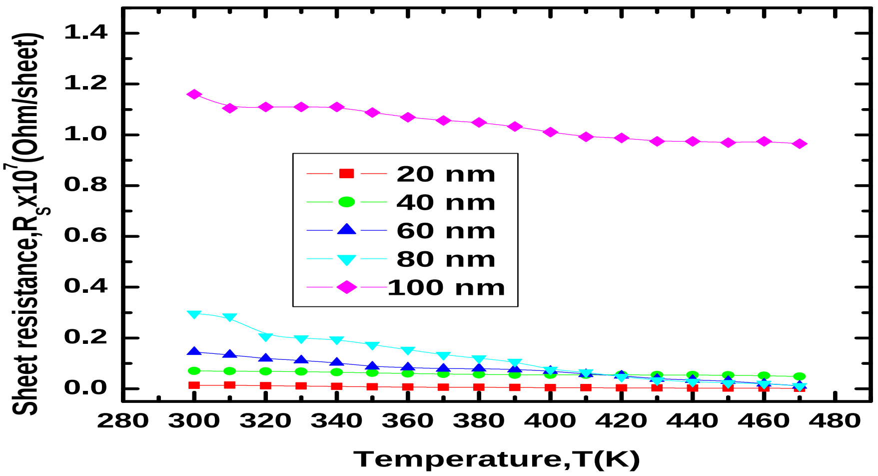

Fig-3.5: For deposited TiO_2 thin film of different thicknesses.

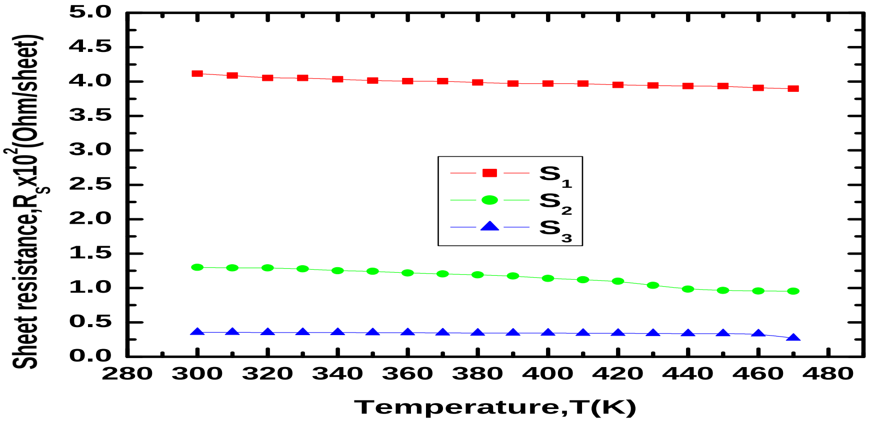

Fig-3.6: For deposited Co/TiO_2 multilayer thin film of different thicknesses.

Temperature effect on temperature coefficient of resistance (T.C.R) for thickness variation as deposited Co and TiO_2 and Co/TiO_2 multilayer thin films are depicted in fig 3.7, 3.8 and 3.9 respectively..

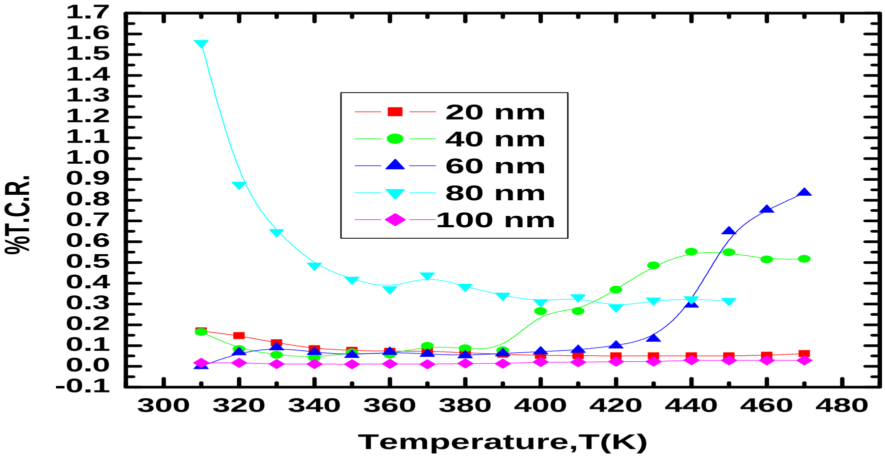

Fig-3.7: For deposited Co thin film of different thicknesses.

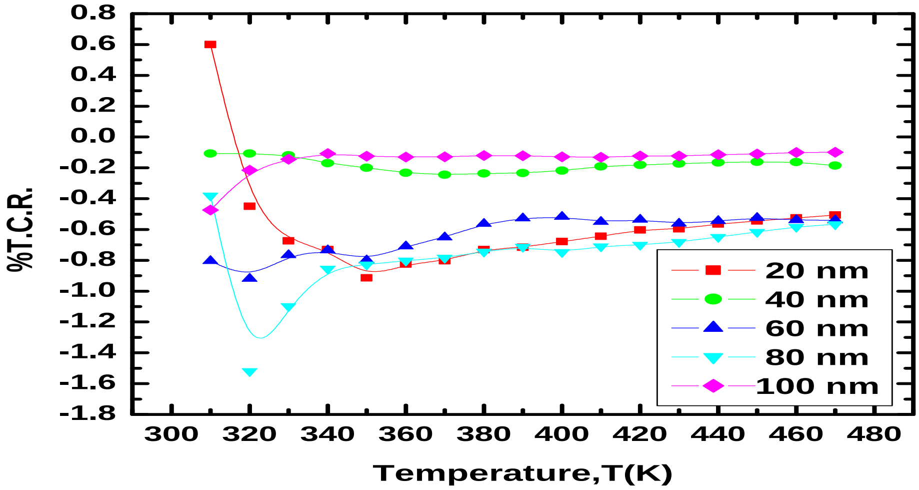

Fig-3.8: For deposited TiO_2 thin film of different thicknesses.

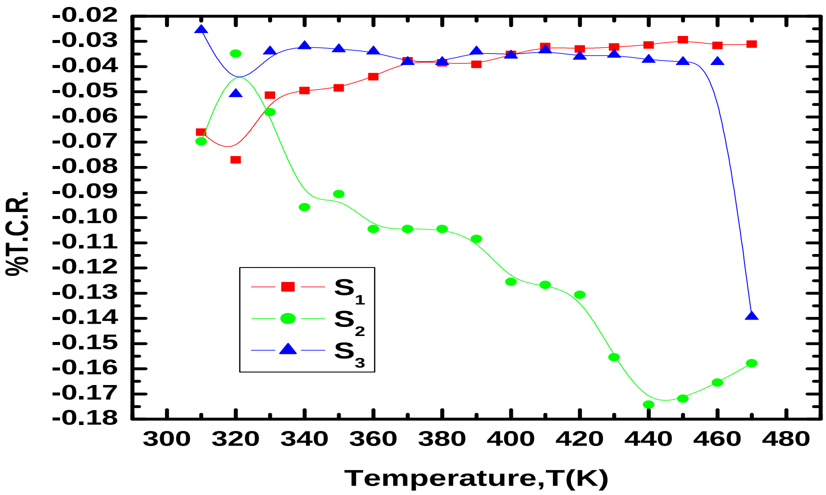

Fig-3.9: For deposited Co/TiO2 multilayer thin film of different thicknesses.

IV. CONCLUSION

Research and development on thin films have lead to the conclusion that different classes of material are of particular interest for different applications. In the light of the experimental investigations and analysis on the electrical studies of Co, TiO_2 and Co/TiO_2 multilayer thin films of different thicknesses deposited by e-beam technique. Co, TiO_2 and Co/TiO_2 multilayer thin films with variable thickness ranges from 20 to 100 nm have been prepared onto glass substrate by e-beam evaporation technique in vacuum at a pressure of $\sim 4\times10^{-5}$ Pa. The deposition rate is about 1.33nms^{-1} for Co and 1.25nms^{-1} for TiO_2. The various effects on electrical properties of the films have been studied. In the case of the as deposited Co thin film, conductivity decreases with increasing temperature but conductivity increased with temperature for deposited TiO_2 thin film .Conductivity of the as deposited TiO_2 thin films decreases with film thickness where in the case of as deposited Co, Co/ TiO_2 multilayer thin films increases with increasing film thickness. In the case of TiO_2 thin films, higher thickness has higher sheet resistance however in the case of as deposited Co, Co/ TiO_2 multilayer thin films, higher thickness has lower sheet resistance. The T.C.R. of Co thin films is positive which are shown to exhibit the as deposited Co thin film are metallic in nature and T.C.R. of TiO_2 thin films is negative which indicates that the as deposited TiO_2 thin films are insulating in nature. The T.C.R. of Co/TiO_2 multilayer thin films is negative in all cases which exhibits that as deposited Co/TiO_2 multilayer thin films are semiconducting in nature.

Acknowledgements

The authors would like to thank the concerned authority of the University of Rajshahi, Rajshahi, Bangladesh for providing us laboratory facilities (Central Science Laboratory, Rajshahi University) for the purpose of completing this research work. The financial support of the ministry of information and communication technology, Bangladesh (Fellowship 2010-2011) is gratefully acknowledged.

REFERENCES

[1] S.A. Chambers, S. Thevuthasan, R.F.C. Farrow, R.F. Marks, J.U. Thiele, L..Folks, M.G. Samant, A.J. Kellock, N. Ruzycki, D.L. Ederer and U. Diebold,Epitaxial growth and properties of ferromagnetic co-doped TiO_2 anatase, *American Institute of physics,79(21)*,2001, 3469.

[2] T.Fukumura, Y. Yamada, K.Tamura, K. Nakajima, Exploration of oxide semiconductor electronics of epitaxial thin films, in Y Fujikawa(Ed),*Frontier in materials Research*, (German: Springer- berlin,2008) 923-541.

[3] H.Ohno, Making Nonmagnetic Semiconductors ferromagnetic, *Science Magazine, 281(5379),* 1998, 951-956.

[4] S. A. Chambers, C. M. Wang and A. S. Lea,Transition from granular to dilute magnetic semiconducting multilayers in ion-beam-deposited ZnO/Co, *American Institute of physics,83(21),*2003, 4357

[5] L.J. Vander PAUL, A method of measuring specific resistivity and hall effect of discs of arbitrary shape, *Philips Research Reports*, *13(1*),1958,334.