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PREPARATION AND PROPERTIES OF β-$(Al_xGa_{1-x})_2O_3$ THIN FILMS BY SPRAY PYROLYSIS

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Introduction. As a third-generation semiconductor material, Ga_2O_3 is widely used in high-power semiconductor devices because of its wide band gap (~4.8 eV), high breakdown electric field (> 8 MV/cm), and thermal stability and radiation resistance [1]. There are six polymorphics of Ga_2O_3 discovered, among which the β-phase is the most stable [2]. Intrinsic semiconductor materials have poor conductivity due to low carrier concentration. Introducing impurities can change the properties of semiconductor materials as needed. We prepared β-$(Al_xGa_{1-x})_2O_3$ thin films with band gaps of 5 eV by spray pyrolysis method through alloying with Al. The content of Al is about 3.6%. The experimental equipment for the sol-gel method is simple and does not require a vacuum environment, so it is less expensive. Therefore, this work is important for the mass production of $(Al_xGa_{1-x})_2O_3$ thin films.

Main part. The steps of the experiment and measurements were as follows:

1) Ethylene glycol [$C_2H_6O_2$] (99.5%) was used as a solvent, gallium nitrate [$Ga(NO_3)_3*8H_2O$] (99.9%) and aluminum tri-sec-butoxide [$C_{12}H_{27}AlO_3$] were used as starting components; monoethanolamine [C_2H_7NO] (99.5%) was used as a reaction stabilizer. To obtain a sol, chemical reagents were mixed at 200°C for 1 hour. The substrates were ultrasonically cleaned with isopropanol for 10 min and then dried in air.
2) For fabrication of $(Al_xGa_{1-x})_2O_3$ thin films, we sprayed the solution onto the quartz glass (SiO_2) substrate using a high-pressure plunger pump with a 0.1 mm diameter outlet nozzle. Below the substrate was the heating plate, which was connected to the temperature controller. The distance between the nozzle and the substrate was approximately 30 cm. The temperature of the heating plate under the substrate was 140°C, and each layer was deposited on the substrate for 2 s. The substrate was then left to dry on a hot plate for 2 min.
3) The above procedure was repeated until 30 thin layers were deposited. Finally, the sample was annealed at 900 °C for 2 h to convert it into 1 micron thick β-$(Al_xGa_{1-x})_2O_3$ film.

According to Scanning Electron Microscopy (SEM) data, the cracks were found in the film. This effect may be associated with the difference in the thermal expansion coefficients of the substrate and the film, as well as the presence of aluminum.

The chemical composition of the resulting films was determined using Energy-Dispersive X-ray Spectroscopy (EDS). The films have the correct stoichiometric composition Ga/O = 40/60, uniformly distributed over the entire area and the presence of aluminum about 3.6%.

The samples have demonstrated transmission in the near ultraviolet, visible and near infrared regions of the spectrum (300-1000 nm) and the absorption band in the range of 200-250 nm. It can also be noticed that the absorption band for samples with aluminum was shifted to the UV region, which indicates the formation of a β-$(Al_xGa_{1-x})_2O_3$ crystal structure and an increase in the band gap compared to Ga_2O_3 films. The band gap was determined to be about 5 eV by analyzing the absorption spectrum.

Conclusions. This work proposed a modification of the sol-gel method (spray sol onto a substrate) for the formation of thin films of β-$(Al_xGa_{1-x})_2O_3$. It was necessary to use a temperature of at least 200˚C when synthesizing a sol. Analysis of the chemical composition by EDS spectroscopy revealed the composition of the films β-$(Al_xGa_{1-x})_2O_3$ with the introduction of 5 vol.% of Al. Analysis of the transmission spectra made it possible to estimate the band gap of the material, which was 5.0 eV.

References

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