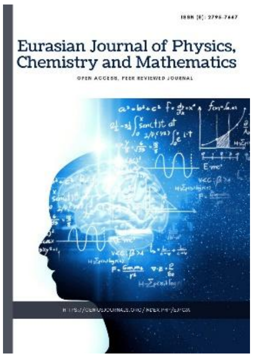

Effect of erbium atom on photoluminescent properties of $Al_xGa_{1-x}As$

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ABSTRACT

Radiation characteristics of GaAs and $Al_xGa_{1-x}As$ epitaxial layers with addition of rare-earth element Yb are determined by photoluminescence method. In the exciton regions of epitaxial films, new lines of photoluminescent maxima $Al_xGa_{1-x}As$ determined for the intended ytterbium atoms. The effect of the concentration of the ytterbium atom on the change in the photoluminescence characteristics of the GaAs and $Al_xGa_{1-x}As$ epitaxial films was determined.

Keywords: photoluminescence, quantum well, temperature.

Epitaxial layers of $Al_xGa_{1-x}As$ and GaAs are obtained by liquid-phase epitaxy with addition of rare-earth element Yb to gallium melt. Measurements of electrophysical parameters, photoluminescence and stoichiometry showed that when REM is introduced, there is an optimal concentration of Yb in the melt ($N^{ж}_{Yb} \sim 0.5 \times 10^{-4}$), which makes it possible to obtain high quality layers. At this concentration, Yb mainly acts as a getter for residual impurities and a catalyst of heterogeneous equilibrium in the melt, its entry in the form of single atoms into the solid ¬ two phase does not worsen the electrophysical parameters of the layers. When small REE additives are added to the melt by liquid phase epitaxy (LFE), especially pure unalloyed layers of GaAs [1,2], InP, InGaAs . In this case, the effective getter properties of REE are used, and the degree of purification depends on the initial number tot of materials, the features ¬ the technological process [2], as well as the type of REE. However, the question of the form of inclusion of REE impurities in the composition of epitaxial layers (ES) (in the form single atoms and/or microinclusions) is up date controversial. Quantitative direct estimates of REE content in ES $A_{III}B_V$ depending on its content in the melt are very contradictory. In order to understand the effect of REE on the formation of the properties of POS obtained by the GFE method and the fur ¬ nests of their entry into the solid phase, we ¬ conducted experiments on GaAs POS at various concentrations of Yb in the melt [3]. According to ¬ semi ¬ linear results, optimal conditions for growing ES $Al_xGa_{1-x}As$ were selected. GaAs ES and 6-12 μm thick $Al_xGa_{1-x}As$ were grown under identical conditions from the Ga melt on semi-insulating GaAs (100) substrates in a hydrogen stream (~ 15 L/h) at an epitaxy onset temperature of 680 ° C, the cooling rate for GaAs ES was ~ 1.2 ° C/min and for $Al_xGa_{1-x}As$ 0.7 ° C/min.

Parameters of studied epitaxial layers GaAs and $Al_xGa_{1-x}As$

Epitaxial layers	*d* layers, mkm	Dopant	N_b x10^4 ,ат.доли	Wire type property	~300 К,sm^2 /(В с)	*n,p,* cm^{-3}
GaAs	11	—	—	*n*	2600	7.5 x IO^{17}
GaAs	8.2	Yb	0.01	*n*	3840	1.3 x 10l^7
GaAs	8.8	Yb	0.18	*n*	3530	1.3 x IO^{17}
GaAs	7.3	Yb	0.34	*n*	3000	4.6 x IO^{16}
GaAs	6.0	Yb	0.48	*n*	5000	3.0 x IO^{16}
GaAs	10.0	Yb	0.49	*n*	3700	1.4 x IO^{17}
GaAs	9.2	Yb	0.64	*n*	4200	7.3 x IO^{16}

The concentration of Yb in the Ga melt (N^j_{Yb}) was varied for GaAs layers (0 < N^j_{Yb} < 8 x IO^{14} atomic fraction). To saturate the melt with arsenic, polycrystalline GaAs (AGN-1) was used, the homogenization time of the melt with > 1.5 hours, similar to [3]. Graphite cassettes were used, annealed in hydrogen for 5 hours at a temperature of ~ 950 ° C. The layers are given in the table. A detailed study of changes in GaAs ES parameters as a function of Yb concentration in pool showed that many of them, in particular, stoichiometry, the position of the maximum of the marginal luminescence moose and its half-width, are non-monotonically associated with an increase in N^j_{Yb}. Based on the totality of all experiments mental results, we proposed a qualitative ¬ qualitative model of the influence of rare earth elements on the formation of the properties of POS and the mechanism of Yb joining the GaAs POS. The concentration range of N^j_{Yb} can be divided into t The first region is the end train of REE in the melt N^j_{Yb} ≤ 0.48 x 10^{-4} atomic fractions: at minimal concentrations, Yb is mainly a getter for residual impurities and one temporarily a catalyst for heterogeneous equal this in the melt that changes the stoichiometry of ES; with an increase in N^j_{Y}, ytterbium enters the solid phase in small amounts as single atoms wo regions.

At increase in a soderkzhaniye of RZE N^j_{Yb} 1> 0.48x10 $^{-4}$ ат. add, i.e. at a pekrekhoda to the second area, remaining a getter and the catalyst, Yb is a part of ES in the form of micro inclusion, at the same time processes of coagulation amplify with increase in N^j_{Yb}. Thus, when Yb is used in gallium rasp, there is a certain area of its concentrations, at which it becomes possible to obtain sufficiently clean, stoichiometric, with good electrophysical parameters of ES GaAs. These representations were used in the selection of the conditions for the preparation of the $Al_xGa_{1-x}As$ films. They were grown at a concentration of N^j_{Yb} corresponding to ¬ optimal value for ES GaAs (~ 4.8 x $Al_xGa_{1-x}As$ - 10^{-4} atomic fractions). The SEs obtained under the same conditions and with the same additives A1 in melt (N^j_{Yb} = 2.32 x 10-4 atomic fractions) $Al_xGa_{1-x}As$ with and without Yb sharply differed in electrophysical characteristics (tables). At the level of resolution of the X-ray topographic and diffractometric methods used, changes in the flow tour perfection of ES obtained once ¬ personal conditions were not observed. We managed to achieve quite high parameters both in terms of mobility and concentration of free charge carriers, which indicates the correct of the ideas used about the choice of op thymal samples Yb. some improvement ¬ their quality (for example, an increase in the intensity of the edge band of radiation and a narrowing of its half-width), which is obviously associated with the influence of the A1 itself on the formation of film properties [3]. The characteristics of the edge band obtained at temperatures indicate up to ¬ statistically high quality of ES $Al_xGa_{1-x}As$. Typical FL spectra for $Al_xGa_{1-x}As$ with and without Yb at T = 4.2 K are shown in Fig. 1. Comparison FL spectra for POS $Al_xGa_{1-x}As$ with and without Yb showed that when the POS parameters are improved, there is a slight shift in the position the maximum of the edge band towards low low energies (by ~ 3 meV) without a significant change in the of its half-width (W ~5.8 meV). When processing FL spectra measured at different temperatures, they indicate up to ¬ statistically high quality of ES $Al_xGa_{1-x}As$ 3 Typical FL spectra for $Al_xGa_{1-x}As$ with and without Yb at T = 4.2 K are shown in Fig. 1.

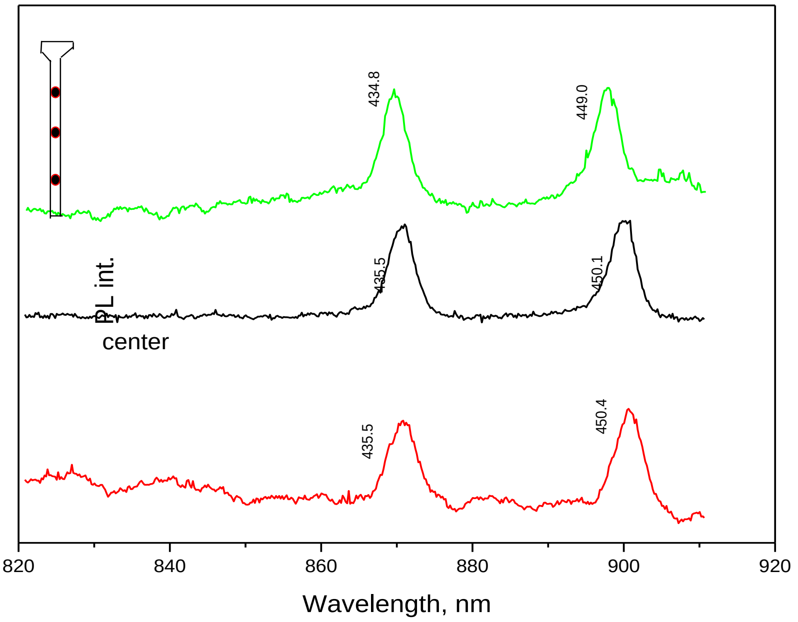

Fig. 1. FL spectra in the marginal region (0.79-0.92 μm) at T = 4.2 K for ES $Al_xGa_{1-x}As$ without Yb (1) and with up to Yb (2) wafer.

Comparison ¬ FL spectra for POS $Al_xGa_{1-x}As$ with and without Yb showed that when the POS parameters are improved, there is a slight shift in the position ¬ the maximum of the edge band towards low ¬ low energies (by ~ 3 meV) without a significant change in the ¬ of its half-width (W ~ 5.8 meV). This may be due to several processes occurring during ¬ formation of POS. So, it can be assumed that Yb with an atomic radius, su ¬ essentially exceeding the atomic radius Ga ($r_Y > r_{Ga}$), enters the ES and the compression deformations that occur in the layer (in the substrate - stretched) cause a shift of the maximum towards high energies, and a decrease in the content of A1 leads to a shift of the maximum to other side. Therefore, it is difficult to judge unambiguously from the change in the value of x, which was determined for $Al_xGa_{1-x}As$ layers without Yb, in ES with Yb. One ¬ to it can be assumed that the concentration of A1 in ES is slightly lower. Calculation of the composition of solid solutions in the $Al_xGa_{1-x}As$ was carried out using the formula ^ (AlxGa1-xAs) = (GaAs) + 1.247x, where x is the mole fraction of A1, Y-co; - energy position of the maximum of the FL edge strip at Γ = 4.2 K. In the range 0 < x < 0.1, the influence of internal mechanical stresses arising from mismatch of film and substrate lattice parameters ($\varepsilon < 10^{-5}$) was not taken into account. Homogeneity of the ES composition of AlGaAs was monitored with a layer-by-layer grasses linen. This may be due to both a decrease in the concentration of ¬ radio A1 in the epitaxial structure, and a not significant increase in the concentration of Yb, which is part of the ES [3] (assuming that all A1 atoms occupy places in the Ga sublattice -A1 (for and all Yb atoms are also located in the Ga sublattice - Yb^{Ga}). However, if we use the idea of the influence of Yb on the processes of forming the properties of GaAs films, then a decrease in the value of x is very likely, which is consistent with the results of FL. Thus, the use of Yb in the Ga melt in a certain range of its concentration (N^ = $4.8x10^{-4}$ atomic fractions) allows to obtain fairly pure ES $Al_xGa_{1-x}As$ by the GFE method, while the presence of Yb in ES does not have a ¬ on the electrophysical parameters of the layers. However, the presence of REE in the melt solution can change the proportion of A1 in ES AlGaAs compared to ES obtained without Yb. This must be taken into account ¬ taken into account when developing the technology, and the issue can be finally resolved only with the use direct high-resolution methods for monitoring the composition of the solid phase, which requires further research. Nevertheless, the studies carried out have yet found that for a particular REE (in the present work - Yb) there is an optimal content ¬ it in the melt (when REE does not yet affect the electrophysical parameters), which makes it possible to obtain high-quality ES of both binary and triple compounds for industrial ¬ industrial use.

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