

Influence of strain on thin film growth of Si on the Ge (111) surface

Izumi MOCHIZUKI, Aki TOSAKA, Yukichi SHIGETA*

*Nanoscience and Technology International Graduate School of Arts and Sciences,
Yokohama City University.*

The electric state of nanostructures has been investigated because it is essential for creating new devices. Since it is known that the electric state of nanostructures depends on its structures, it is necessary to understand the influence of the lattice strain on thin film growth to reveal the electric state of nanostructures. To control the strain in the surface lattice, we have selected the $\sqrt{3}\times\sqrt{3}$ -Ag structure which is typically formed on both surfaces of Si(111) and Ge(111) by a Ag adsorption[1,2] and studied about the influence of the strain on the quasi two-dimensional electron gas (2DEG) state formed on the $\sqrt{3}\times\sqrt{3}$ -Ag structure. The dispersion of the 2DEG state could be modified with the lattice strain introduced by hetero-epitaxial growth such as the Ge/Si(111) or the Si/Ge(111). Since the lattice constant of Si is about 4 % smaller than that of Ge[3,4], the compressive strain is induced in the Ge layer grown on the Si(111) and the tensile strain is induced in the Si layer on the Ge(111) such as a Ge/Si(111) and a Si/Ge(111) [5,6].

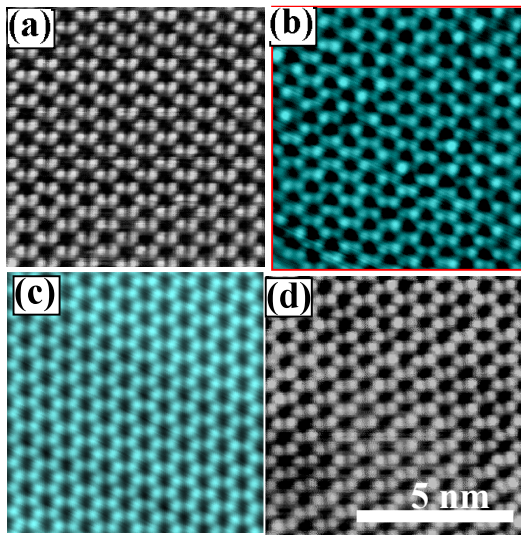


Fig. 1 RT-STM images of (a) Si(111) - $\sqrt{3}\times\sqrt{3}$ -Ag, (b) S- $\sqrt{3}$ Ag surface with $\theta_S = 1.0$ BL, (c) Ge(111)- $\sqrt{3}\times\sqrt{3}$ -Ag and (d) G- $\sqrt{3}$ Ag surface with $\theta_G = 1.0$ BL (8×8 nm²). All STM images show a typical feature of the HCT structure.

We have investigated that the electronic states of the compressive and tensile $\sqrt{3}\times\sqrt{3}$ -Ag structure on the Ge/Si(111) and Si/Ge(111) measured with a scanning tunnelling microscope (STM) and an angle resolved ultraviolet photoelectron spectroscopy (ARUPS), and reported that the relation between the strain and the effective mass of the 2DEG shows that the tensile strain makes the effective mass heavy [5, 6]. Since the results are based on the relation in the film thickness with in 1BL, we have tried to investigate the relation over 1 BL.

The STM observations were performed in our laboratory (U-STM, ULVAC), and the ARUPS observations were performed in BL-18A (Institute for Solid State Physics, University of Tokyo). The STM images were taken in the constant-current

mode with a tunnel current I_t of 50 pA and several sample bias voltages V_s , at room temperature (RT). All ARUPS spectra were measured with the polarized light with the photon-energy of 21.2 eV at low temperature (about 120 K). The angular resolution was less than 0.3° , which corresponds to 0.010 \AA^{-1} indicated by a wave number, and the energy resolution was less than 0.05 eV.

Figures 1(a)-(d) show the STM images: (a) the Si(111)- $\sqrt{3}\times\sqrt{3}$ -Ag surface, (b) the Si/Ge (111)- $\sqrt{3}\times\sqrt{3}$ -Ag surface (the S- $\sqrt{3}$ Ag) with a coverage of Si at 1.0 BL and (d) the Ge/Si(111)- $\sqrt{3}\times\sqrt{3}$ -Ag surface (the Ge- $\sqrt{3}$ Ag) with a coverage of Ge at 1.0 BL.

These images show a same feature from the honeycomb chained trimer (HCT) structure at RT [5], and we have confirmed that each electronic structure observed with the ARUPS is similar to each other. The relation between the strain and the effective mass of the 2DEG shows that the tensile strain makes the effective mass heavy. However, the mass in the $\sqrt{3}\times\sqrt{3}$ -Ag structure on the Si/Ge(111) decreases over 2 % of the deformation as shown in Fig. 1.

The result is incompatible with the linear relation between the strain and the effective mass with in the thickness of 1 BL [6]. For this reason, we assume that the increase of lattice spacing in the Si(111) layer over the 2BL is due to the intermixing of Ge atoms into the Si layer and the tensile stress in the Si layer is relaxed by the intermixing. We will make clear the intermixing by using Core-Level Photo electron Spectroscopy.

References

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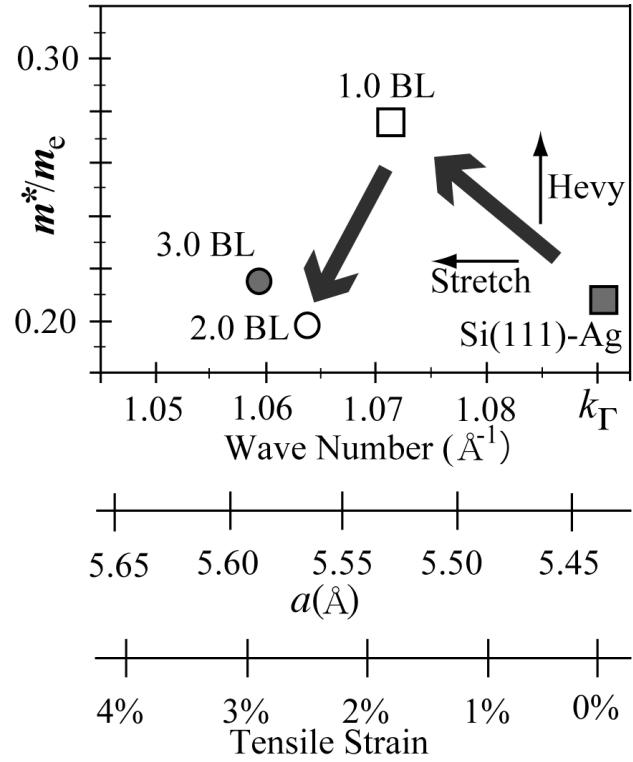


Fig. 2. Relation between the strain and the effective mass of the 2DEG in the $\sqrt{3}\times\sqrt{3}$ -Ag structure on the Si/Ge(111).