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Investigation of self-organized nanoheterostructure properties in InGaAsP solid solutions

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Abstract. Properties of self-organized InGaAsP nanoheterostructures grown on InP and GaAs substrates have been investigated by photoluminescence and transmission electron microscopy (TEM) methods. The dependence of epitaxial growth temperature and solution supercooling on the rate of self-organization of periodical InGaAsP nanoheterostructures has been determined. Periodical picture in the plan view and cross section of TEM image of InGaAsP epitaxal layers have been observed.

Introduction

In our previous works it was shown experimentally that in the miscibility and spinodal decomposition region of quaternary InGaAsP solid solutions the formation of self-organized periodical nanoheterostructures takes place during the growth process [1, 2, 3]. Boundaries of miscibility and spinodal decomposition regions for liquid phase epitaxy grown InGaAsP epitaxial layers lattice matched to InP and GaAs were determined. Also initial technological conditions for unstable growth of InGaAsP epitaxial layers by liquid phase epitaxy method were obtained. In present work we continued study of InGaAsP solid solution lattice matched to InP and GaAs in the miscibility and spinodal decomposition region at technological conditions facilitating the unstable growth of epitaxial layers.

1 Results and discussion

According to theoretical predictions [4] a decrease of growth temperature of epitaxial layer widens the boundary of miscibility and spinodal decomposition region. In this connection we investigated the influence of growth temperature on the effect of formation of self-organized InGaAsP nanoheterostructures lattice matched to InP. Epitaxial layers grown at 650, 600 and 550 °C were investigated by photoluminescence method. It was found that temperature decrease first leading to the improvement of nanoheterostructure self-organization effect ($T = 600$ °C) then results in it decrease ($T = 550$ °C). Such discrepancy with theoretical predictions we connected with the fact that in theoretical model the temperature dependence of diffusion coefficient had not been taken into account. In order to investigate the influence of nonequilibrium condition of liquid phase on self-organization process of nanoheterostructures in epitaxial layers of InGaAsP solid solutions the temperature of solution supercooling was varied. Supercooling temperature was increased up to the value when it becomes difficult to remove solution from the substrate. Experiment was carried out at two cooling velocities of the solution —

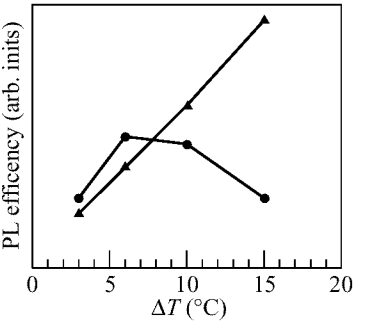

Fig 1. The dependence of photoluminescence line efficiency of InGaAsP/InP epitaxial layer on supercooling temperature of the solution for two cooling velocities (triangles — 0.1 °C/min, circles — 2 °C/min).

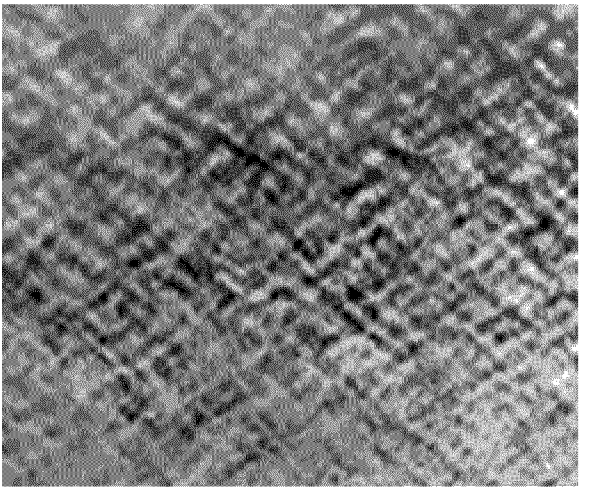

Fig 2. TEM image in the plan view of InGaAsP/InP epitaxial layer.

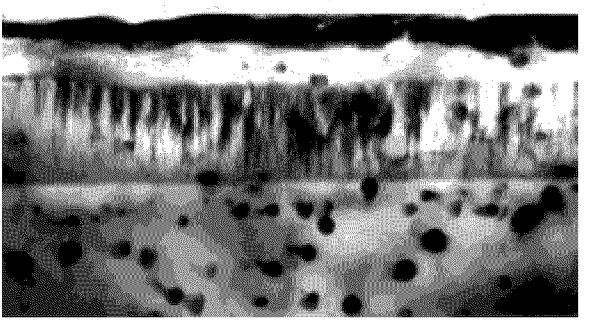

Fig 3. TEM image in the cross section of InGaAsP/InP epitaxial layer.

0.1°C/min and 2 °C/min. Fabricated samples were investigated by photoluminescence method. The rate of nanoheterostructure self-organization effect was evaluated by efficiency of photoluminescence lines. The dependence of efficiency of photoluminescence line which characterizes nanoheterostructure formation on supercooloing temperature of the solution is presented on Fig. 1

An increase of solution supercooling temperature results in the increase of photoluminescence line efficiency for samples grown at 0.1 °/min cooling velocity. For the samples grown at 2 °/min cooling velocity and at 10 °C supercooling temperature the decrease of photoluminescence line efficiency was observed. At 15 °C supercooling temperature it was impossible to remove the solution from the substrate. In our opinion it confirms the fact that nanoheterostructure self-organization effect increases with the increase of nonequilibrium state of solution liquid phase. Fabricated samples were also investigated in plan view and cross-section by transmission electron microscope EM-420. The most difficulties presented the preparation of samples on InP substrate for the view in cross section due to the formation of islandes during ion-beam sample processing. The original method of sample preparation allowing to minimize this effect was developed. TEM images in plan view and cross section of typical epitaxial layer samples are presented in Fig. 2 and Fig. 3, respectively. A large scales on both photographs are the same. In plan view and cross section periodically repeated regions with different solid solution composition were observed. The self-organized nanostructure dimensions were found to be 500–600 Å.

2 Conclusion

On the base of carried out investigations the influence of diffusion coefficient temperature dependence on nanoheterostructure self-organization effect was observed with the decrease of growth temperature. The increase of nanoheterostructure self-organization effect with the increase of supercooling solution temperature was shown. Periodical structure in plan view and cross section in TEM images of samples was observed.

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