International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Humidity Sensing Studies of Ag Doped TiO_2

Anupam Kumar Tripathi[1], Anoop Kumar[2]

[1]Department of Physics, Faculty of Engineering & Technology, University of Lucknow, Lucknow U.P. India

[2]Department of Physics, University of Lucknow, Lucknow U.P. India
Email: *tripathi198117[at]gmail.com*
Mobile No. 09450358456

Abstract: ***Practical applications of TiO_2 are limited due to its wide band gap and fast recombination of electron-hole pairs within nanoseconds. So far numerous researches have been focused on defeating these disadvantages by introducing the noble metals into titania lattice. Noble metals deposited or doped in TiO_2 have the high Schottky barriers among the metals and act as the electron traps, facilitating electron-hole separation and promotes interfacial electron transfer process. These additives capture electrons resulting in lower recombination rate of electron-hole pairs. However, some noble metals such as Pt, Pd, Rh, Au are too expensive to be used for the industrial scale. Therefore, the research on Ag-doped TiO_2 has significant practical value. Silver is suitable for industrial applications due to its comparable cost and easy preparation. It is a suitable element, which improves the TiO_2 photo-catalytic performance, it is also believed that the silver ions interact with sulfur, oxygen and nitrogen in the molecules of microorganisms and inactivate the cellular proteins resulting in titania as better bioactivite material. Ag-doped titania layers with different morphologies have been grown by Sol-gel method. As the Fermi levels of these noble metals are lower than that of TiO_2, photoexcited electrons can be transferred from the conduction band to the metal particles deposited on the surface of TiO_2, while photogenerated valence holes remain in the TiO_2. These activities greatly reduce the possibility of electron-hole recombination, resulting in efficient separation and stronger photo-catalytic reactions.***

Keywords: Electron-hole recombination, Humidity sensors, Photo-catalytic performance etc.

1. Experimental Procedure

The synthesized TiO_2 powder was doped with Ag with 20 wt% and made fine on grinding it in mortar with pestle for 2 hrs. The pellet of this material having dimensions 9 mm in diameter and 3 mm in thickness, has been made by hydraulic pressing machine (M.B. Instruments, Delhi, India) under pressure of 616 M Pa at room temperature. This pellet TA-20 was annealed in an electric muffle furnace (Ambassador, India) at 500°C, 600°C and 700°C for three hrs successively and after each step annealing process; it was exposed to humidity in the humidity chamber. Inside the humidity chamber, a thermometer (±10C) and standard hygrometer (Huger, Germany, ±1RH%) are placed for the purpose of calibration. Variation in resistance was recorded with the change in relative humidity. Variation in resistance of the pellet was recorded using a resistance meter (Sino meter ±0.001MΩ, Model: VC 9808). Copper electrode was used to measure the resistance of the pellet.

Specific Sensitivity of the sensor is defined as the change in resistance (ΔR) of sensing element per unit change in relative humidity (RH %) per unit resistance, i.e.

$$\Delta S = \Delta R/ R\ (\Delta\ RH\ \%) \quad ------ \quad (1)$$

After studying humidity sensing properties, sensing elements were kept in the laboratory environment and their humidity sensing characteristics were regularly monitored. The effect of ageing on the sensing properties of these elements was examined again in the humidity chamber after six months of fabrication of the pellet for the stability analysis of the sensor.

Study of Surface morphology

XRD Study of Ag doped TiO_2:

The XRD pattern of Ag doped TiO_2 annealed at 500ºC, 600ºC and 700ºC is shown in Figure 3.13. X-ray Diffraction by X-Pert PRO XRD system (Netherland) shows extent of crystallization of the sensing element as shown in Table 1.

The average crystallite size has been calculated using Debye-Scherer formula. The minimum crystallite size is 108 nm at 600ºC. .

Table 1: XRD Study of Ag doped TiO_2

Ag doped TiO_2 annealed at 500ºC		Ag doped TiO_2 annealed at 600ºC		Ag doped TiO_2 annealed at 700ºC	
Average crystallite size is 116 nm		Average crystallite size is 108 nm		Average crystallite size is 119 nm	
2θ values	Corresponding Miller Planes	2θ values	Corresponding Miller Planes	2θ values	Corresponding Miller Planes
25.28º	(101)	25.38º	(101)	25.71º	(101)
36.88º 38.09º	(103)	37.04º 38.19º	(-205)	28.71º 34.10º	(200)
44.23º 47.85º	(111)	44.41º 48.05º	(111)	35.71º 41.74º	(002)
49.88º	(200)	53.99º	(200)	49.98º 54.64º	(-202)
54.86º	(002)	55.14º	(021)	55.79º	(-331)
62.66º	(020)	62.78º	(105)		(122)
	(105)		(211)		(131)
	(204)		(002)		(421)

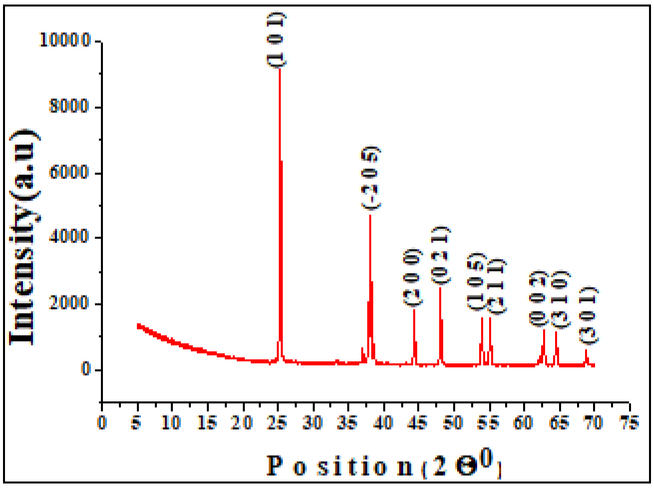

Figure 1: XRD pattern of sensing element TA-20 annealed at 500 ^{0}C.

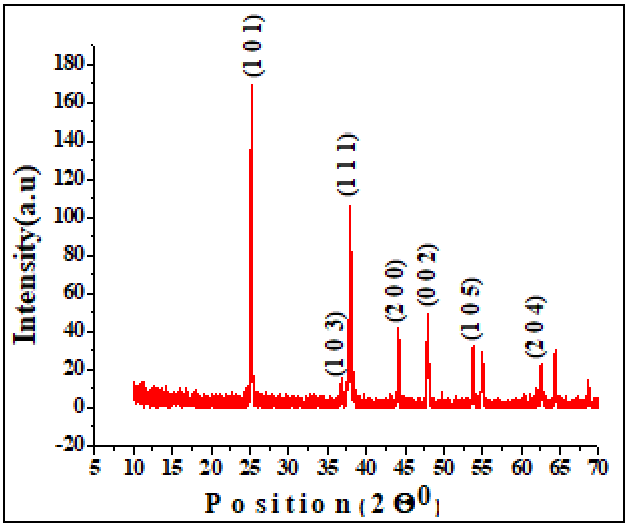

Figure 2: XRD pattern of sensing element TA-20 annealed at 600 ^{0}C.

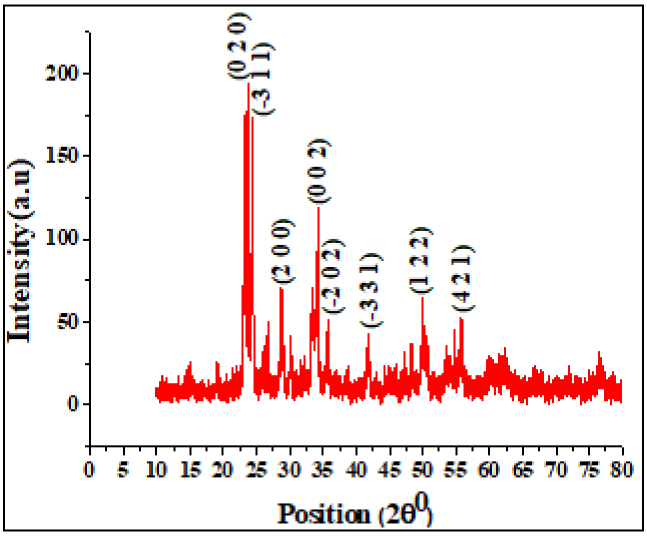

Figure 3: XRD pattern of sensing element TA-20 annealed at 700 ^{0}C.

Scanning Electron Microscopy

Surface morphology was studied using Scanning Electron Microscope Unit (SEM, LEO-0430, Cambridge). SEM micrograph shows that grains are of nano size and surface is porous in nature. These pores are expected to provide sites for humidity adsorption. The structure favors the adsorption and condensation of water vapors. The surface morphology of sensing elements TA-20 annealed at 700°C was studied. Grain size of sensing element TA-20 annealed at 700°C is found to be 98 nm. It shows uniform distribution of particles having approximately rounded shape.

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR spectra were recorded by KBr disc on Tensor-27 Spectrum. IR spectroscopy was used for understanding the nature of organics present in the final products. FTIR absorption peaks shown in Fig.4 for the samples show positive agreement when compared with data in infrared spectra of inorganic compounds. The peaks of pure TiO_2 were observed at 609, 1130 and 1409 cm^{-1} whereas the peaks of TiO_2-Ag were 1335 and 2360 cm^{-1}.

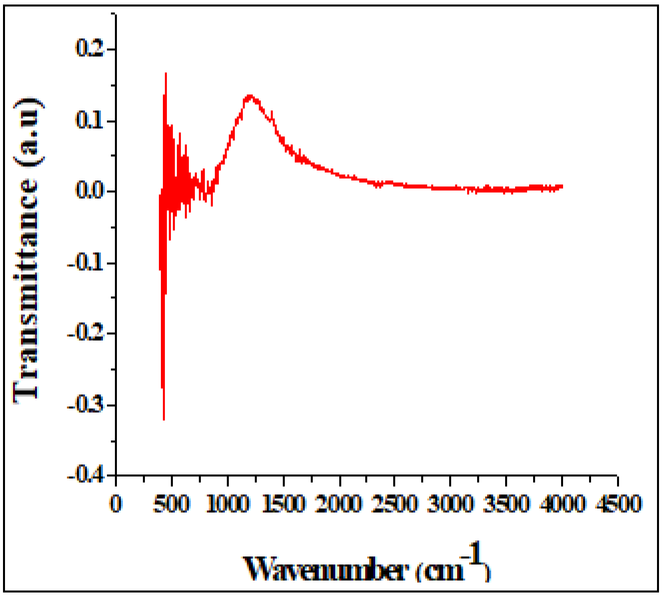

Figure 4: FTIR spectrum of the sensing element TA-20 annealed at 700^{0}C

2. Results and Discussion

Resistance of the sample pellet T-20 has been measured after each time of annealing during controlled exposure to humidity in the range of 5% to 95%. Variation of resistance with change in relative humidity at temperatures 500°C, 600°C and 700°C of sample T-20.

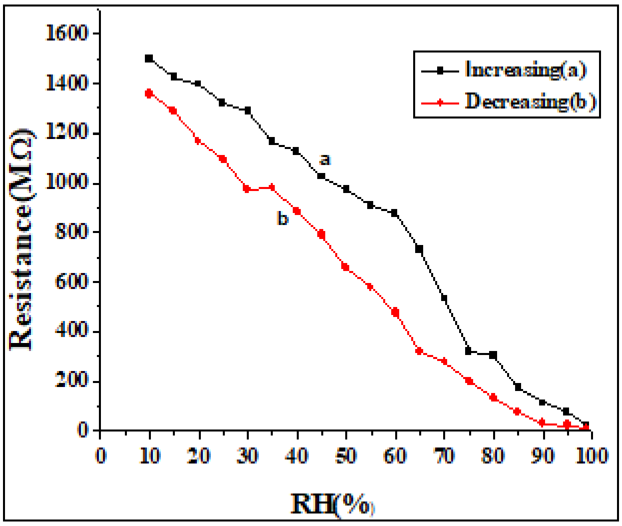

Figure 5: Hysteresis graph for the sensing element TA-20 annealed at 500^0C

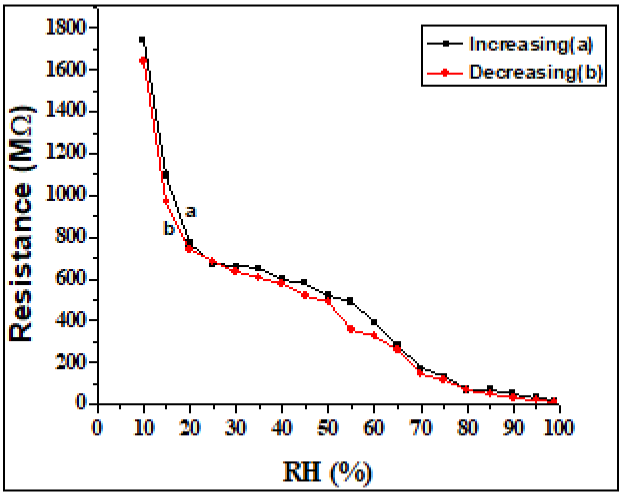

Figure 6: Hysteresis graph for the sensing element TA-20 annealed at 600^0C

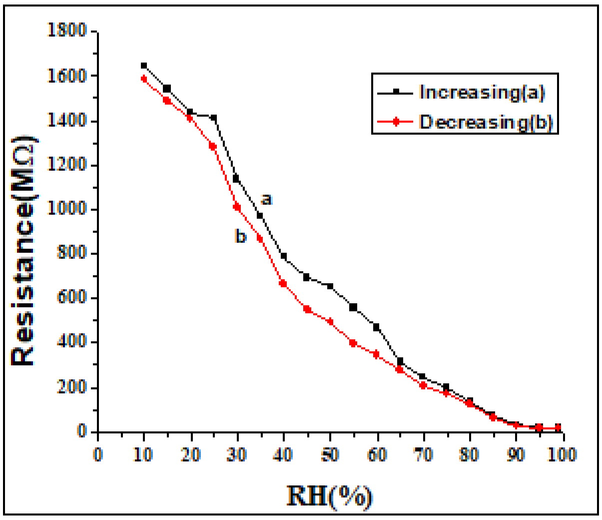

Figure 7: Hysteresis graph for the sensing element TA-20 annealed at 700^0C

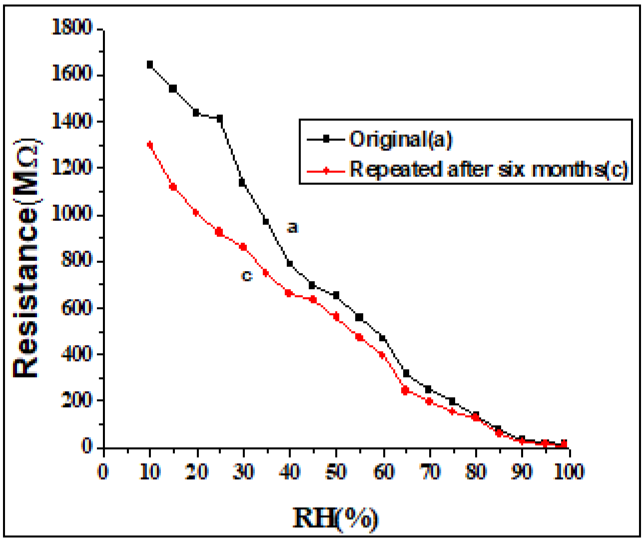

Figure 8: Repeatability graph for six months at sensing element TA-20 annealed at 700 ^{0}C

References

[1] Kulwicki B.M. 'Humidity Sensors' J.Am.Ceram.Soc.74 (1991) p.697-708.

[2] Mistry Kalyan Kumar, Saha Debdulal, Sen Gupta Kamalendu, 'Sol-Gel Proceed Al_2O_3 Thick Film Template as Sensitive Trace Moisture Sensor, Sen & Act.B 106(2005) p.258-262.

[3] Kummer Adrian M, Hierlemann Andreas, 'Configurable Electrodes for Capacitance Type Sensors and Chemical Sensors' IEEE Sen. Journal 6(2006) p.3-10.

[4] Bayhan M, Hashemi T, Brinkman A.W, 'Sintering and Humidity Sensitive Behaviour of the $ZnCr_2O_4$-K_2CrO_4 Ceramic System, J Mater. Sci.32 (1997) p.6619-6623.

[5] Traversa E, 'Ceramic Sensors for Humidity Detection, The State of The Art and Future Development', Sen.Act.B 23(1995) p.135-156.

[6] Yeh Y.C., Tseng T.Y., Cheng D.A., 'Electrical Properties of TiO_2 Porous Ceramic Humidity Sensors' J. Am.Ceram.Soc. 73 (1990) p.1992-1998.

[7] Wu L., Wu C.C.Wu M.M, 'Humidity Sensitive SrO_2 Ceramics', J. Electron mater. 19(1990) p.197-200.

[8] Nitta T., Terrada Z., Hayakawa S., 'Humidity Sensitive Electrical Conduction of $MgCr_2O_4$-TiO_2 Porous Ceramics' J. Am. Ceram. Soc. 63(1980) p.295-299.

[9] Chachulski B, Gebicki J, 'Properties of A Polyethyleamine Based Sensor for Measuring Medium and High Relative Humidity' Meas. Sci.Technol. 17 (2006) p.12-16.

[10] Yadav B.C, Pandey N.K., Srivastav Amit K, Sharma Preeti, 'Optical Humidity Sensors Based On Titania Films Fabricated By Sol-Gel And Thermal Evaporation, J.Measurment Science and Technology, vol.18, p.260-264, 2007.

[11] Pandey N.K., Tripathi Anupam, Tiwari Karunesh, Roy Akash, Rai Amit "Humidity sensing studies of WO_3 mixed with ZnO and TiO_2 powders" SENSORS 13 Proc. Univ. of Pune, Pune March 3-5,2008

[12] Parvatikar N, Jain Shilpa, Bhorasker S.V., 'Electrical and Humidity Sensitive Properties of Polyaniline/WO_3 Composites', Sens. and Act. B, 114 (2006) p.599-603.