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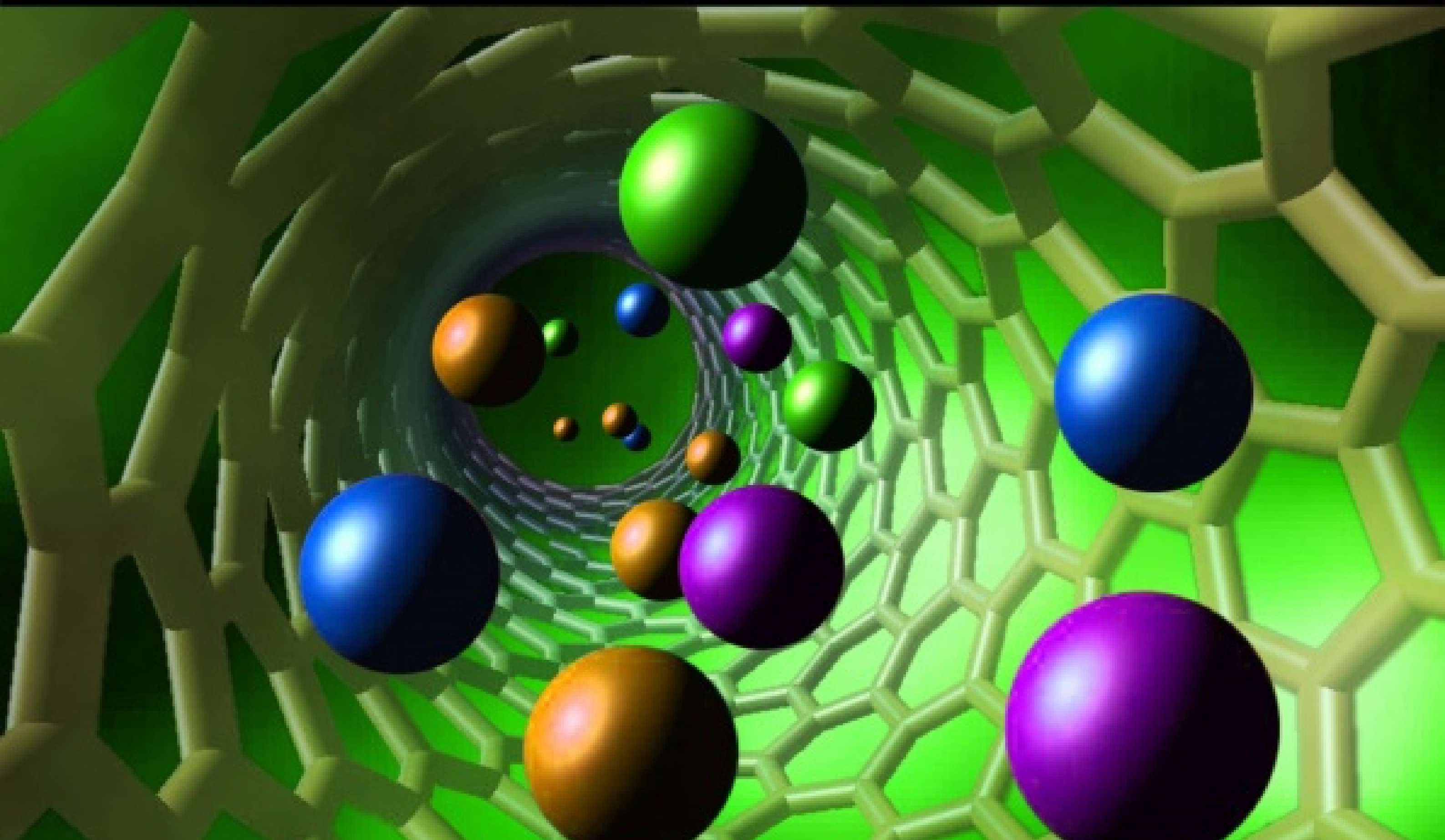

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Contents

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Humidity Sensing Behaviour of Niobium Oxide: Primitive Study

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Abstract: This paper reports the characterization and humidity sensing properties of niobium oxide. For this purpose, pellet of NbO has been made by using hydraulic-pressing machine (KBR Press, Germany) at pressure 30 MPa. This pellet is used as sensing element and thermally annealed at different temperatures 200, 400 and 600°C successively. After each time of annealing this sensing element has been put within a specially designed conductivity holder and exposed to humidity inside a controlled humidity chamber. Variations in resistivity with relative humidity have been observed. Sensitivity of sensor has been calculated at different temperatures. Characterization of sensing material has been done. Effect of temperatures on characterization has also been studied. During thermal annealing it is found that weight loss of sensing material occurs. Sensor is suitable for entire range of RH. *Copyright © 2007 IFSA.*

Keywords: Humidity sensor, Ceramic, Sensitivity and resistivity

1. Introduction

Air around us has some content of water vapour, it is commonly known as humidity. It plays an important role in human life in many ways. Water since present in all living organisms from simplest to the most complex like human being drastically influenced their life and working efficiency. The temperature of human body is controlled at skin by perspiration and subsequent evaporation strongly depends on environmental temperature and humidity. The presence of water in the atmosphere strongly affects the amount of infrared energy penetrating in the air hence water vapor acts as an infrared shield for earth. Thus humidity plays very important role in human life. Hence control and measurement of humidity is quite necessary. In this paper we have studied humidity sensing properties of niobium oxide which is a ceramic material and appears as white crystals or powder. It is hard and brittle. Niobium oxide is easily available at lower cost. It has stable electrical parameters [1] and it shows various useful properties [2-9]. Capacitors made by this material show various need full features such as it exhibits lead free systems [10], no piezo effect/ microphonic effect [11], lower weight, lower ESR at higher temperatures. Because of no piezo effect, it can be used in audio-video application. NbO capacitors are able to absorb higher load stresses. Also the films of niobium oxide work as humidity sensor [12]. Therefore in this paper, we have studied characterization and humidity sensing properties of niobium oxide bulk material. Sensitivity of sensing element at different temperatures has also been studied.

2. Preparation of Sensing Element

After vigorous grinding of NbO (800mg) (Johnson & Mathey, London) for 4 hours in mortar with pestle, powder form of NbO has been obtained. The pellet of this powder has been made under pressure of 30MPa at room temperature with the help of hydraulic pressing machine (KBR Press, Germany). This pellet has been thermally annealed at temperatures 200ºC, 400ºC and 600ºC respectively. After annealing, this pellet is used as sensing element.

3. Characterization

3.1. SEM Studies

The morphology of sensing material in the form of pellet was investigated with a Scanning Electron Microscope. Fig.1 reveals SEM of NbO in the form of pellet at room temperature. Annealing effects on morphologies of NbO in the form of pellets have also been studied at temperatures 200ºC, 400ºC and 600ºC respectively. Figs. 2, 3 and 4(a) show Scanning Electron Micrographs of NbO in the form of pellet at 200ºC, 400ºC and 600ºC respectively. Fig. 4(b) shows SEM of cross-sectional view of sensing element in the form of pellet at 600ºC. From these micrographs it is observed that as annealing temperature increases pore size between the particles of NbO increases and material becomes highly porous at temperature 600ºC.

3.2. Study of Percentage Weight Loss

For the measurement of percentage weight loss of the sample with annealing temperatures, 300 mg NbO powder has been taken within a weighing bottle and put it inside an electrical furnace and heated at temperatures 100°C, 200°C, 400°C and 600°C respectively for 1 hour. After each time of heating, percentage variations in weight of sensing material with annealing temperatures have been recorded and it is plotted in Fig.5. This shows that as annealing temperature increases sensing material oxidizes and weight loss occurs [13]. Maximum weight loss is found 22.67% in the range of temperature from 400-600ºC.

Principle of Sensing Mechanism

When sensing material comes in to contact with the water vapour /moisture, adsorption takes place and this phenomenon is totally responsible for modulations in conductivity of sensing material. As sensing material is porous, it will provide more surfaces for adsorption. Also NbO has electron vacancies so they attract H^+ ions dissociated by H_2O molecules. Further physisorption of water molecules takes place then after word capillary condensations occur. Overall the conduction is due to protonation and deprotonation of surface hydrolysis [14].

Sensitivity of humidity sensor has been defined as the change in resistivity (Δρ) of sensing element per unit change in relative humidity (RH%). Variations in resistivity with the variations in RH% for the sensing element at room temperature and at 200°C, 400°C and 600°C have been studied.

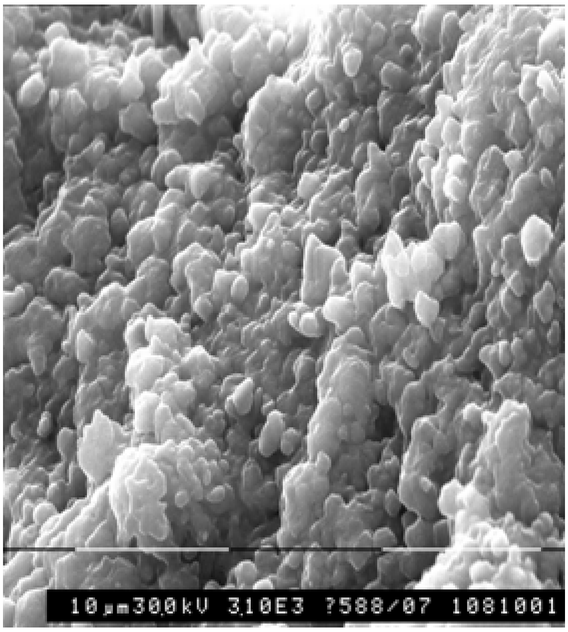

Fig. 1. Scanning Electron Micrograph of NbO at room temperature.

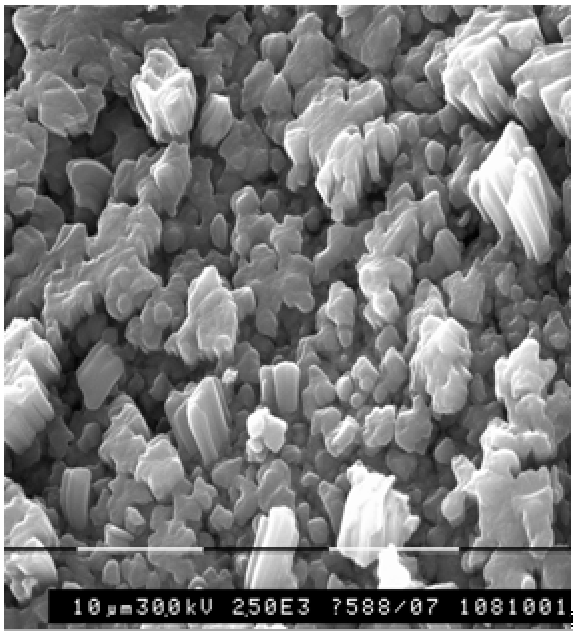

Fig. 2. Scanning Electron Micrograph of NbO at temperature 200ºC.

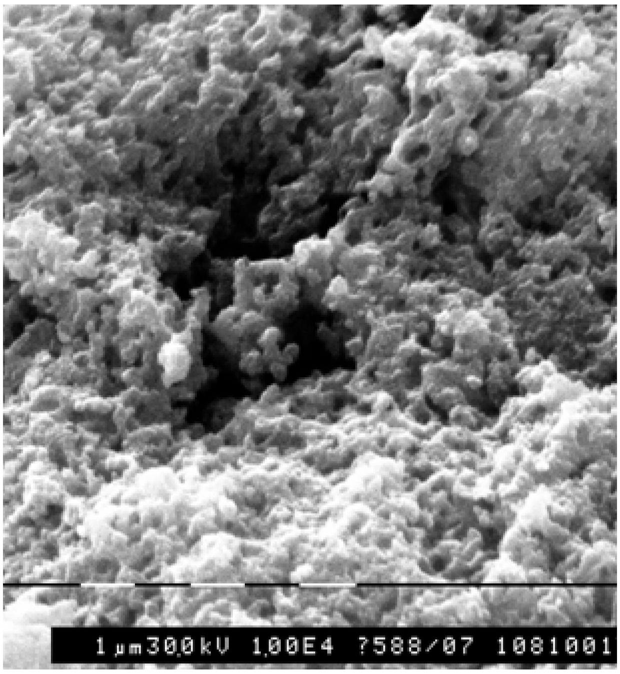

Fig. 3. Scanning Electron Micrographn of NbO at temperature 400ºC.

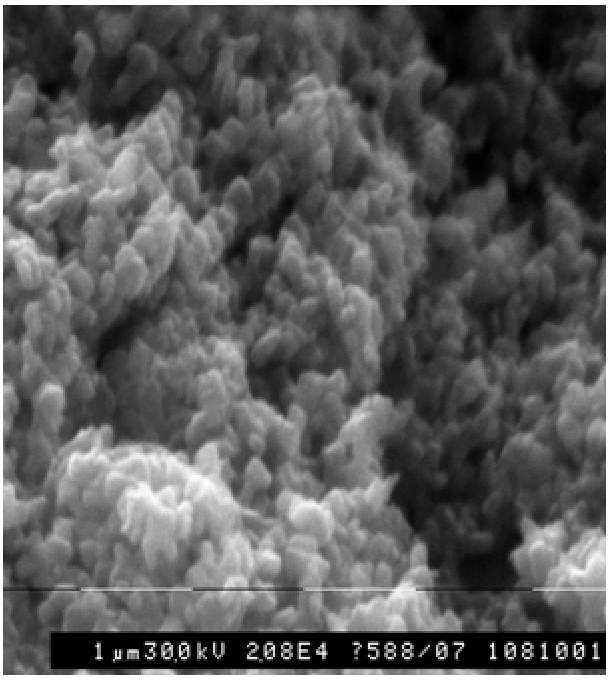

Fig. 4(a). Scanning Electron Micrograph of NbO at temperature 600ºC.

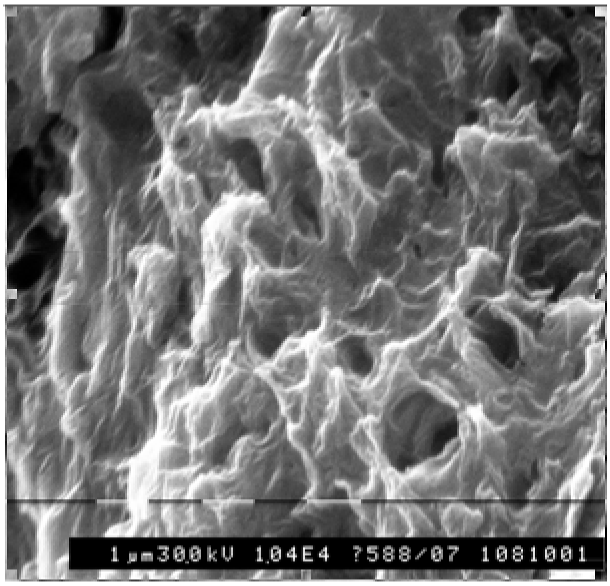

Fig. 4(b). Scanning Electron Micrograph of cross-section of sensing element at temperature 600ºC.

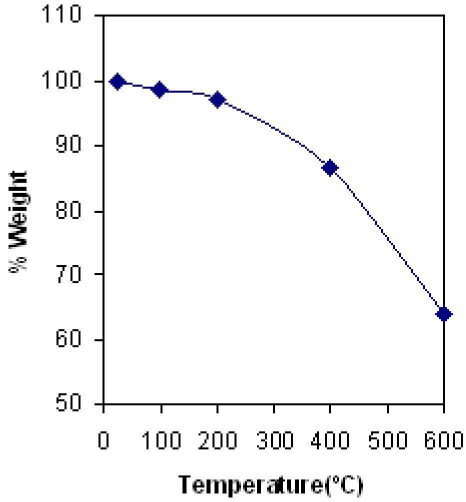

Fig. 5. The variations in %weight of NbO powder with annealing temperatures.

Experimental Details

A controlled humidity chamber has been designed [15]. Potassium hydroxide is used as dehumidifier and potassium sulphate is used as humidifier. Variations in resistivity have been noted by using a digital multimeter (VC 9808, India). Relative humidity is measured using standard hygrometer associated with thermometer (Huger, Germany) [16].

The humidifier/dehumidifier is kept in a dish over a stand. In the process, the temperature of the chamber remains same throughout the experiment and it is dehumidified up to 5% RH by using the dehumidifier potassium hydroxide. The least count of hygrometer used here is 1% RH and that of the thermometer 1°C. Pellet of NbO powder has been made by using hydraulic pressing machine (KBR press, Germany). This pellet has been put within a conductivity-measuring holder and then it is exposed to humidity inside a specially designed controlled humidity chamber. It has been observed that as Relative Humidity (RH %) inside the chamber increases, resistance of pellet decreases for the entire range of humidity i.e. from 5% to 95%. Further the pellet, which acts as sensing material, has been annealed for 3 hours at temperatures 200°C, 400°C and 600°C in an electric furnace (Ambassador, India) successively. After each time of annealing, the pellet is exposed to humidity and variations in resistivity with relative humidity have been observed.

Results and Discussion

Variations in resistivity with the variations in RH% for the sensing element of NbO prepared at room temperature 25˚C and annealed at 200˚C, 400˚C and 600˚C are shown in Fig. 6. The plots for sensor annealed at various temperatures show similar nature at different range of RH%. Curve for room temperature shows that as RH increases, resistivity decreases normally from 5 to 95% RH. Curves for annealing temperature θ = 200˚C show that as RH increases, resistivity decreases slowly from 5 to 40% RH and shows highest sensitivity in this range. After that it decreases slowly from 40 to 95% RH. Curve for annealing temperature θ = 400˚C show that as RH increases, resistivity decreases rapidly from 5 to 50% RH and shows highest sensitivity in this range. After that it decreases normally from 50 to 95%RH.

Curve for annealing temperature θ = 600˚C shows that as RH increases, resistivity decreases drastically for entire range of RH as compared to other temperatures and shows highest average sensitivity (202.44x10^3Ω-m/RH%). The variations in average values of sensitivity of sensor against different annealing temperatures at 10%RH are shown in Fig. 7.

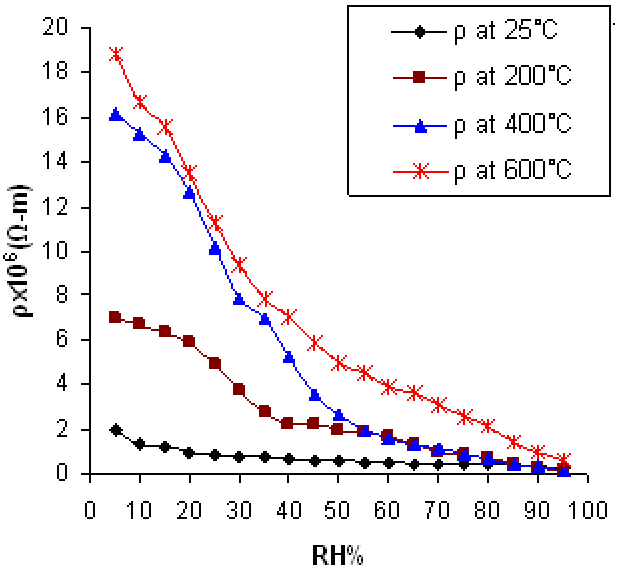

Fig. 6. Variations in resistivity (Ω-m) with the variations in RH% for the sensing element of NbO heated at 25˚C, 200˚C, 400˚C and 600˚C.

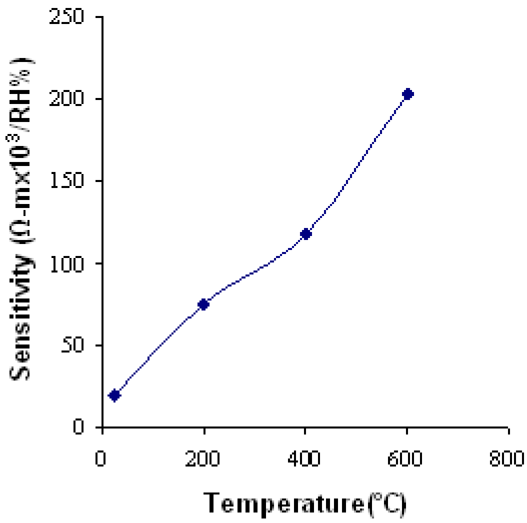

Fig. 7. Variations of Average Sensitivity in Ω-m/RH% against annealing temperatures of sensing element.

Conclusion

It is concluded that NbO in bulk behaves like a humidity sensor and if particle size can be reduced by using some synthesis techniques, surface area of particles will increase, resulting enhancement of adsorption/desorption powers. Still work is under investigation. Also the annealing temperatures affect the morphologies of sensing element, which is very important for designing humidity sensor. Thus humidity sensor reported here based on electrical resistivity is easy to fabricate, cheap and can be used for measuring a wide range of relative humidity.

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Sensors & Transducers Journal (ISSN 1726- 5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

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