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Hydrogen Gas Sensors Using Two-Dimensional Electron Gas

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Extended Abstract

Hydrogen (H_2) has been considered as a clean and environment-friendly energy source on account of its low ignition energy and high heat of combustion from which the combustion product is H_2O.[1] Recently, H_2 gas is regarded as the most important energy source for the operation of electrical vehicles.[2, 3] However, H_2 is not only flammable but also explosive in the concentration of 4-75%. Unfortunately, it is impossible to detect H_2 gas by human beings because of its colorless and odorless property. Therefore, a development of sensitive H_2 gas sensor is required for human safety.[4,5]

Two-dimensional electron gas (2DEG) was observed at the interface of oxide heterostructure in 2004.[6] The model system for 2DEG at the oxide heterostructure is epitaxial interface of $LaAlO_3/SrTiO_3$ heterostructure. Recently, we reported that 2DEG can be created at the oxide heterostructure by using amorphous Al_2O_3 top layer.[7] Here, we demonstrate high-performance H_2 gas sensor using 2DEG at the interface of $Al_2O_3/SrTiO_3$ heterostructure using atomic layer deposition (ALD). Palladium (Pd) or platinum (Pt) catalysts are used on top of the $Al_2O_3/SrTiO_3$ heterostructure.[8] At first, we will show a H_2 gas sensing performance using 2DEG at the interface of $Al_2O_3/SrTiO_3$ heterostructure. The H_2 gas sensor using $Al_2O_3/SrTiO_3$ exhibited a wide sensing range of H_2 concentration (5ppm-1%) even room temperature with fast response time. The more H_2 gas concentration increased, the more H_2 gas sensitive increased. The $Pd/Al_2O_3/SrTiO_3$ sensor showed a fast response time to detect H_2 gas (<30 s) at room temperature. Owing to a wide bandgap (>3.2 eV) of $Al_2O_3/SrTiO_3$, a transparent gas sensor (transmittance >83% in the visible spectrum) was realized. 2DEG resistance is changed by adsorbing H_2 gas because the work function of Pd nanoparticles is modulated by the H_2 adsorption. Alteration of work function induced the change of the 2DEG resistance. The detailed detection principle will be explained in the presentation.

H_2 gas sensor using 2DEG at heterostructure such as AlGaN/GaN is another candidate for H_2 detection, thus, H_2 sensor using AlGaN/GaN is compared with $Al_2O_3/SrTiO_3$ sensor. H_2 gas sensor using AlGaN/GaN heterostructure showed a slow H_2 detection speed, but superior sensitivity (~30000%) compared to the $Al_2O_3/SrTiO_3$ sensor. In addition, enhanced detection performances of H_2 gas sensor with AlGaN/GaN heterostructures using atomic-layer-thick ZnO on Pt (or Pd) on 2DEG are addressed, which improved a decrease of recovery time. The atomic-layer-thick ZnO layer was grown by ALD which will be introduced in the presentation.

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