Electronic band structure of Au-induced nanowires on Ge(001) studied by angle-resolved photoelectron spectroscopy

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One-dimensional electronic systems have attracted much attention with intriguing physical phenomena such as a Tomonaga-Luttinger liquid and Peierls-type metal-insulator transition. Atomic nanowires (NWs) formed on semiconductor surfaces are suitable systems to quest such intriguing physics. However, electrons in these NWs are not always strictly one-dimensional even if the atomic structures of the NWs were one-dimensional. For instance, two-dimensional undulation of the Fermi surface, reflecting inter-chain interaction, was observed in In/Si(111)-(4×1) [1].

Au-induced nanowires on Ge(001) (Au/Ge(001) NWs) is a unique example, of which a Luttinger liquid was claimed on the basis of decreasing density of state (DOS) with power-law behavior as a function of the binding energy near the Fermi level (E_F) [2-4]. On the other hand, it has been reported that the surface-state bands of Au/Ge(001) NWs exhibit two-dimensional nature [5-6]. The electronic band structure of Au/Ge(001) NWs is still in discussion [7].

In this project, we make clear the detail of the band structures of Au/Ge(001) NWs by angle-resolved photoelectron spectroscopy (ARPES) using synchrotron radiation with linearly polarized right. In the beam-time at BL19A in KEK-PF, we performed preliminary experiment in order to find the optimal condition for coming beam-time at CASSIOPÉE beamline in synchrotron SOLEIL.

Au/Ge(001) NWs were prepared *in situ* in a molecular beam epitaxy chamber connected to an analysis chamber. We used a flat *n*-type Ge(001) substrate. The Ge(001) substrate was prepared by several cycles of Ar^+ sputtering and annealing up to 900 K in a few minutes. Au was then deposited onto the surface at 740 K from a tungsten filament coated by Au. The surface periodicity and its quality were checked by LEED. A typical LEED pattern observed with the primary energy of 60 eV is exhibited in Fig. 1. ARPES measurements were performed at room temperature (RT) at BL19A in KEK-PF.

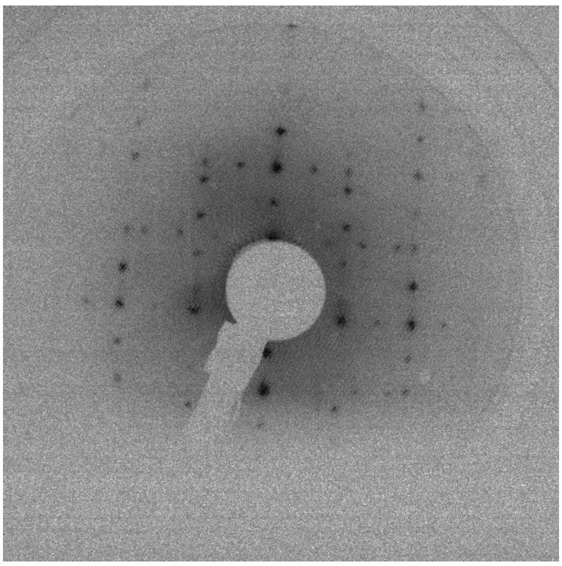

Fig. 1 LEED pattern of Au/Ge(001) NWs with the primary energies of 60 eV at RT. A *c*(2×8) reconstruction with double domain is observed.

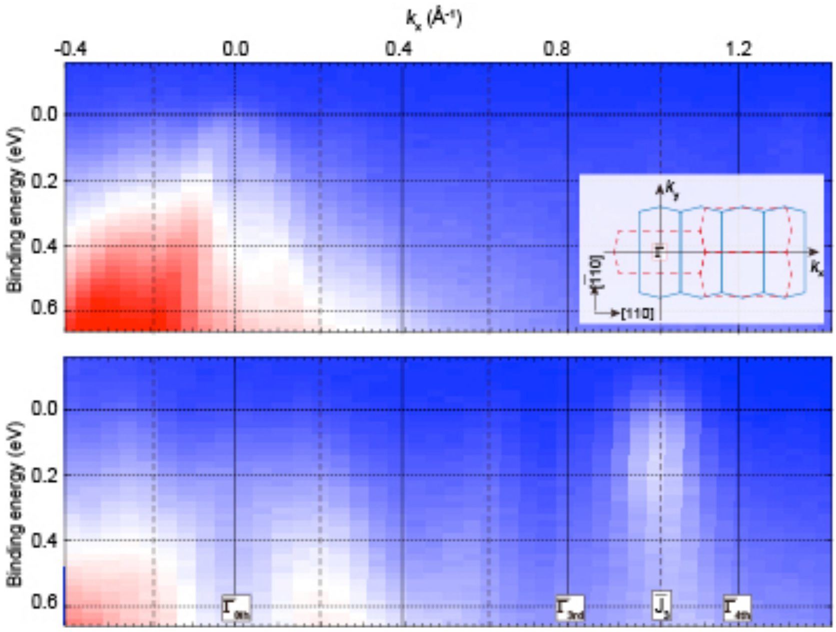

Fig. 2 (*upper panel*) ARPES intensity map recorded with the photon energy of 21 eV. In the inset, surface Brillouin zones of the double-domain surface are represented. (b) ARPES intensity map with $h\nu = 30$ eV.

Figures 2(a) and 2(b) show ARPES intensity maps along $\bar{\Gamma}\bar{J}$ recorded with the photon energies of 21 eV and 30 eV with *p*-polarized light, respectively. For the measurement with 21 eV, we observed several bands dispersing downward from $\bar{\Gamma}_0$, which are attributed to Ge-derived bulk bands. We could not clearly detect a surface-state band with this photon energy. On the other hand, we observed a surface-state band with $h\nu = 30$ eV around $\bar{J}_3$ in the projected bulk band gap. The surface-state band obviously crosses the Fermi level, Thus, we can conclude that the photoelectron intensity from the surface-state band of Au/Ge(001) NWs is largely enhanced with the photon energy of 30 eV.

In summary, we found optimal condition to observe the surface-state band of Au/Ge(001) NWs. We would investigate the Fermi surface and the band structure of Au/Ge(001) NWs by high resolution ARPES at CASSIOPÉE beamline in synchrotron SOLEIL under this way. The results can provide conclusive information on the electronic band structure of Au/Ge(001) NWs.

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