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CuO nanowire sensing at room temperature

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Abstract

CuO nanowires (NWs) based sensors were fabricated and characterized. Cuo NWs were synthesized by thermal oxidation and deposited onto gold electrodes. The sensing layer was morphologically characterized by scanning electron microscopy (SEM) and transmission electron microscopy (TEM) showing a monocrystalline structure for CuO NWs. At room temperature these sensors exhibited a non-linear I-V response and showed sensitivity to different concentrations of ethanol. Results are important for low cost and low power consumption gas sensor fabrication.

Key words: CuO nanowires, gas sensing, room temperature, low power consumption.

Introduction

Semiconductor sensors have been used to monitor gases based on their resistance change. In this regard, metallic oxide one-dimensional nanostructures have attracted researchers toward the development of sensors with high gas sensitivity and rapid response [1]. Thin-layer metallic oxide gas sensors show acceptable sensitivity within a range of 300 to 500ºC. This fact increases the fabrication complexity and the power consumption when they are heated. Recently, research has focused on developing sensors which can be operated at room temperature [2, 3].

CuO exhibits a p-type semiconducting behavior and can give rise to structures with different aspect ratios and shapes (NWs, nanoribbons and nanorods) depending on the synthesis routes. CuO NWs prepared by thermal oxidation have shown higher crystallinity and aspect ratios than those prepared with solution-based methods. The natural abundance of CuO as well as its low production cost makes it ideal for sensing applications [4].

In the present study, we describe the fabrication and characterization of a sensor based on CuO NWs grown by thermal oxidation. We also evaluate sensor sensitivity to ethanol at room temperature.

Experimental

CuO NW synthesis: Pieces of high purity Cu (30 mm x 10 mm x 0.10 mm) were washed in HCl 1.5 M for 1 min, rinsed using deionized water and ethanol, and then dried in air at 25ºC. The samples were heated to the thermal oxidation temperature (400ºC) for 2 hours under wet air (150 mL/min). The heating rate was fixed at 1.5ºC/min. The CuO NWs were separated from the Cu substrate by ultrasonic treatment and dispersed in 4 mL of isopropyl alcohol.

Sensor fabrication: Two electrodes (200-nm Au layer on 20-nm Ti) were fabricated via standard photolithography and lift-off processes onto a $Si\text{-}SiO_2$ substrate. A droplet (5 μl) of the CuO NWs dispersion was dropped between the electrodes and the isopropyl alcohol was allowed to evaporate. This procedure was repeated until a resistance level of KOhms was achieved.

Sensor characterization: The morphological characterization of the CuO NWs sensor film was performed using a Quanta 200 SEM (FEI, OR, USA). The crystallinity of the CuO NWs was determined by a CM 200 TEM (Philips, Amsterdam, The Netherlands). The electrical characterization of the sensor was performed at room temperature using a SMU Keithley 2612A (OH, USA). The current vs. voltage (I-V) curve

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in air and the gas sensing behavior in the presence of ethanol were measured. An airflow of 2 L/min was saturated on water or on different solutions of ethanol in water (20, 40, 60, 80 and 100 %) for 3 min.

Results and Discussion

Morphological characterization: SEM image of CuO NWs is shown in Fig. 1a. The synthesized NWs were 1 to 15 μm long and 80 to 170 nm wide. CuO NWs coating the Au electrodes separated by 5 μm are shown in Fig 1b. Monocrystalline structure of NWs is evidenced in Fig. 1c corresponding to the [1 0 1] zone axis.

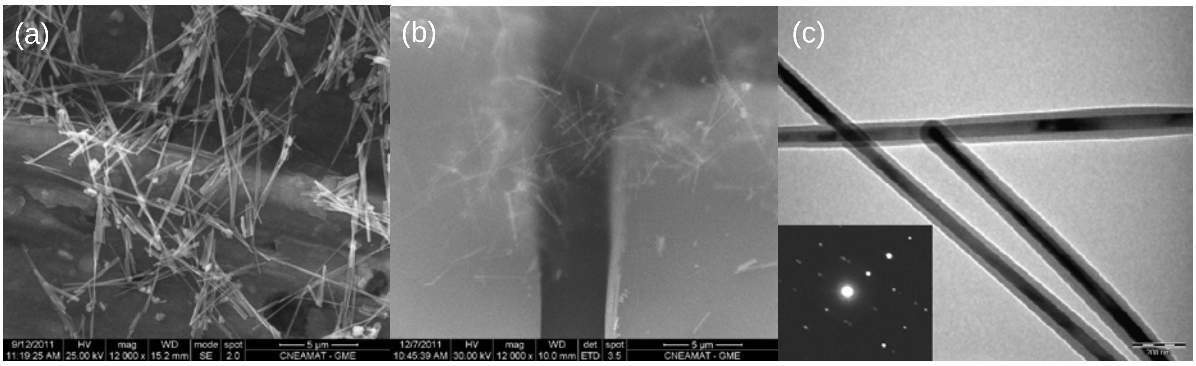

Fig. 1: SEM images: (a) Droplet of CuO NWs dispersion, (b) CuO NWs onto Au electrodes; (c) TEM image of CuO NWs, inset: SAD pattern.

Electrical characterization: The I-V measurements indicated that the fabricated sensor exhibits a non-linear response (Fig. 2). When analyzing the gas sensing behavior, a decrease of 15% with respect to the baseline was observed for 100% of ethanol. Fig. 3 shows decreasing resistance values as a function of the increase of ethanol concentration.

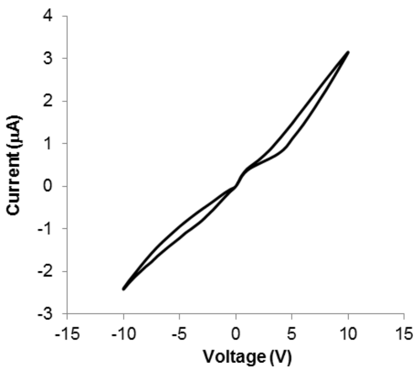

Fig. 2: I-V curve of the sensor in air.

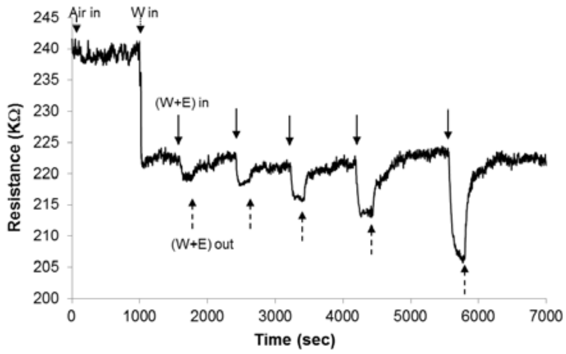

Figure 3: Gas sensing behavior for increasing concentrations of ethanol gas (W: Water, E: Ethanol; see the text).

Conclusion

A new sensor based on monocrystalline CuO NWs, which operates at room temperature, was developed. It shows a non-linear I-V response and sensitivity to different concentrations of ethanol. The fabrication simplicity and very low power consumption of this sensor would benefit sensor industry.

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