TWO-STAGE MODEL OF NANOCONES FORMED ON A SURFACE OF SEMICONDUCTORS BY LASER RADIATION

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Nowadays, nanostructures are one of the most investigated objects in semiconductor physics, especially due to Quantum confinement effect in quantum dots (0D), quantum wires (1D) and quantum wells (2D). A new laser method elaborated for nanocones formation in semiconductors is reported. A cone possesses the following unique properties: a small cone is a quantum dot – 0D and a long one is a quantum wire – 1D with the gradually decreasing diameter from the base till the top of the cone. Everywhere radii of cone are equal or less than Bohr' radius of electron, exiton or phonon Quantum confinement effect takes place.

Nanocones on the surface of elementary semiconductors Si [1] and Ge [2] single crystals, compound semiconductors GaAs [3] and 6H-SiC [4] crystals, and on a surface of of$Si_{1-x}Ge_x$[5](x=0.3 and x=0.4) and $Cd_{1-x}Zn_xTe$ (x=0.1) [6] solid solutions were formed by fundamental frequency and second harmonic of Nd:YAG laser radiation. Properties of nanostructures formed on the surface of semiconductors using Atomic force microscope (AFM), Electron scanning microscope, Photoluminescence (PL) and Raman back scattering spectra methods was studied. Unique photoluminescence spectra from the irradiated surfaces of the semiconductors were found in the visible range of spectrum. Photoluminescence from Ge, SiGe/Si and GaAs nanostructures can be explained by Quantum confinement effect. A shift of micro-Raman scattering spectra in Ge and GaAs is a good evidence of this suggestion.Asymmetry of photoluminescence spectra of the irradiatedSiO_2/Si structure is explained by Quantum confinement effect in nanocones-nanowires with a graded decrease of diameter toward the top of nanocone. It is graded band gap structure.As a result of study of the irradiated surface morphology by AFM was found that properties of nanostructures such as: shape and height of nanocones and their concentration, depend on wavelength and intensity of laser radiation and parameters of semiconductor and content of the components in solid solution. Therefore, for elaboration of a new technology it is necessary to know a mechanism of nanocones' formation on the irradiated surface of a semiconductor. For this aim two-stage model is proposed [7]: Laser Redistribution of Atoms (LRA) and Selective Laser Annealing (SLA). For instance, in case of$Si_{1-x}Ge_x$ the first stage is characterized by formation of strained top layer, enriched by Ge atoms in $Si_{0.7}Ge_{0.3}$ due to their drift to the irradiated surface in temperature gradient field induced by laser radiation. The

main role in this process has Thermogradient effect [8]. LRA is a nonlinear optical process: concentration of Ge atoms in the top layer of SiGe solid solution increase with number of laser pulses and at the same time absorption coefficient of the top layer increases. As a result Ge/Si heterostructure is formed on the irradiated surface. The second stage of nanocones' formation on the irradiated surface of semiconductor is selective laser absorption of the light by the top stained layer with further mechanical plastic deformation of the top layer due to relaxation of the mechanical compressive stress arising between these layers due to mismatch of their crystal lattices and heating up the top layer. A similar two-stage model can be used for nanocones' formation by laser beam on ternary component solid solution $Cd_{0.9}Zn_{0.1}Te$. In the case of the elementary semiconductors, at the first stage of the process a thin top layer with mechanical compressive stress is formed due to concentration of interstitials on the irradiated surface of the semiconductors. At the second stage of the process nanocones are formed on the irradiated surface of the semiconductors due to plastic deformation of the top layer in the same way as in the previous case with semiconductor solid solutions. The model is confirmed by "blue shift" in PL spectrum, "red shift" of LO line in Raman back scattering spectrum of Ge crystal and non-monotonous dependence of Si crystal micro-hardness as function of the laser intensity.The "blue shift" of exciton bands by 0.2 eV in photoluminescence spectra of the irradiated$Cd_{1-x}Zn_xTe$ ternary compound is explained by Exciton Quantum confinement effect.

For the first time the possibility of graded band gap 1D structure formation in elementary semiconductors was shown. Thermogradient effect has a main role in first stage of nanostructures formation by laser radiation in semiconductors.

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