Nanooptics and Nanophotonics

Optical spectroscopy of quasi-atomic nanostructures: Ge quantum dots in a matrix of Si : Theory

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Nanoheterostructures Ge / Si quantum dots (QD) heterostructures Germany belong to the second type. Such nanoheterosystems characterized by the presence of significant discontinuities in the valence band and the conduction band. They are the main electronic level is in the silicon matrix, and the main hole level is within the scope of QDs Germany. A significant gap in the valence band is the localization of the holes in the amount of QD . The significant gap in the conduction band is a potential barrier to electrons (electrons flow in the matrix and do not penetrate the volume QD) . In the study of the optical propert ies of nanoheterostructures Ge / Si QD of germanium in the experimental work [1] was first observed spatial separation of electrons and holes, in which electrons are localized on the surface of QD and the holes move in the QD volume. To create based on Ge / Si heterostructures new efficient optoelectronic devices is necessary to study the mechanisms of absorption of light in such nanoheterostructures .

The effect of a significant increase in the exciton binding energy of spatially separated electrons and holes (hole moves in the volume of QD, and the electron is localized on a spherical surface (QD - matrix)) [2 - 4] in nanosystems containing germanium QDs grown in a matrix of Si by compared with the binding energy of an exciton in a single crystal of Si. It was found that in such nanosystem in the conduction band of the Si matrix is first a zone of states of electron-hole pair that with increasing radius of the QD becomes a zone of exciton states, located in the band gap of Si matrix .

It is shown that the mechanisms of absorption in Ge /Si heterostructures with QDs Ge caused by intraband transitions of electrons between quantum-levels of the electron-hole pairs, arranged in the conduction band of the Si matrix and intraband electron transitions between quantum- exciton levels located in the band gap of silicon matrix, and and interband electron transitions between quantum-level E h (a) (a – radius QD), located in the valence QD Ge , and quantum-levels of the electron-hole pairs, and interband electron transitions between quantum-level E h (a) and quantum- exciton levels located in the band gap of silicon matrix .

Built here the theory allows for the absorption spectra of Ge /Si heterostructures with Ge QD detected experimentally at room temperature electron transitions between exciton states of space - separated electrons and holes (the primary (n = 0) and excited (n = 1)) .

Localization of nonequilibrium electrons in the vicinity of the spherical surface section (QD - matrix) (the electrons are within the exciton states) reduces the concentration of electrons and, as a consequence, a drop of conductivity of the heterostructure Ge / Si QD germanium (i.e. to ef fect negative photoconductivity [1]).

By changing the parameters of the Ge /Si heterostructures with QDs Ge (radii a QD, as well as the ratio of the effective mass of the quasiparticles , can be directed to vary the position of the energy levels of the electron-hole pairs and excitons (of spatially separated electrons and holes), the exciton binding energy, the width of the exciton bands, as well as the energies of transitions in exciton bands. The latter circumstance, as well as the effect of a significant increase in the exciton binding energy, apparently, opens up new possibilities in the use of nanoheterostructures as the active region nanolasers working on excitonic transitions at room temperature [5].