4-12 Attempt to Control Quantum Dot Size

－Measurement of the Number of Atoms in a Nanocluster－

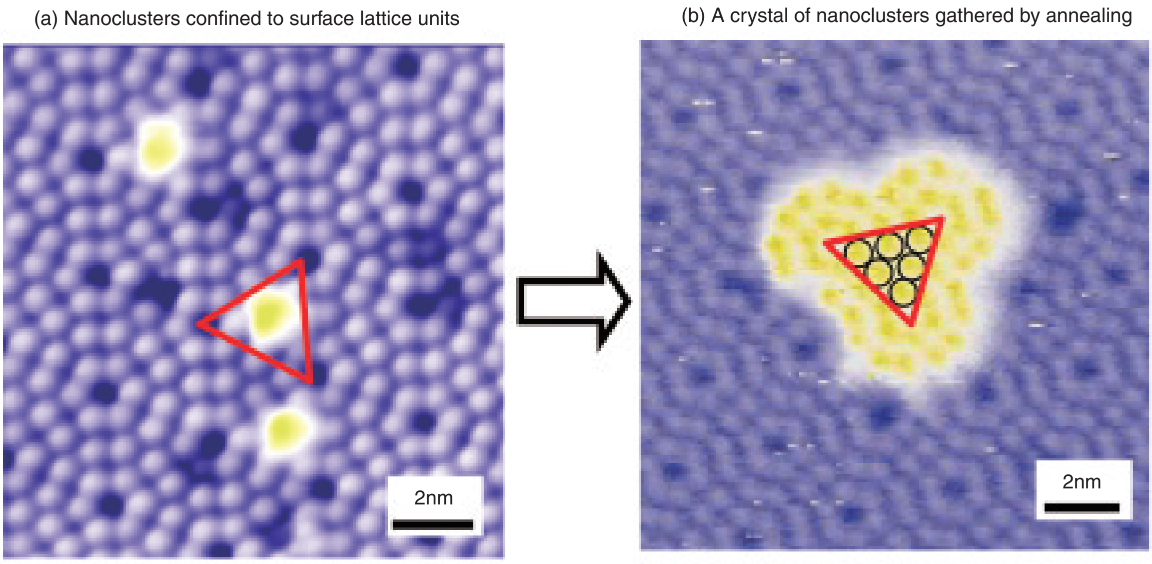

Fig.4-27 Scanning tunneling microscopy (STM) images of Germanium (Ge) nanoclusters in surface lattice units of Ge(111) and a nanocluster crystallized by annealing
Nanoclusters which are precursors for quantum dots in the initial growth stage are confined to half of the surface lattice unit (red triangle in (a)). The atoms in the nanoclusters (yellow mass at the center of red triangle in (a)) could not be recognized separately. We present a method for measurement of the average number of atoms in a cluster by using nanoclusters crystallized by annealing to make atoms directly recognizable.

Quantum dots are well known to confine electrons to a dot of quasi-zero dimension. This confinement leads to discrete energy levels, much like an atom, so that they are sometimes called “artificial atoms”. The energy levels can be controlled by changing the size and shape of the quantum dot. As a result, they are researched for use in future applications such as diode lasers and solid-state quantum computation. The quantum dots nucleate spontaneously under certain conditions during molecular beam epitaxy (MBE), when elements with different lattice constants are grown on a substrate. The resulting strain produces self-assembled nanodot islands on top of a two-dimensional layer. However, it is difficult to control quantum dot size by using such a crystal growth mode. We tried to determine the number of atoms in a nanocluster, which is a precursor for a dot, to control the dot size quantitatively.

The confinement of the clusters to half of a surface lattice unit (red triangle at Fig.4-27(a) will result in a limitation of the size of the clusters to a maximum value. However, the atoms in the nanoclusters could not be individually recognized. We present a method for measurement of the average number of atoms in a cluster by crystallizing nanoclusters. To determine the number of the atoms, the amount of deposited material per area has to be divided by the number of clusters per area. The number of clusters per area can be easily determined from STM images such as the one presented in Fig.4-27(b). More difficult thing is the reliable measurement of the deposited amount of material. Fig.4-27(b) on the right shows a STM image of a crystal of nanoclusters gathered by annealing. In half of the surface lattice unit (red triangle in left figure), 6 atoms can be recognized separately. This structure is well known to have 45 atoms under the surface 6 atoms. As a result, we found that 8 atoms exist in the cluster in Fig.4-27(a), and the number of atoms in a cluster depends critically on the size of the surface lattice unit. And also the cluster size was found to be largely independent on the cluster material. These results have opened up a way to control quantum dot size by using quantitatively determined nanoclusters.

Reference
Asaoka, H. et al., Size of Small Si and Ge Clusters on Si (111) and Ge (111) Surfaces, Surface Science, vol.588, 2005, p.19-25.