INFLUENCE ON THE GROWTH OF GERMANIUM OF TEMPERATURE ON SILICON*

O.I. KUKENOV[1], V.V. DIRKO[1], K.A. LOZOVOY[1], A.P. KOKHANENKO[1]

[1]National Research Tomsk State University, Tomsk, Russia

Numerous studies of the heteroepitaxial growth of germanium on silicon show that, under certain conditions, the formation of several morphologically different types of islands is possible in this system: with a square and rectangular base [1]. In addition, under certain growth conditions, it is possible to form so-called whisker-like quantum dots, which have a very high ratio of length to base width [2]. At the same time, for effective device use it is necessary to create heterostructures with a very narrow size distribution of nanoislands, since this is what provides the best conditions for the manifestation of quantum effects. The homogeneity of the islands critically depends on the growth parameters, such as the growth temperature, the deposition rate of germanium and its amount, as well as the annealing time of the structure after growth. The required size distribution of quantum dots can only be achieved through careful selection and constant monitoring of synthesis conditions.

In this work, when analyzing the synthesis of Si on Si(100) by the method of reflection high energy electron diffraction (RHEED) in a wide temperature range, we plotted the dependences of the intensity ratio and the ratio of the oscillation periods of the 2×1 and 1×2 reflections, as well as the dependence of the intensity of the 1/N reflection on growth time [3]. The combination of these quantities determines the dominant growth mechanism of two-dimensional layers at a given temperature. It was found that near a temperature of 550°C there is a critical point at which monoatomic steps of different types are as close as possible, and the dimer rows are still small. Based on this, a temperature of 550°C was chosen as a priority for creating quantum dots. For comparison, samples with Ge nanoislands on Si(100) grown at temperatures of 470–600°C were studied using scanning electron microscopy.

It was shown that with such a small change in the growth temperature near the critical temperature, the samples differ significantly in the densities of quantum dots per square centimeter and in the sizes of nanoclusters. The density of quantum dots decreases sharply with increasing temperature above 550°C, and their size also increases significantly, making it impossible to observe quantum effects. In addition, the sample grown at 550°C is distinguished by a large ratio of the length of the base of the islands to their width and a small scatter of island sizes. Therefore, this point is of great interest for the creation of elongated nanoclusters and quantum wires [4].

REFERENCES

[1] L.V. Arapkina, and V.A. Yuryev, “Classification of Ge hut clusters in arrays formed by molecular beam epitaxy at low temperatures on the Si(001) surface,” Physics-Uspekhi, vol. 53, pp. 289–302, 2010, doi: 10.3367/UFNr.0180.201003e.0289.

[2] J. Tersoff, and R.M. Tromp, “Shape transition in growth of strained islands: Spontaneous formation of quantum wires,” Physical Review Letters, vol. 70, pp. 2782–2785, 1993, doi: 10.1103/PhysRevLett.70.2782.

[3] V.V. Dirko, K.A. Lozovoy, A.P. Kokhanenko, and A.V. Voitsekhovskii, “High-resolution RHEED analysis of dynamics of low-temperature superstructure transitions in Ge/Si(001) epitaxial system,” Nanotechnology, vol. 33, pp. 115603 (1–8), 2022, doi: 10.1088/1361-6528/ac3f56.

[4] K. Liu, I. Berbezier, L. Favre, et al., “Self-organization of SiGe planar nanowires via anisotropic elastic field,” Physical Review Materials, vol. 3, pp. 023403 (1–7), 2019, doi: 10.1103/PhysRevMaterials.3.023403.

* The work was supported by the Russian Science Foundation and Tomsk State University Development Programme (Priority 2030).