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The Interaction of the Dipole Moment of The Water Molecule with the Interface States of the Cuprous Oxide/Cupric Oxide Junction

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Abstract

An Au/CuO/Cu_2O/Cu sandwich structure has been obtained by growing successive Cu_2O and CuO layers on a Cu sheet. A gold metal contact was formed CuO side at pressure of 1×10^{-6} Torr. Current-voltage characteristics and capacitance of the system were seen to change over a great extent due to the presence of humidity. The effect of the humidity on Au/CuO/Cu_2O/Cu is explored through the effect of water's dipole moment.

Introduction

CuO was first used as a humidity sensor by Ming [1] during his studies of thick films. However, there have been a number of works on humidity sensing structures containing CuO in their construction such as the CuO/ZnO thin film heterojunction [1-7]. These works indicate that oxides of copper might be useful for the construction of humidity sensors, and thus their properties need further study.

For this purpose a structure of Au/CuO/Cu_2O/Cu sandwich structure was produced and both its current-voltage characteristics and capacitance values were measured at various humidities. The next section is a description of experimental details and we discuss the results in section 3.

Experiment

We started by obtaining a very clean copper surface and this was done by first chemically cleaning the sample using deionized water , the acetone(CH_3COCH_3) and a mixture

of deionized water and nitric acid(50% H_2O+50% HNO_3) in standard way. The sample , with dimensions 10mm×10mm and 200 μm thickness , was put in the oven [4] for 10 minutes at 700 °C with dry hydrogen gas passing over it. Cuprous oxide layer was grown by hanging the sample in the furnace at 1040°C temperature for 5 minutes and then cooled to room temperature. The sample was then annealed at 600°C then cooled outside the oven in the room [7]. Afterwards an n/p junction was formed within the Cu_2O layer by quenching it in deionized water. The formed Cu_2O was 32 μm thick and

CuO layer's thickness was 1 μm. We proceeded by taking one side of the sample(CuO/Cu_2O/Cu) and fixing it on a fiber holder by araldite, and then a lead was soldered to the copper side. A gold Ohmic contact was created on the CuO side at a vacuum of 1×10^{-6} Torr.(Fig.1).

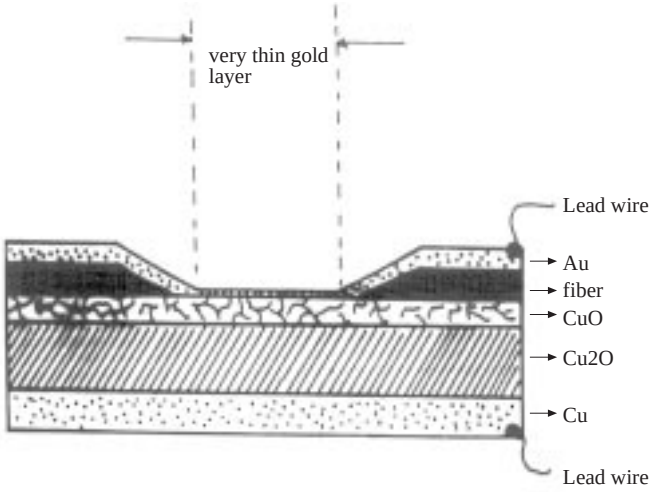

Figure 1. The structure of Au/CuO/Cu_2O/Cu device.

Result and discussion

The types of Cu_2O and CuO were determined both by four probe method and by galvanometric method. The Cu_2O samples were p-type and CuO n-type consistent with the literature [8]. The current-voltage characteristics of the quenched Au/CuO/Cu_2O/Cu structure (Fig.2) showed that an n/p junction had been formed within the Cu_2O layer. To check this conclusion we produced two structures , one Au/CuO(n-type)/Cu and other Au/Cu_2O(quenched)/Cu from which, it was seen that only the latter had the diode behavior. From the polarity of the applied voltage we concluded with the behavior shown in Fig.6 that the p-type portion of the n/p junction was located near the copper and n-type region near the CuO layer. Under increasing humidity we observed a large increase in the forward current , while the reverse current decreased (Figs. 3 ,4 and 5).

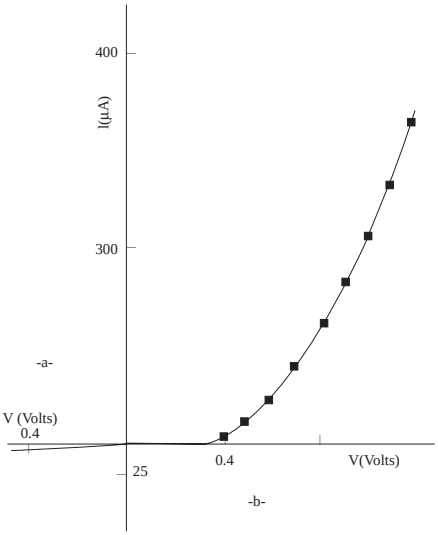

Figure 2. Current-voltage characteristic of Au/CuO/Cu_2O/Cu structure at 20°C for a constant humidity, a) reverse bias; (+)Au/CuO/Cu_2O/Cu(-), b) (-)Au/CuO/Cu_2O/Cu(+) ; forward bias.

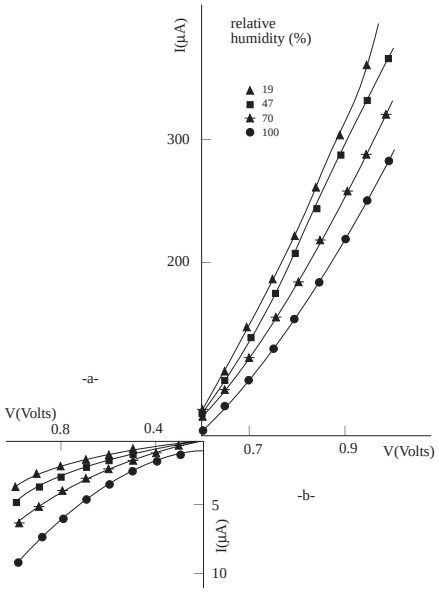

Figure 3. Current-voltage characteristic of Au/CuO/Cu_2O/Cu structure versus relative humidity at 20°C, a) reverse bias, b) forward bias.

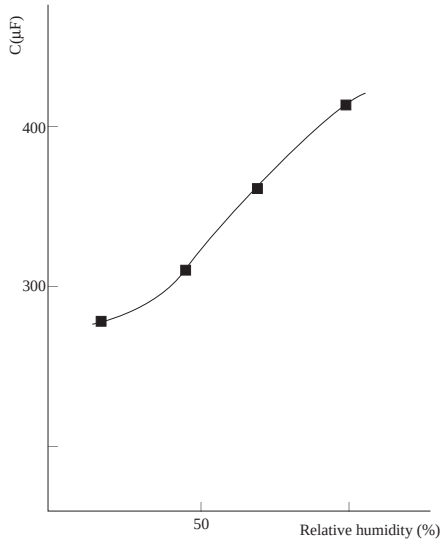

Figure 4. Current-relative humidity characteristic of Au/CuO/Cu_2O/Cu structure at 20°C for 1.0 Volt forward bias.

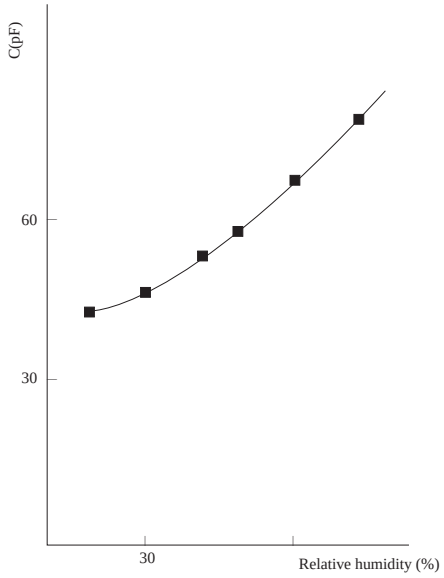

Figure 5. Capacitance of Au/CuO/Cu_2O/Cu structure at 1 KHz versus relative humidity.

The effect of humidity on the Au/CuO/Cu_2O/Cu sandwich structure can be explained by the help of an n/n heterojunction created by CuO with band gap of 2.0 eV. and Cu_2O with band gap 1.95 eV. at the CuO/Cu_2O interface [9-10]. As is seen from Figure 6 the CuO/Cu_2O interface contains an n/n heterojunction with a small diffusion barrier height. The pinholes in gold film and the grainy structure of the cupric oxide(CuO) allow the water molecules to diffuse into the n/n heterojunction which contains surface states. Dipole moment of the water molecules interacts with these interface states and alters the electrical potential profile in n/n heterojunction , resulting in the electrical charge distribution in depletion layer of the n/n heterojunction being rearranged. As a result the barrier height of n/n heterojunction is changed and the capacitance and current-voltage characteristics of the Au/CuO/Cu_2O/Cu sandwich structure are modified by the humidity [11]. The theoretical explanation of humidity effect on the interface states , as well as more intense measurements , will be carried out in our forthcoming work. The results will be published in a detailed paper later.

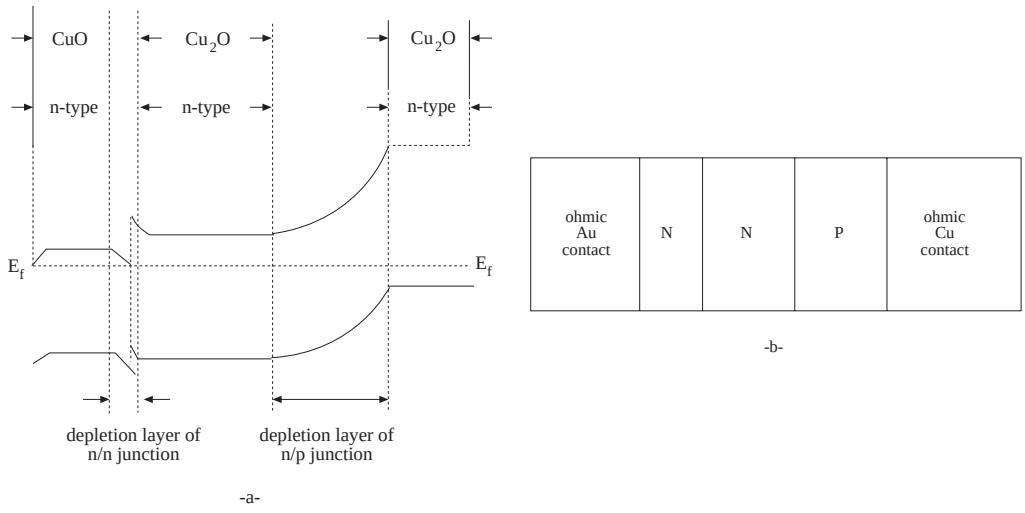

Figure 6. a) Energy band-diagram proposed for CuO/Cu_2O sandwich structure and b) represantation of Au/CuO/Cu_2O/Cu sandwich structure.

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