ELECTRONIC STRUCTURE OF STRAINED Si (111) √3×√3-Ag SYSTEM

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The strained Si devices have been widely studied because of its potential for improvement in electrical properties. It is difficult to observe the strains in a bulk system precisely. However, in the case of a surface system, we can observe the quantity of the strain and a change of electrical properties, directly. We have investigated the influence of the lattice strain to a quasi-two-dimensional electron gas state (2DEG) of the √3×√3-Ag structure formed on the strained Ge and Si thin films using Angle-resolved Photoemission Spectroscopy (ARPES) [1, 2].

We utilize the difference of the lattice constant between the Ge and the Si crystals to prepare strained surfaces. Since the lattice constant of Ge is 4% larger than that of Si, it is expected that a Si film on the Ge(111) surface has tensile strains and a Ge film on the Si(111) surface has compressive strains as shown in Fig.1. Though the structure on the surfaces is changed depending on the quantity of the strain, the √3×√3-Ag structures on both the Si(111) and Ge(111) surfaces show the Honeycomb Chained Trimer (HCT) structure, independently of the strain. So we can observe the 2DEG of these surfaces to study the relation between the strain and the electric properties.

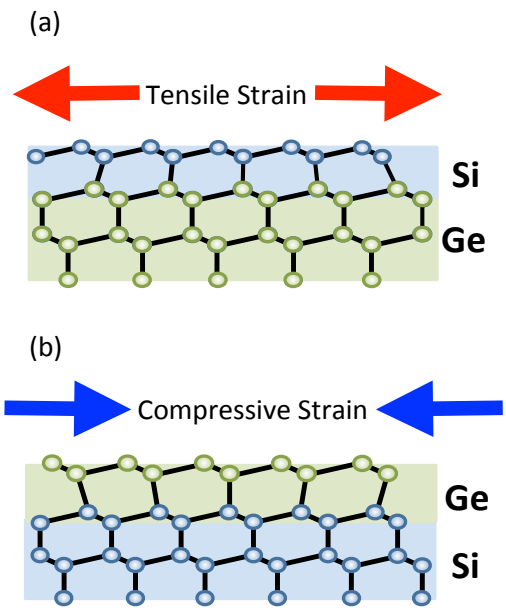

Fig. 1 Schematic diagram of (a) tensile strained Si layer on Ge(111) surface and (b) compressive strained Ge layer on Si(111) surface.

As reported previously, we found that the compressive strain makes the effective mass m^* of the S_1 state in the 2DEG to be light and the tensile strain makes the m^* of the S_1 state to be heavy [1, 2]. Figure 2 shows the relation between m^* and the quantity of the strain. The compressive strain of the Ge bilayer (BL) on Si(111) is 2.7% and an decrease of m^* is 30%, and the tensile strain of the Si bilayer on Ge(111) is 2.1% and an increase of m^* is 33%. The dependence of m^* on the quantity of strain is very interesting. In order to study the relationship between the strain and the m^*, the system which have a smaller value of the strain should be prepared.

To introduce the small vale of the strain, we form the system of Si/Ge/Si(111)√3×√3-Ag which is schematically shown in Fig. 3. First, two BL of Ge is deposited on the clean Si(111) surface and annealed at 630 °C. Next, one BL of Si is deposited on the Ge/Si(111) and annealed at 450 °C. Then, one monolayer of the Ag is deposited on Si/Ge/Si(111) and annealed at 450 °C. We prepared the samples in the preparation chamber of PF BL-18A and the surface structures were checked by Low Energy Electron Diffraction (LEED). The surface of the Ge layer deposited on Si(111) shows the clear 5×5 LEED pattern after annealing. The result shows that the Ge layer has compressive strain. The surface of the Si layer on the Ge/Si(111) shows the 1×1 LEED pattern after annealing. Finally we confirmed √3×√3 LEED pattern after the deposition of Ag on Si/Ge/Si(111) and the annealing. To form atomically flat surfaces without intermixing, we have done a feasibility study on the deposition conditions (the appropriate film thickness and annealing temperature) by using the Scanning Electron Microscope and Atomic Force Microscope.

The 2DEG state of Si/Ge/Si(111) √3×√3-Ag sample was observed by ARPES at PF BL-18A. Though observed S_1 peak is obscure, the result shows that the Si/Ge/Si(111) √3×√3-Ag surface has the tensile strain of 1.8±0.4 % which is the smaller than one BL of Si on Ge(111) √3×√3-Ag surface as expected. And the ARPES result may suggest that the relation between the strain and the m^* does not linear.

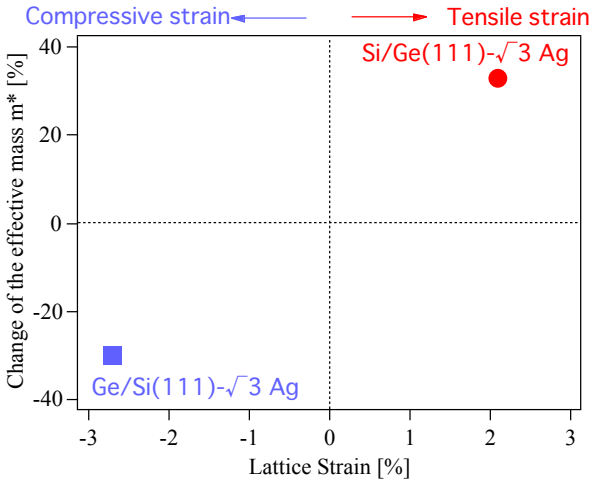

Fig.2 The relation between the effective mass m^* and the quantity of the strain[1,2].

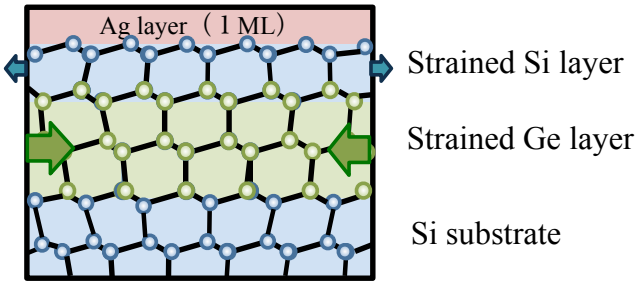

Fig. 3 Schematic diagram of Si/Ge/Si(111)-√3×√3-Ag sample.

[Acknowledgment]
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[References]

[1] Izumi Mochizuki, Ryota Negishi and Yukichi Shigeta, J. Appl. Phys. 106 013709 (2009)
[2] Izumi Mochizuki, Ryota Negishi, and Yukichi Shigeta, J. Appl. Phys. 107, 084317 (2010)