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Temperature-dependent NO_2 gas sensing study of hydrothermally prepared CuO nanoplatelets

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Abstract

Development of gas sensors operating at low temperature, <100 °C, utilizing *p*-type CuO nanoplatelets for indoor air quality monitoring with excellent response, high sensitivity and good reliability are highly desirable. Therefore, herein, the **A2-CuO**-based sensors, CuO sensing layer prepared for 12 hours at 120 °C, revealed a remarkable response of 697, sensitivity of 10.9 ppm^{-1} and speedy response time of 70 s towards 40 ppm NO_2 at 100 °C. An increased amount of point defects was observed when subject to photoluminescence studies at temperatures of 50 and 100 °C. The findings affirmed that such sensor response/sensitivity is dependent on the specific surface area and point defects and the average crystallite size.

Key words: Temperature study, NO_2 sensing, point defects, crystallite size, hydrothermal

Introduction

As *p*-type material, copper oxide (CuO) has received a lot of attention for its possible application as gas sensors.[1] The gas sensing capability of CuO is dependent on the operation temperature, showing selectivity towards gases including ethanol, carbon monoxide, NOx, propanol, ammonia and acetone have been reported by previous researchers.[2] A limited amount of cases have been reported for effective low temperature CuO gas sensors; cases include selectivity to ammonia and hydrogen sulfide gases.[3]

Herein, we investigate the influence of synthetic conditions, i.e. reaction temperature and time, point defects and crystallize size on the response, NO_2 sensitive CuO nanoplatelets at low operating temperatures ranging from 25 to 100 °C.

Experimental

In a typical procedure, a NaOH solution (30 mL of 1.0 M) a was added to a $Cu(NO_3)_2$ (12.5 mL, 0.5 M) solution before transferring it to an autoclave, where it was hydrothermally treated at 120 °C for 6 hours. The black product was collected and washed with distilled water and absolute ethanol, and finally dried at 100 °C for 24 h. The obtained powder were denoted as **A1-CuO**. The same procedure was repeated at 120 °C with products prepared (12 and 24 h) denoted as **A2-CuO** and **A3-CuO**. The materials were characterized by XRD, SEM, BET surface analysis, VSM and PL spectroscopy. Sensors were prepared by depositing a mixture of dispersed CuO powders with ethanol onto interdigitated electrodes, and subsequent drying at 100 ºC for 1 h. The gas sensing tests were carried out using a standard configuration for resistive sensor measurement, with Pt-interdigitated electrodes and a Pt-resistive-type heater printed onto an alumina substrate.

Results and Discussion

The XRD patterns show that all the peaks can be indexed into monoclinic CuO, (JCPDS: 48-1548), with no other peaks observed, which demonstrate the purity of the as-synthesized products. The morphology of the as-prepared CuO powder was confirmed to be nanoplatelets, as seen in the inserts of Figure 1. BET surface areas of 8.876 ± 0.054 and 3.800 ± 0.172 m^2/g was reported for **A2-CuO** and **B3-CuO** nanoplatelets. Initially, the gas sensing performance of the 12 as-prepared CuO nanoplatelets products was tested against the following test gases, CO, NO_2, NH_3, CH_4 and H_2S, at room temperature. The **A2-CuO** and **B3-CuO**-based sensors showed an increased response to NO_2 gas, thus further temperature-dependent 40 ppm NO_2 gas studies was conducted, as seen in Figure 1

(top). The **A2-CuO**-based sensor showed an increased sensitivity of 10.9 ppm^{-1} to NO_2 gas at 100 °C, 100 fold compared to room temperature analyses (see Figure 1, bottom).

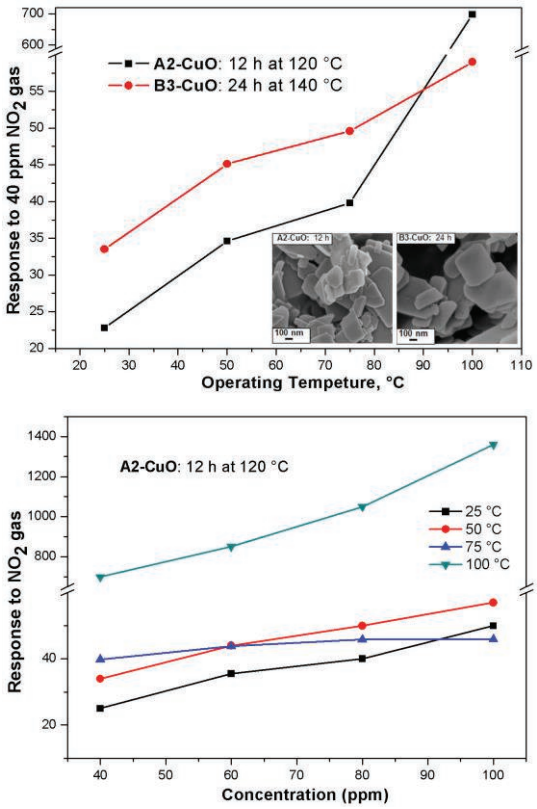

*Figure 1: Top: Gas sensing response to 40 ppm NO_2 at 25, 50, 75 and 100 °C, with SEM micrograph inserts. Bottom: Temperature-dependent NO_2 gas sensing study of **A2-CuO** based sensor.*

The higher NO_2 sensing performance of **A2-CuO** can be attributed to the larger surface area. However, to further justify the phenomena occurring on our **A2-CuO** sensing material; a photoluminescence spectroscopy study was conducted at 25, 50 and 100 °C, as depicted in Figure 2.

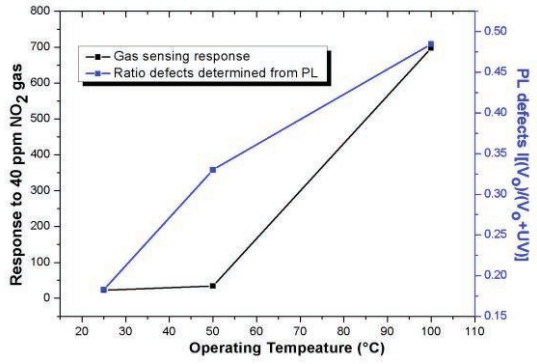

*Figure 2: NO_2 gas sensing response of **A2-CuO** based sensor and PL defects observed at 25, 50 and 75 °C.*

The point defects, such as oxygen vacancies of **A2-CuO** appeared to play a big role on the gas sensing response, especially at an elevated temperature of 100 °C. As previously reported, an increase in point defects can lead to an increase in gas sensing response.[4]Therefore, to compare the significance of the NO_2 gas sensing response found in this study and the possible influence of crystallite size on the gas sensing properties, the three highest responses at a gas concentration of 40 ppm NO_2 gas, was compared to previously reported work, as seen in Figure 2.[5]

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