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Low temperature gas sensing properties of Graphene Oxide/SnO₂ nanowires composite for H₂

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Abstract

In this work Graphene Oxide (GO) and SnO₂ nanowires (NWs) composite sensing performance were studied. Single crystal SnO₂ NWs were directly grown by thermal evaporation method and GO was successfully synthesized using modified Hummers method. RF magnetron sputtered Pt particles were used as a catalyst for the growth of SnO₂ NWs. Drop cast technique was used to deposited GO on top of the SnO₂ NWs. FE-SEM (LEO 1525) was used to investigate the morphology of SnO₂ NWs and GO. Fabricated sensors were tested towards various concentration of H₂ at different working temperatures. This GO/SnO₂ hybrid sensors show a reversible response to H₂ at low operating temperature.

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1. Introduction

Hydrogen is a well-known energy source that has the potentiality to reduce the problem of global energy demand. Unfortunately, H₂ is colorless and flavorless gas and can easily explode in air at concentration of only 4% and above [1]. It is important to detect H₂ at low temperature, enabling its use in a wide range of industrial

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applications.

Metal-oxide semiconductor (MOX) nanostructured, such as SnO₂, are the most interesting materials widely used for detection of gases, due to their high sensitivity, high stability and simple interface electronics [2]. However, their main disadvantage is the power consumption needed to reach high working temperature. GO have been considered as gas sensing material because of its high surface to volume ratio, and due to the functional groups present in the basal plane and edges that decrease the conduction and increase the sensitivity to gases. However, as widely known, GO is a high resistive material and it is important to reduce or combine with metal oxides to be used as chemical gas sensors [3].

In this work, nanowires of SnO₂ are combined with GO to form a heterojunction, for the detection of low concentration of H₂ at low temperatures.

2. Experimental

Alumina (99.9% purity, 2 mm x 2 mm, Kyocera, Japan) substrates were used to synthesize SnO₂ nanowires. Alumina substrates were ultrasonically cleaned for 15 minutes in acetone and dried with synthetic air. A thin layer of Pt catalyst was deposited on the alumina substrates by RF magnetron sputtering (75W argon plasma 5.5x10⁻³ mbar, room temperature).

2.1. SnO₂ nanowires growth by VLS technique

SnO₂ powder was placed into a tubular furnace and heated to a temperature of 1370 °C to promote evaporation of the powder. Moreover Pt-coated alumina substrates were placed into a tubular furnace for growth of SnO₂ nanowires. A pressure of 100 mbar was kept and argon gas flow of 100 SCCM was injected in the furnace to form vapors and to transport the vapors towards the alumina substrates in order to promote the growth of the nanowires.

2.2. Device fabrication and Graphene Oxide deposited on SnO₂ by drop cast method.

Platinum contacts and heater were deposited on the alumina substrates by DC magnetron sputtering. The prepared device was mounted on TO packages using electro-soldered gold wires.

GO was synthesized from natural graphite using modified Hummers method. Aqueous dispersions of GO at different concentrations were prepared to be deposited on top of SnO₂ NWs. GO powder was dissolved in pure water and stirred in 300rpm for 15 minutes in order to make homogeneous dispersion. Afterwards GO suspension was ultrasonicated for 15 minutes to reduce the size of GO flakes. GO solution (0.05 mg ml⁻¹) of 5 µl was dropped on a gold wire mounted device and dried in room temperature.

2.3. Gas sensing

The devices were mounted in the test chamber to investigate the electrical response of the sensors toward hydrogen gas in different working temperatures and at several concentrations.

Table 1. Working condition of gas sensing.

Chamber temperature	20 °C
Voltage applied for sensors	1V
Gas Flow	200 sccm
Working temperature	20-150 °C
Hydrogen concentration	20,50,100 ppm

3. Results

The morphology of SnO₂ and GO/SnO₂ NWs was investigated by FE-SEM. SEM measurement shows that the

SnO₂ NWs were grown on the Pt catalyst as dendritic tips (Fig. 1 (a)) and that SnO₂ NWs were covered by thin layer of GO sheet in hybrid GO/SnO₂ samples (Fig. 1 (b)).

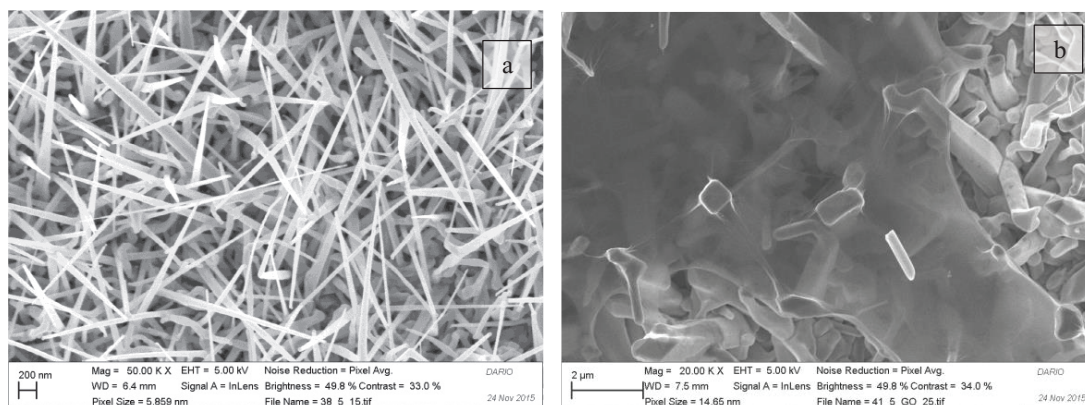


Figure 1: (a) The surface morphology of the SnO₂ nanowires (b) The surface morphology of the SnO₂ nanowires covered with GO

These sensors give better response toward hydrogen in the low temperature range and figure 2(a) shows a dynamic response to hydrogen at 100 °C. The gas sensing properties of the fabricated devices were investigated and optimal working temperature range for H₂ was identified (Figure 3 b). The optimal operation temperature is 50 °C and the response towards 100ppm of hydrogen resulted in about 24, with a response time several minutes. When operation temperature is increased to 100 °C the response is about 23 and response time is decreased more than 50%. Calibration curves are in-line with the power law.

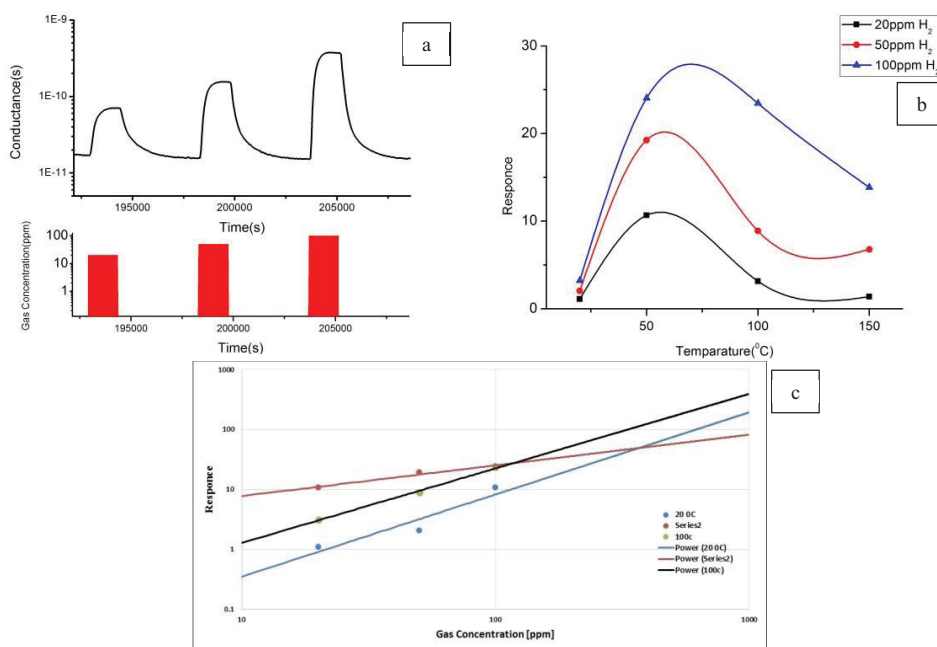


Figure 2: (a) Dynamic response of Go /SnO₂ NWs for hydrogen at 100 °C. (b) Response of GO/SnO₂ sensors towards hydrogen. (c) Calibration curve and power fitting of Go /SnO₂ °C with RH =50%

4. Conclusions

The detection of hydrogen is important now a today to facilitate its use in a varied range of industrial applications. SnO₂ NWs were grown on alumina substrate by thermal evaporation method and GO was drop cast on top of the SnO₂ NWs. These GO/SnO₂ hybrid sensors show a reversible response to H₂ at low operating temperatures. GO/SnO₂ sensors exhibit a high response $\Delta G/G=24$ at 50°C towards 100ppm of H₂ using a bias voltage of 1V. In conclusion, the use of GO/SnO₂ hybrid sensors is compatible with low cost synthesis and has a potential in the detection in the hydrogen at low working temperature for new range of applications.

Acknowledgements

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