Room Temperature Humidity Sensor Based on Single β -Ga₂O₃ Nanowires [†]

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1. Summary

Monoclinic gallium oxide (β -Ga₂O₃) nanowires were fabricated via a metal-assisted vapor-liquid-solid process using chemical vapor deposition techniques and carbothermal reduction. The fabricated nanowires were structurally and optically characterized, revealing a high crystalline nature, with strong photoluminescent emission and a bandgap of 4.2 eV. Using focused electron beam techniques, nanowires were individually contacted for their use as gas sensors. The fabricated devices were tested against different concentrations of gases up to temperatures of 200 °C. Fast, stable and reproducible responses were measured towards water vapor at room temperature, with a power consumption in the nW range. The reaction promoting this response is strongly related to pre-adsorbed oxygen, a tight requirement for the water vapor sensing.

2. Motivation and Results

In the early nineties β -Ga₂O₃ appeared as an interesting material for high-temperature oxygen and reducing gases sensors in form of thin films [1]. As gallium oxide requires temperature above 600 °C to sense oxygen, several alternative strategies were explored to lower this threshold: surface functionalization with metal-particles, dopants or the use of morphologies with higher surface-to-volume ratio, like nanowires. The β -Ga₂O₃ nanostructure-based sensors have shown enhanced sensing performance when compared to thin film gas sensors, being able to sense reducing gases and volatile organic compounds at considerably low temperatures or even at room temperature with less power consumption than their thin film counterparts [2].

In this study, we present single β -Ga₂O₃ nanowire-based sensors, Figure 1a, and their behavior when exposed to different concentrations of water vapor at room temperature, Figure 1b. The response measured increased with concentration and was always fast, between 7 and 2 min to reach a steady state when exposed from 40 to 80% of relative humidity, respectively. The maximum response lies around 97%. With increasing temperature, the response decreased, disappearing at ~150 °C. This occurrence seems to indicate that the sensing process is due to physisorption.

Figure 2. (a) Gallium oxide nanowires grown via gold-assisted vapor-liquid-solid process using chemical vapor deposition techniques and carbothermal reduction at 800 °C; (b) Gallium oxide nanowire-based gas sensor's resistance evolution towards varying concentrations of relative humidity in synthetic air at room temperature.

To study possible reaction paths, tests were repeated under nitrogen ambient, revealing that water vapor promotes the oxygen desorption from the β -Ga₂O₃ nanowires and, therefore, the presence of oxygen at the surface or the surrounding of the sensing material is necessary for effective sensing. The oxygen adsorption on the surface of the nanowires was very fast, around 1 min for varying oxygen concentration.

References

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