[III-1] [초청]

Atomic and electronic structure of the Ge(111)-c(2x8) surface studied by STM

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The geometric and electronic structures of the semiconductor surfaces including Si and Ge have been the objects of the intensive studies. Among them, much of the past works were focused on the surfaces of Si, but relatively less on those of Ge have been studied until the interest on Ge surfaces emerged due to unique electronic properties of Si/Ge overlayer structure. While chemically similar to Si, the surfaces of Ge show both similarities and dissimilarities with those of Si. The cleaved surfaces of Si(111) and Ge(111) have common 2x1 structure, yet the annealed surface of Ge(111) has a c(2x8) reconstruction, different from that of Si(111) having 7x7 reconstruction. The difference in the stable geometric structures is also accompanied by difference in the surface electronic properties, i.e., Si(111)-7x7 surface is metallic, whereas the Ge(111)-c(2x8) surface is semiconducting.

We have used scanning tunneling microscopy (STM) with various bias voltages to investigate the atomic and electronic structures of the Ge(111)-c(2x8) surface and the defects on it. The clean surface was prepared by repeated cycles of Ar^+ ion bombardment at 400°C and subsequent annealing up to 650°C. The atomically resolved STM images verified the simple adatom model of Ge(111)-c(2x8) in which adatoms of alternating (2x2) and c(2x4) subunits cover the (1x1) substrate, leaving an equal number of rest atoms. When the various bias-voltage is applied, the STM images of the Ge(111)-c(2x8) surface manifest variations in contrast. While only adatoms of appear in the images with negative sample biases (occupied-state images), both adatoms and rest-atoms are simultaneously imaged with positive biases (unoccupied-state images) but changing contrast with varying voltages. The image reveals that various types of the defects are observed to form on the surface. These defects also exhibit significant voltage-dependent variations in brightness. In particular, delocalized brightness variation near the defects is prominently observed with low bias voltages. The delocalization in the image is of electronic origin and found to be associated with the band banding near the defects which changes the amount of the states contributing to the tunneling. This is found to be due to the defects being charged relative to the clean, perfectly-ordered part of the Ge(111)-c(2x8) surface. We identify these defects and characterize their charged nature. Information about the electronic structure of the Ge(111)-c(2x8) surface can be extracted from the voltage-dependent variation in the image. The amplitude of the bias-dependent delocalized brightness will be also discussed in relation to the electronic structure of the clean surface.