

Enhanced Gas Sensing Performance of Pt-Coated Ag-Doped Ga_2O_3 via Surface Modification

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Summary:

In this paper, Gallium oxide (Ga_2O_3) thin films are studied for their n-type semiconducting behavior and stability at high temperatures, making them suitable for hydrogen sensing. The resistivity of Ga_2O_3 thin films is influenced by hydrogen concentration, which forms the basis for their use in hydrogen detection. Silver (Ag) doping and platinum (Pt) coating improve sensor performance, including response and recovery times. The films show strong hydrogen sensitivity at 400°C , with fast resistivity changes within seconds. Furthermore, Pt coated Ag doped Ga_2O_3 thin films show promise as catalytically inactive hydrogen sensors, provided that appropriate temperature compensation is applied to ensure measurement stability.

Keywords: H_2 sensor, Gallium Oxide, High-Temperature, Fast response/recovery, Ag doping

Background, Motivation and Objective

Hydrogen sensing is vital for safety and efficiency in energy, environmental, and industrial applications due to hydrogen's flammability and invisibility. Nanomaterials are widely studied for this purpose because of their high surface area and enhanced sensitivity. Gallium oxide (Ga_2O_3), a wide-bandgap semiconductor, stands out for its thermal stability and suitability for high-temperature sensing ($400\text{--}1000^\circ\text{C}$). Its conductivity changes with hydrogen concentration due to interactions with lattice oxygen, enabling detection [1].

Research on Ga_2O_3 for gas sensing applications, including hydrogen detection, has shown promising results. For instance, Y. Ogo et al. [2] demonstrated that Ga_2O_3 nanomaterials exhibit excellent sensitivity to hydrogen, particularly when combined with noble metal catalysts such as platinum (Pt). Recent studies found that Ag doped Ga_2O_3 nanostructures exhibited faster response times and higher sensitivity to hydrogen compared to their undoped materials [3-4]. Ag promotes charge transfer at the gas-material interface, improving the sensing mechanism for hydrogen detection. Sensor performance can be significantly improved through doping and surface modification. Silver (Ag) doping enhances charge transport and gas interaction, leading to faster response and higher sensitivity. Platinum (Pt) is widely used in hydrogen sensors as a catalyst layer due to its exceptional catalytic activity in hydrogen dissociation. Several studies have

demonstrated that Pt coating significantly boosts the hydrogen sensing performance of semiconductor materials, including Ga_2O_3 [5]. The performance of the Pt coated Ag doped Ga_2O_3 thin films sensor was prepared for catalytic analysis, as shown in Fig. 1. This study investigates Pt-coated, Ag-doped Ga_2O_3 nanomaterials, focusing on response, recovery, and stability. The combined approach offers a promising path for highly sensitive and durable hydrogen sensors with stable operation around 400°C .

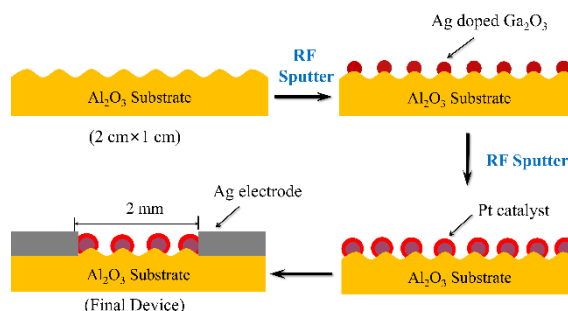


Fig. 1. Schematic diagram of a hydrogen sensor.

Results

The typical SEM images (Fig. 2) confirm the formation of nanoparticle (NP) thin films. The Ag-doped Ga_2O_3 sample shows a densely packed, uniform granular surface with well-dispersed particles, indicating good film coverage and microstructural quality. EDS mapping further

confirms the successful growth of Pt-coated, Ag-doped Ga_2O_3 NPs.

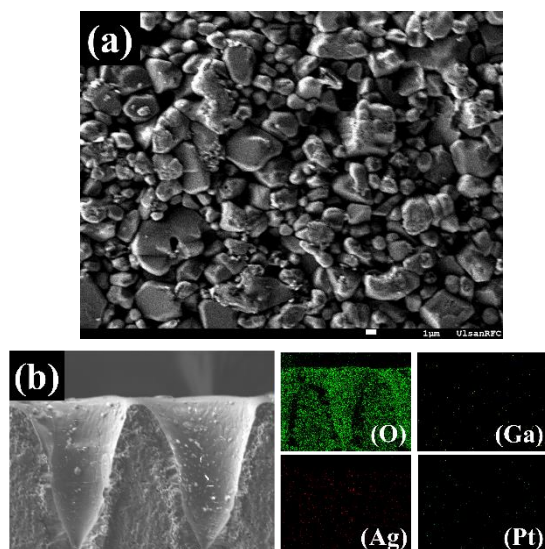


Fig. 2. SEM analysis of Pt coated Ag doped Ga_2O_3 NPs (a) Surface analysis (b) Cross-section and EDS mapping analysis

The response and recovery analysis for the Pt coated Ag doped Ga_2O_3 thin film sensor is shown in Fig. 3. The relatively quick response time (8 s) and recovery time (27 s) indicate that the Pt coated Ag doped Ga_2O_3 sensor can rapidly detect hydrogen and revert to its original state when the gas is no longer present. At 400°C operating temperature, the sensor has the greatest response of 2.7%.

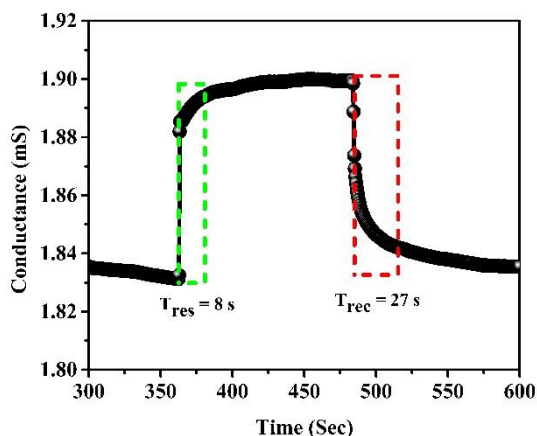


Fig. 3. Response-recovery analysis of Pt coated Ag doped Ga_2O_3 structure.

The repeatability of the gas sensor based on the Pt coated Ag doped Ga_2O_3 sensor is shown in Fig. 4 based on conductance change and response. The sensor shows consistent cyclic behavior in response to repeated hydrogen exposure cycles. Fig. 5 shows the sensing response of the Pt coated Ag doped Ga_2O_3 based sensor to different gases.

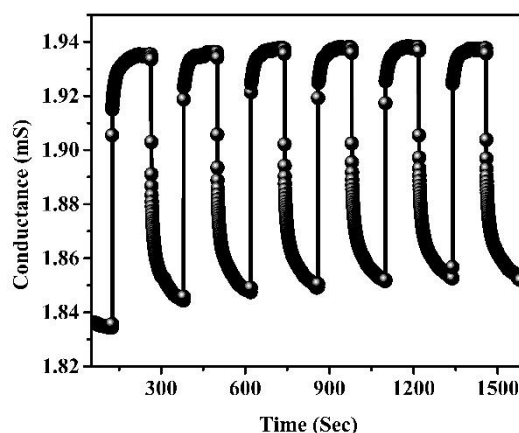


Fig. 4. Repeatability characteristics of the Pt coated Ag doped Ga_2O_3 sensor.

Among all tested gases, hydrogen generates an exceptionally high response (2.7%) nearly an order of magnitude higher than other gases, while O_2 , CO , NO , CH_4 , and C_3H_8 show negligible sensitivity.

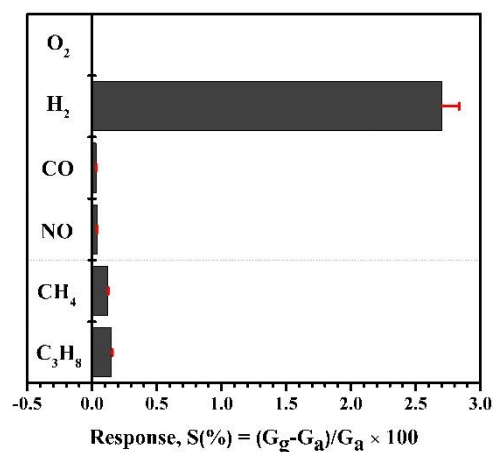


Fig. 5. Selectivity of the Pt coated Ag doped Ga_2O_3 sensor.

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