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Laser Engineering Branch

Design and Implementation of Gas Sensor Based on Multilayer Nanocomposite Using Pulsed Laser Deposition Technique

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Abstract

The sensor production method was manufactured to display and measure gases effectively. Nevertheless, this technology faces challenges such as delays in response time, measurement accuracy, and sensor response. To overcome these challenges, the devices are developed to improve sensor performance, confirm accurate results, and achieve an excellent response time.

In this work, the Pulsed Laser Deposition (PLD) method was used to deposit Aluminum Gallium Nitride (AlGaN) thin films on Porous Silicon (PSi) substrates under varying growth conditions, including laser wavelengths (1064, 532, and 355), material composition (25, 50, and 75 percent of Al_2O_3/GaN), laser energies (600-1000mJ), and substrate temperatures (200-400°C).

PSi substrates were fabricated using the photoelectrochemical etching (PECE) technique, assisted by a diode laser, under etching parameters of current density (20 mA/cm^2) and etching time (10 minutes).

The influence of laser wavelength, material composition, laser energy, and substrate temperature has been investigated to study the structural, topographical, morphological, and spectroscopic properties of AlGaN thin films. XRD, AFM, and FESEM also studied the structural properties of the sensor films.

The XRD analysis revealed that Aluminum Gallium Nitride on PSi was a hexagonal structure and has been found in optimum condition (532 nm, 50 % of Al_2O_3/GaN, 900 mJ, 300 °C) with high peak intensity and crystallite size at 2θ = 34.5°, 34.6°, and 63.1° related to the (002), (002), and (103) planes, respectively. The FESEM images showed an average particle size reduction, and the nanoparticles were spherical, like cauliflower. The AFM results showed that the average roughness increased to 20.63 nm for GaN and 9 nm for Al_2O_3 at 532 nm. It also increased to 21.5 nm at 50% of the AlGaN concentration, 85.3 nm at 900 mJ, and 20.8 nm at 300 °C. Additionally, the exceptional quality of the crystal structure at 532 nm and 900 mJ at 300°C, along with the homogeneous distribution of high-quality crystals, contributed to a rise in the root mean square.

The photoluminescence (PL) measurements show an emission peak attributable to AlGaN films in the ultraviolet band (UV). A UV-VIS spectrophotometer (UV-VIS) examined the optical transmittance, absorbance, and energy gap.

This research looked at the features of the AlGaN over PSi-substrate Nitrogen Dioxide (NO_2) sensor, such as how the electrical resistance changed when the sensor reacted with gas at different operation temperatures (25–200 °C) and gas concentration (20–100 ppm). At 200°C and 100 ppm of concentration, the sensor demonstrated the highest sensitivity of 96.7% at 3.9s and 5s of response time and recovery time, respectively.