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CONTROLLING OF Ge QUANTUM DOTS ARRAYS PARAMETERS IN Ge/Si NANOHETEROSTRUCTURES GROWN BY MOLECULAR BEAM EPITAXY METHOD

This scientific work is devoted to investigation of Ge quantum dots arrays parameters in Ge/Si nanoheterostructures. The analysis of methods for control and management options of these parameters during the synthesis process by molecular-beam epitaxy is conducted. The results of experiments on the synthesis and surface control of the Si/Ge nanoheterostructures sampes grown in the molecular-beam epitaxy installation "Katun-100" are given.

Keywords: *quantum dot, molecular-beam epitaxy, high energy electron diffraction, atomic force microscopy.*

Currently optoelectronics is experiencing rapid development, and the main objects of research are complex heterostructures with nanoscale inclusions. A breakthrough in this area became possible because of the development of manufacturing technologies of nanostructures. The main focus is on structures based on silicon constituting basic elements of most modern electronic devices. New types of photodetectors based on silicon-germanium low-dimensional heterostructures using intrasubband and intersubband transitions in these materials are intensively being developed. Interest in Ge / Si structures is also shown due to the possibility of their use in solar energy. Ge / Si materials system with Ge quantum dots (QD) has turned out to be perspective for creating solar cells. Improving the efficiency of devices based on Si nanoheterostructures with Ge QDs is possible due to the effects of spatial quantization. For the manifestation of these effects the geometric dimensions of nanostructures should be 10 nm or less. Besides a high density of nanoinclusions arrays is also required [1–5].

The main method of obtaining Ge / Si nanoheterostructures is molecular-beam epitaxy (MBE). Formation of Ge nanoislands on Si thus occurs by the Stranski-Krastanov mechanism owing to self-organization effects taking place due to the mismatch on crystal lattice constant (4.2 %). Ge islands formation during growth occurs spontaneously, and controlling of the parameters of the array is possible only by changing the synthesis conditions: the deposition rate, the temperature of the substrate, the thickness of the deposited layer. Crystallographic orientation of the substrate also affects the characteristics of germanium clusters.

Controlling the surface morphology *in situ* plays an important role during the synthesis process. High energy electron diffraction (HEED) is widely used in MBE. It is a method of studying solid surfaces, based on the analysis of diffraction patterns of electrons with energies of 5–100 keV elastically scattered from the object surface at grazing angles. Sharpness and brightness of the diffraction reflections allow to qualitatively judge of the structural perfection of the surface and to obtain the projection of the reciprocal lattice that can be used to reconstruct two-dimensional surface lattice in real space. HEED is also used for the quantitative structural analysis. During the epitaxial growth if the islands begin to form on the surface of the sample, they can be immediately detected by the appearance of new reflections in HEED patterns.

The synthesis of Ge/Si nanoheterostructures has been conducted on the MBE installation "Katun-100". Si (100) substrates were used, as it was shown [6] that the greatest density of QDs array can be obtained using exactly the (100) substrate orientation. A series of experiments on the synthesis of nanostructures has been held, controlling of the surface during growth was performed by HEED, and after the images of the surface were obtained using an atomic force microscope (AFM) NT-MDT Solver. HEED patterns obtained in the synthesis show the presence of Ge QDs formed on the surface and are in good agreement with the AFM images of the surface of fabricated samples.

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