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Study of formation processes of thin nitride material layers from laser plasma

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Laboratory scale laser technology has been developed for synthesis of thin nitride films AlN, AlN:Mn, GaN, GaN:Zn, GaN:Cr, $MgSiN_2$:Ti. The main structure and cathodoluminescence characteristics of the films have been studied. Spectral and kinetic characteristics of vapor-plasma torch in the target-substrate gap at laser evaporation in nitride medium have been investigated. The dependence character of the transport rate and the plasma ionization extent on nitrogen pressure in the chamber and distance to the target has been determined. Interrelations have been established between thermodynamic parameters of nitrogen medium (nitrogen pressure, substrate temperature), energy and time regimes and the laser evaporation geometry at the one hand and the structure and cathodoluminescence properties of the thin nitride layers obtained at the other one. The main regularities of pulse laser crystallization and the cathodoluminescence brightness variation character as a function of the laser annealing energy density have been studied.

Разработана лабораторная лазерная технология синтеза нитридних тонких слоев AlN, AlN:Mn, GaN, GaN:Zn, GaN:Cr, $MgSiN_2$:Ti, изучены их основные структурные и катодолюминесцентные характеристики. Исследованы спектральные и кинетические характеристики паро-плазменного факела в промежутке мишень-подложка при лазерном испарении в нитридной среде. Установлен характер скорости переноса и степени ионизации плазмы от давления азота в камере и расстояния от мишени. Установлены закономерности взаимосвязи между термодинамическими параметрами азотной среды (давление азота, температура подложки), энергетически-временными режимами и геометрией лазерного напыления, с одной стороны, и структурой и катодолюминесцентными свойствами полученных тонких нитридных слоев, с другой стороны. Изучены основные закономерности импульсной лазерной кристаллизации и характер изменения яркости катодолюминесценции в зависимости от плотности энергии лазерного отжига.

Nitrides of III Group are today of a great scientific and practical interest, since it is possible to develop optoelectronic devices based thereon which can be operated in visible and UV spectral regions [1]. To obtain high-quality thin nitride layers of pre-specified composition is a technical task of considerable difficulty. It is just the pulse laser reactive technology of thin layers that has shown already its advantages that is among most promising ways to solve this problem [2, 3]. The wide control possibilities of the laser emission spatial, energy, and temporal characteristics as well as of the chemically active medium and electromagnetic field parameters extend substantially the technologic potential of the method. This, in turn, makes it necessary to consider the whole variety of physical processes occurring when a layer is formed using said method and to select the optimum laser means as well as the process parameters. It is just the main purpose of this work.

To that end, a setup was used based on an LTI-205-1 optical laser ($\lambda = 1.06$ μm, $\tau_i = 10$ to 150 ns, $q = 10^4$ to 10^9 W/cm^2, $n = 1$ to 56 Hz) and a VUP-5 high-vacuum device ($P = 10^{-6}$ Torr, $P_{N_2} = 10^{-4}$ to