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Anisotropic two-dimensional metallic state on Au adsorbed Ge(001) surface

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One-dimensional (1D) metallic systems on metal-adsorbed Si and Ge surfaces attract much interest since exotic properties such as charge density wave transition and Luttinger liquid phase are expected to appear. Au adsorbed Ge(001) surface has been reported as a candidate for 1D metallic system[1]. The scanning tunneling microscopy (STM) revealed that the surface consists of chain structures which elongate along <110> direction and are separated in 4× periodicity of the substrate unit cell[1-3]. One of the structural models proposed so far includes periodic arrangement of Au adsorbed (111) nano-facets, and the buckled Ge dimer row with dangling bonds at the ridge of the nano-facets[3].

Recently, we have measured the electronic structure by angle-resolved photoelectron spectroscopy (ARPES) using He Iα light source[3]. A metallic state in the bulk band gap was observed in <110> direction around the J points of the c(8×2) surface Brillouin zone. The Fermi surface of the metallic band exhibits oval which indicates anisotropic two-dimensionality (2D) of the metallic band. If the metallic state was 2D and localized in the (111) nano-facet, the Fermi wave number on the (001) plane should depend on the incident photon energy (hν) because of the change of the emission angle of the photoelectron. In the present study, we have investigated hν dependence of the dispersion relation of the metallic band, and measured Ge 3d core levels to discuss the atomic structure in terms of the nano-facet model.

The experiments have been performed at the beamline 18A at KEK-PF. After the cleaning of the substrate Ge(001) surface (Sb-doped, n-type) by Ar^+ ion sputtering and annealing at 950 K, about 1 mono-layer (ML) of Au was deposited from a tungsten basket at substrate temperature of 675 K. A clear c(8×2) pattern and extra 8× spots were observed in the low-energy electron diffraction[3]. A hemispherical analyzer (VG Scienta SES100) was used both for ARPES and core-level measurements.

Figures 1(a-c) show dispersion relation around the J point in <110> (k_x) and k_y directions measured at hν =33 eV at room temperature. The spectra in the k_y direction were obtained by 90º rotation of the SES100 analyzer at the bottom of the band in the k_x direction. As clearly seen in the figure, the band has its bottom at the binding energy (E_B) of 0.13 eV and disperses towards and crosses the Fermi level, which confirms its anisotropic 2D metallic character. The Fermi wave number is the same as that observed at hν =21.22 eV both in the k_x and k_y directions. No hν dependence was observed between 17 and 40 eV[3]. Therefore, the metallic state extends in the (001) plane even if the surface local structure had nano-facets.

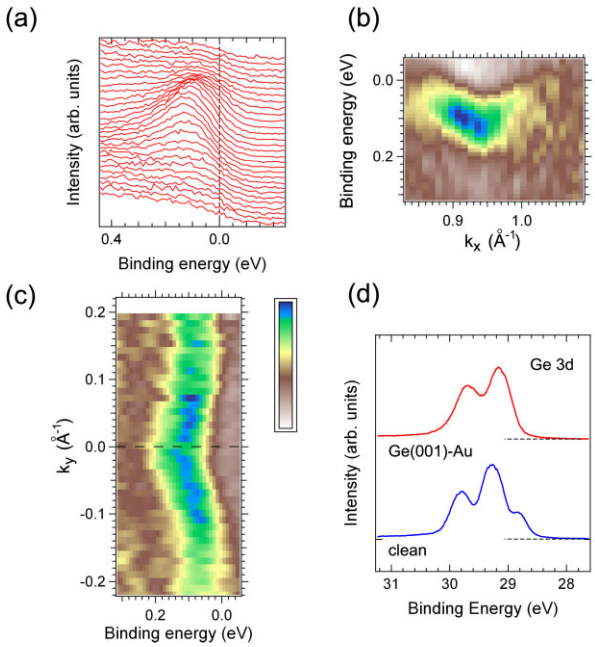

Figure 1: ARPES spectra of the metallic state in k_x direction (a) and their second derivative image (b). The image in k_y direction is also shown (c). Ge 3d core-level spectra are shown in (d).

Figure 1(d) shows Ge 3d core-level spectra on the clean and Au-adsorbed surfaces recorded at 80 K and at the photoelectron emission angle of 60° from the surface normal. Note that the energy difference of the main peak should be due to the different band bending. A shoulder structure at E_B ~28.8 eV on the clean surface originated from the upper dimer atoms disappears on Ge(001)-Au, suggesting that the buckled Ge dimer atoms with dangling bonds are absent in the chain structure.

Further structural studies are needed to explain all the experimental results and to reveal the relationship between the 1D morphology of the chain structure and the anisotropic 2D metallic character of the electronic structure.

References

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