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Contents

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ISSN 1726-5479

Research Articles

Design and Fabrication of Micromachined Absolute Micro Pressure Sensor
P. A. Alvi, J. Akhtar, K. M. Lal, S. A. H. Naqvi and A. Azam 1

A Micromechanical Sensor of Temperature Based on Surface Plasmons Resonance
Juriy Hastanin, Yvon Renotte, Karl Fleury-Frenette, Serge Habraken 8

Recent Advances in Lactate Estimation and Lactate Sensors for Diagnosis of Diseases
Suman and Ashok Kumar.. 18

Sensitivity Evaluation of a Love Wave Sensor with Multi-guiding-layer Structure for Biochemical Application, *Wen Wang, Shitang He* 32

Morphological and Humidity Sensing Studies Of WO3 Mixed With ZnO And TiO2 Powders
N. K. Pandey, Anupam Tripathi, Karunesh Tiwari, Akash Roy, Amit Rai,
Priyanka Awasthi, Aradhana Mishra, Alok Kumar 42

A Bioelectrical Impedance Analysis Device for Monitoring Haemoglobin Status in Dengue Patients, *Herlina Abdul Rahim, Fatimah Ibrahim, Mohd Nasir Taib And Ruzairi Abdul Rahim* 47

Studies on Gas Sensing Performance of Pure and Li2O-modified CdIn2O4Thick Film Resistors, *L. A. Patil, M. D. Mahanubhav* 56

Benzene and Toluene Vapor Sensing Properties of Sr(II)-added Barium Aluminate Spinel Composites, *B. Jeyaraj, L. John Kennedy, G. Sekaran and J. Judith Vijaya.* 68

Direct Monitoring and Control of Transformer Temperature in Order to Avoid its Breakdown Using FOS, *Deepika Yadav, A. K. Nadir and Pragati Kapoor* 81

Multi Channels PWM Controller for Thermoelectric Cooler Using a Programmable Logic Device and Lab-Windows CVI, *Eli Flaxer* 93

Study of A Modified AC Bridge Technique for Loss Angle Measurement of a Dielectric Material, *S. C. Bera and D. N. Kole* 104

Analysis of Programmable Voltage Source Under Power Supply Interference
Sheroz Khan, Salami Femi Abdulazeez, Lawal Wahab Adetunji... 112

Assessment of Structural Behavior of Non-corroded and Corroded RCC Beams Using Finite Element Method, *Anand Parande, P. Dhayalan, M. S. Karthikeyan, K. Kumar and N. Palaniswamy*.. 120

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

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Morphological and Humidity Sensing Studies of WO_3 Mixed with ZnO and TiO_2 Powders

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Abstract: This paper reports resistive type humidity sensing properties of composite powder of WO_3, ZnO and TiO_2 taken in the ratio of 8:2:1. Tungsten oxide powder has been obtained by oxidizing Tungsten powder (Lobachemie, 99 % pure) at 600 ^{0}C. 250 mg of ZnO (qualigens, 99% pure) and 125 mg of TiO_2 (qualigens, 98% pure) have been mixed with 1 gram of WO_3. Pellet of this powder mixture has been made at pressure of 3 tones for half an hour. The pellet has been annealed at temperatures of 300 ^{0}C, 400 ^{0}C and 500 ^{0}C. Humidity sensing application of pellet has been studied in a specially designed chamber. Standard solution of potassium sulphate has been used as humidifier and potassium hydroxide as de-humidifier. Variation in resistances has been noted using Sinometre (MΩ range,VC 9808). Relative humidity is measured using standard hygrometer (Huger, Germany). It has been observed that as relative humidity increases, there is decrease in the resistance of the pellet. After annealing of sample at each temperature, it has been exposed to humidity in the chamber. The mean sensitivity of the pellet is calculated for each annealing temperature. It has been observed that as annealing temperature increases from 300 ^{0}C to 500 ^{0}C, mean sensitivity increases. This composite material carries a good scope for the development of resistive type humidity sensor. *Copyright © 2008 IFSA.*

Keywords: WO_3, ZnO, Hygrometer, Sinometre, Annealing, TiO_2

1. Introduction

Various materials have been studied and used as sensing elements in humidity measurement applications [1-3]. Some metal oxides such as TiO_2, SnO_2, ZnO, Cr_2O_3 and WO_3 are semi-conducting materials among which WO_3 has been studied extensively because of its electro-chromic applications. Tungsten oxide and binary systems of tungsten oxide with other metal oxides are also being studied for their gas and humidity sensing applications. Sensors of great variety of application have been developed, numerous materials have been utilized for humidity sensing of which the metal oxides that are physically and chemically stable, have been extensively used at both room and elevated temperature[4-9]. In general, metal oxides have good chemical and thermal stability. Sensors based on change in resistance and capacitance are preferred. In this paper we report the resistive type humidity sensing studies of WO_3 mixed with ZnO and TiO_2 Powder.

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

$$\Delta S = \Delta R / R(\Delta \text{ RH } \%) \quad (1)$$

2. Experimental Procedure

The starting material is Tungsten powder. When tungsten powder is annealed at temperature 600 ^{0}C for three hours it gets converted into tungsten trioxide. Our sample has been prepared by pressing powder WO_3, ZnO and TiO_2 taken in the weight percent ratio 8:2:1, under a load of 3 tones up to half an hour. The pellet so formed has been annealed in an electric furnace at temperature 300 ^{0}C, 400 ^{0}C and 500 ^{0}C for three hours and after each time of annealing it has been exposed to humidity in the specially designed experimental setup [10-11]. Relative humidity chamber consists of sample holder capable of holding the sample in the form of pellet. The sample pellet has been fitted in this holder and kept in the chamber. The holder carries two copper probes as well connected to a Sino metre used for electrical resistance measurement. Resistance of the sample pellet has been measured after each time of annealing during controlled exposure to humidity in the range of 5 % to 85 %.

3. Results and Discussion

The decrease in resistance or increase in conductivity with increasing humidity can be attributed to the mobility of tungsten oxide ions which are loosely attached to the Vander Walls forces of attraction. Adsorption of water makes the material more p-type in nature i.e. the whole concentration is increased by donation of the lone pair from the conducting complex towards the WO_3 water molecules [12]. Thus the partial charge transfer process of conducting species with that of water molecules results in decrease in resistivity.

Variations of resistance with change in relative humidity are shown in Fig.1, 2 and 3. Fig.1 shows the result of sensing element annealed at 300^{0}C. This result shows that as humidity increases from 5 to 20 RH%, resistance of sensing element decreases by 37%. The average specific sensitivity in this range is 0.016.

Fig.2 shows the result of the same sensing element annealed at 400^{0}C. This graph shows that as humidity increases from 5 to 20 RH%, resistance of sensing element decreases by 40%. The average specific sensitivity in this range is 0.016.

Fig.3 shows results for the same sensing element annealed at 500^{0}C. This result shows that as humidity increases from 5 to 20 RH%, resistance of sensing element decreases by 80%. The average specific sensitivity is 0.031.

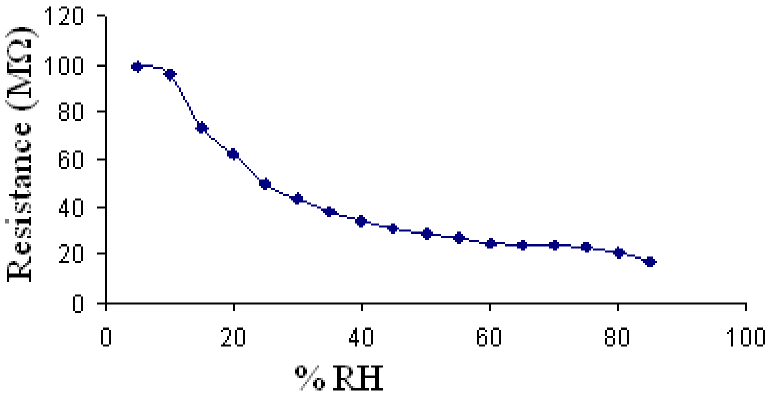

Fig. 1. Variation of Resistance with Change in %RH for sensing element annealed at 300^0C.

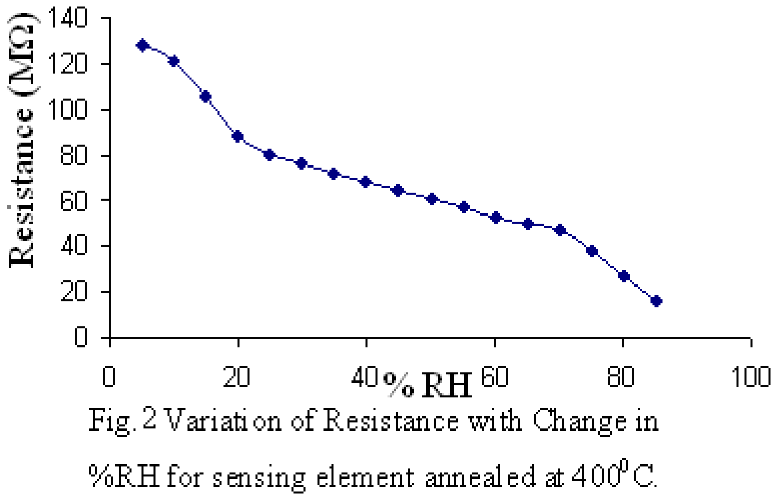

Fig. 2. Variation of Resistance with Change in %RH for sensing element annealed at 400^0C.

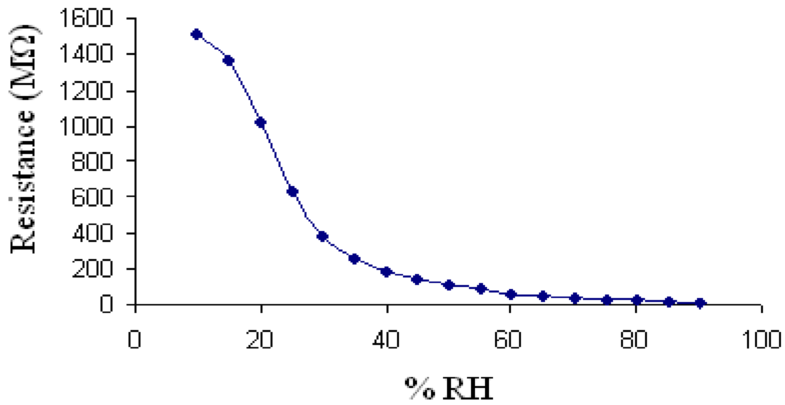

Fig. 3. Variation of Resistance with Change in %RH for sensing element annealed at 500^0C.

Thus increase in annealing temperature results in increase in sensitivity.

These observations are shown in Table 1.

Table 1. Annealing temperature vs. relative humidity and sensitivity

Temperature (^0C)	RH (%)	Specific Sensitivity	Mean Sensitivity
300	5 to 20	0.020	0.016
	20 to 40	0.022	
	40 to 80	0.010	
400	5 to 20	0.021	0.016
	20 to 40	0.011	
	40 to 80	0.015	
500	10 to 25	0.039	0.031
	25 to 60	0.026	
	60 to 80	0.030	

SEM image of the sample given in Figs.4 and 5 are on micro scale. Fig.4 is the SEM image at low magnification (7.19 Kx) whereas Fig.5 is at high magnification (17.41Kx). SEM images reveal that WO_3 composites nanoparticles combine with adhesive glass particles to form mud particles like clusters leaving spaces as pores.

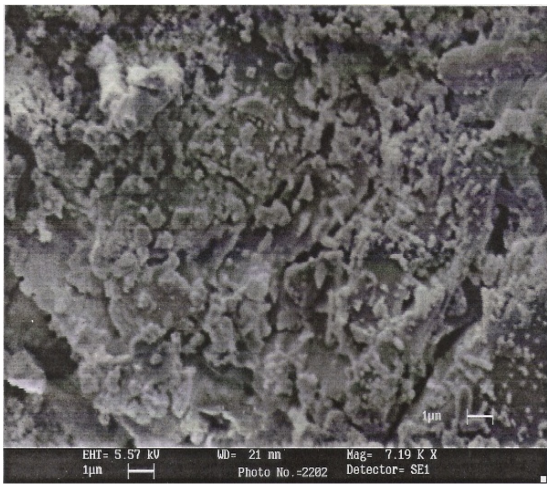

Fig. 4. The SEM image at low magnification (7.19 Kx).

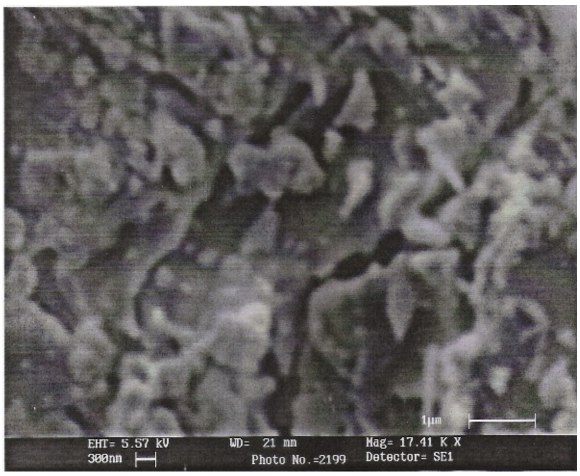

Fig. 5. The SEM image at high magnification (17.41Kx).

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Guide for Contributors

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