MBE growth of (In,Ga,Al)As quantum dots in (Ga,Al)As barrier close to the critical thickness – a comparison varying Al and Ga content

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Quantum dots (QD) are formed during epitaxial growth in In(GaAl)As/Ga(Al)As material system to safisfy equilibrium conditions in compressively strained thin layers. When the thickness of deposited material only slightly exceeds the critical thickness for QD to occur, utilizing a kinetics of QDs formation, post-growth annealing, as well as a dependence of adatom mobility on surface temperature and chemical elements built-in allow for a control of dot sizes and their surface density. An adjustment of growth parameters close to the critical thickness allows for a growth of low surface density of QDs [e.g. 1,2]. It was also reported [3] that composition of QDs/wetting layer is influenced by intermixing of deposited material with barrier layers, which depends on temperature and kinetics. All these factors influence the energy and other optical properties of the emitted light.

In this work, we report the results of growth of (In,Al)As and (In,Ga,Al)As QDs in comparison to InAs ones, with a purpose to establish growth conditions in (In,Ga,Al)As/(Ga,Al)As system allowing for a single dot spectroscopy in the wavelength range below 1 μm.

(In,Ga,Al)As QDs with varying Al and Ga composition are grown in GaAs or (Ga,Al)As barrier by a solid source MBE. The growth is carried at conditions close to the critical thickness of QD formation (for InAs/GaAs QDs 1.5-1.7 monolayer (ML)). The QD growth rate is kept in a range from 0.003 ML/s to 0.3 ML/s. The samples contain two layers of dots, one of them buried in (Ga,Al)As barrier, and the other left uncovered on the top of sample surface. Atomic force microscopy (AFM) measurements are performed on the uncovered QD layer. Photoluminescence (PL) of the covered QD layer is registered under cw excitation carried at 405 nm – 635 nm, at temperature of 10 K.

The critical thickness is found to increase with Al or Ga content in (In,Ga,Al)As due to a lowered lattice mismatch with respect to (Ga,Al)As barrier and resulting decrease of strain. The application of low growth rates leads to a smaller surface density and larger size of QDs for a given monolayer coverage, most probably due to an intermixing of material with (Ga,Al)As barrier layer and resultant lowered local strain or longer adatoms diffusion length on the surface. An incorporation of Al in the dots counteracts the tendency for lower density and larger sizes probably due to a limited surface diffusion of atoms during growth or altered nucleation of dot by Al atoms. The AFM measurements reveal InAs QDs lateral diameter varying between about 60 nm to 20 nm at low surface density of QDs of ~$5x10^9$ cm^{-2} and seems to decrease with Al content. The increase of the wavelength of the QD emission band from around 1500 nm to 900 nm is observed with increasing Al and Ga content.

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