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ABSTRACT

AIIIN compounds that include gallium nitride (GaN), aluminium nitride (AlN), and indium nitride (InN), are commonly applied in the field of optoelectronics and in fabrication of high temperature and frequency devices. Modern electronic devices often consist of 3D structures, which can be produced using two techniques. In top-down architecture, the semiconducting layer is spatially patterned by wet or dry chemical etching, whereas in bottom-up architecture epitaxial structures are grown selectively on a partially masked substrate. Selective epitaxy of AIIIN compounds makes possible to shorten the technological process and to integrate many opto-electro-mechanical systems within one semiconductor substrate, affecting the dimensions, stability and efficiency of manufactured electronic devices. The fabrication of 3D structures by selective area metalorganic vapour-phase epitaxy (SA-MOVPE) is a challenging approach. Numerous factors in the technological process have to be addressed. Therefore, selective epitaxy of AIIIN compounds is a valid research topic.

The aim of the research was to determine the influence of the geometry and material of the masking layer as well as the parameters of the MOVPE process on the profile of selectively deposited AIIIN epitaxial structures. The problem of the mask selectivity was discussed. Both the dielectric masks (SiO_x, SiN_x), fabricated using plasma enhanced chemical vapour deposition (PECVD) technique, and high-melting-point metallic masks (Ti, V, Mo, Ru, W), deposited using electron beam evaporation, were considered. The factors determining the parasitic epitaxial growth on the mask surface were presented. An additional contribution of the author is the study on the chemical and temperature stability of the masking layers during the epitaxy of gallium nitride. It was revealed that metallic mask catalyzes the epitaxial layer decomposition, and that the use of the silicon oxide and silicon nitride masks is associated with the formation of SiO_xN_y parasitic mask on the substrate surface. As part of the dissertation, the influence of the masking layer geometry on the selective growth of 3D AIIIN structures was determined, with emphasis on the so-called "edge effect"and mask interference phenomenon (proximity effect). The results of the research on the impact of selected parameters of the MOVPE process on mass transport in GaN selective epitaxy on a partially masked substrate were discussed. Particular attention was given to the relation between temperature, pressure and reagents molar ratio, and the diffusion length of metalorganic precursors and masking layers stability. Based on the experimental data, a numerical model of the SA–MOVPE process was developed, which was used to implement software to perform simulations of selective growth of the AIIIN structures. The presented mathematical models enable determination of the material parameters of the deposited structures by comparison of the numerical simulation results with experimental data, as well as the profile prediction of structures deposited selectively, based on the material composition, parameters of the MOVPE process and the masking layers geometry.

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