The Effect of Pt Decoration on the Gas Sensing Properties of Copper Oxide Nanorods [†]

Neslihan Sarıca *, Onur Alev and Zafer Ziya Öztürk

Department of Physics, Gebze Technical University, Kocaeli 41400, Turkey; onuralev@gtu.edu.tr (O.A.); zozturk@gtu.edu.tr (Z.Z.Ö.)

* Correspondence: nsarica@gmail.com; Tel.: +90-2626051324

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Abstract: Herein, copper oxide nanorods were hydrothermally synthesized on SiO₂ substrates with inter digital gold electrodes fabricated by photolithography method. This method offers the advantage of practical usage as a sensor device. Hydrothermal synthesis were carried out at 85 °C for 4 h. Fabricated nanorods were decorated with Pt for 30 s via magnetron sputtering system. SEM, XRD and EDX studies were performed to characterize the samples. Sensing properties of nanorods were tested with H₂, NO₂ and CO at 200 °C. Results showed that Pt decoration enhanced sensor response to H₂ while decreasing sensor response to NO₂ and CO.

Keywords: gas sensor; copper oxide; hydrothermal

1. Introduction

Semiconductor metal oxides take an important part as a sensing layer for gas sensor applications due to their superior properties such as selectivity and stability [1]. Moreover, sensing properties of metal oxides can be enhanced by tailoring the surface morphology, metal doping or loading [2]. Although p type metal oxides for gas sensor applications are very limited, p type copper oxide shows promising gas sensing properties [3] and deserves further investigation.

In this study, copper oxide nanorods were hydrothermally synthesized on IDE (inter digital electrode) precoated SiO₂ substrate. In order to examine the effect of Pt decoration on gas sensing properties of CuO nanorods, they were decorated with Pt via RF magnetron sputtering in argon atmosphere at 5.3×10^{-3} mbar. Pure Pt target was used to decorate CuO nanorods for 30 s under 75 W DC power. Gas sensing properties of pristine and decorated nanorods were tested against H₂, CO and NO₂ gases.

2. Experimental

2.1. Synthesis and Characterization of CuO Nanorods

Firstly, SiO₂ substrates were coated with gold IDE on its surface. Before hydrothermal synthesis, 10 mM ethanolic copper (2) acetate monohydrate (CH₃COO)₂Cu·H₂O solution was used to form seed layer by spin coating system instead of wetting. After seed layer formation these substrates were placed inside a Teflon beaker containing 25 mM copper nitrate trihydrate (Cu(NO₃)₂·3H₂O) and 25 mM hexamethylenetetramine aqueous solution at 85 °C for 4 h [4].

SEM (Philips XL 30 S), EDX and XRD (Philips 1820 X-Ray Diffractometer) were used to perform morphological and structural characterization respectively.

2.2. Sensor Measurements

Sensing measurements were performed in a 1 L homemade chamber under 200 sccm high purity dry air flow at 200 °C controlled by a Lakeshore 340 temperature controller. 0.05 V constant bias voltage was applied to samples and direct current was measured with Keithley 6517 A Electrometer/High Resistance Meter. When the steady state was obtained, samples were exposed to desired concentrations of H₂, NO₂ and CO controlled via multi gas controller device (MKS 647C).

Sensor responses of samples against reducing gases (H₂ and CO) and oxidizing gases (NO₂) were calculated according to the below equations respectively [3,5];

$$\text{Sensor Response} = (I_0 - I_g)/I_g$$

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I₀ represents the current of the baseline and I_g is the minimum or maximum current value of the sensor when the sample is exposed to reducing or oxidizing gases respectively.

3. Results and Discussions

Fabricated nanorods with very thin diameter are shown in Figure 1a. Peaks seen in XRD graph (Figure 1b) can be attributed to the monoclinic CuO phase [4]. EDX study on Pt decorated copper oxide nanorods confirms the presence of Pt (data not shown).

Figure 1. (a) SEM image of CuO nanorods; (b) XRD graph of CuO nanorods.

Gas sensing properties of pristine and decorated CuO nanorods were tested against 1000 ppm H₂, 20 ppm CO and 20 ppm NO₂. Dynamic response of pristine nanorods exposed to 1000 ppm H₂ is shown in Figure 2. According to the sensing results as illustrated in Figure 3, pristine nanorods show the highest sensor response to 1000 ppm H₂. It is also seen that sensitivity of pristine nanorods against 20 ppm NO₂ is higher than 20 ppm CO. In the case of Pt decoration, decorated nanorods show higher sensitivity to H₂ compared to the pristine one due to the chemical sensitization via spillover effect of Pt. On the other hand, sensor responses to NO₂ and CO decrease thus, it can be said that selectivity to H₂ is increased by Pt decoration. In addition to this result, sensor responses of pristine and decorated nanorods against NO₂ also increase with increasing concentrations of NO₂.

Figure 2. Dynamic sensor response of pristine CuO nanorods exposed to 1000 ppm H₂.

Figure 3. Sensor responses of pristine and decorated CuO nanorods againsts H₂, CO and NO₂.

4. Conclusions

In this study, copper oxide nanorods were directly grown on IDE coated SiO₂ substrates. In order to examine the effect of Pt decoration on sensitivity, nanorods were decorated with Pt for 30 s by RF magnetron sputtering. Sensing measurements of pristine and decorated nanorods showed that Pt decoration increased sensitivity to hydrogen while decreasing sensitivity to CO and NO₂. Thus, these positive effects of Pt decoration on nanorods provide a sensitive and selective H₂ gas sensors.

Author Contributions: Z.Z.Ö. designed the experiments; N.S. and O.A. performed the experiments; N.S. and O.A. analyzed the data; N.S. wrote the paper. All authors discussed the results and contributed to the final manuscript.

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