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Synthesis and optical properties of Ga_2O_3 nanowires grown on GaS substrate

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ABSTRACT

Gallium oxide (β-Ga_2O_3) nanowires were synthesized by heat treatment of single crystal β-GaS plates in air. Crystal structure and composition of synthesized materials were studied by X-ray diffraction, energy dispersive X-ray spectroscopy and Raman spectroscopy. Thermal treatment of β-GaS plates at 1023 K leads to the formation of a Ga_2O_3 (native oxide) layer on β-GaS (0001) surface of plates. Layer thickness and size of Ga_2O_3 wires contained were found to depend on temperature and duration of applied heat treatment. For 1023 K and 6 h, the length of Ga_2O_3 wires laid in the range from units to tens of nanometers, while for 1123 K and 30 min, between 30 and 40 μm.

1. Introduction

Nowadays, particular attention is paid to the improvement of preparation methods of oxide-semiconductor nanostructures due to their unique optical, photoelectric and photocatalytic properties [1–3]. Among other gallium oxide polymorphs, β-Ga_2O_3 has been extensively studied in recent years; displaying a monoclinic crystal structure with lattice parameters $a = 12.23$ Å, $b = 3.04$ Å, $c = 5.80$ Å, $\alpha = \gamma = 90°$ and $\beta = 103.7°$ [4], it is a *n*-type semiconductor with an energy band gap of 4.2–4.9 eV at room temperature [5–7]. This oxide semiconductor shows promise for diverse applications, including beam emitters at room temperature [8], optically transparent electrodes in solar cells and high temperature gas sensors [9].

Gallium oxide nanostructures with different surface morphologies and crystalline forms and sizes were obtained by various techniques, such as chemical vapor deposition (CVD) [10], thermal vacuum evaporation [11], as well as air quenching of GaN powder [12], and GaSe [4,13–15] and GaS [16,17] single crystals. Different structures with morphologies depending on the vapor temperature have been obtained by oxidation of Ga vapors in an Ar—O_2 atmosphere. In the vapor temperature range between 1150 K and 1273 K, nanostructures displaying morphologies from dispersed crystallites to microplates have been obtained [18]. In works [19–21] single crystalline α-Ga_2O_3 layers on Al_2O_3 substrates were obtained by CVD technique. From the polarized Raman scattering spectra the wavenumbers and symmetry of normal vibration modes characteristic of α-Ga_2O_3 single crystals were determined.

Gallium sulfide (GaS) displays a typical layered structure, each layer being composed of elementary Chalcogen-Metal-Metal-Chalcogen (S-Ga-Ga-S) stratified packings. Besides, own to the atomic arrangement within the crystal lattice, valence bonds of chalcogen atoms at (0001) surfaces are almost completely compensated. Due to its specific structural features, GaS is a promising material for semiconductor heterojunctions with various crystal structures [22–25].

In this work, micrometer-sized (20–50 μm) Ga_2O_3 films, composed of nanowires, are studied. These were obtained by thermal oxidation of GaS plates with the same thickness, in normal atmosphere.

The morphology, type of nano-formations and photoluminescence (PL) spectra of nanowires have been investigated using Scanning Electron Microscopy (SEM) analysis, Raman scattering spectroscopy

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