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Surface states on Pd thin films formed on Au(111) surface

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Introduction

It has been known that a (111) surface of noble metals such as Au, Ag, and Cu has electronic states localized on the surface [1]. With isotropic and quadratic energy dispersion, the surface states can be regarded as one of the ideal two-dimensional electronic systems (2DES). 2DES formed at semiconductor interfaces exhibits various interesting phenomena depending on its electron density, which can be controlled by applying a bias voltage on a gate electrode. It would be interesting if one change and control the electron density of the metal 2DES since the phenomena on the metal 2DES can be directly visualized in a real space by scanning tunneling microscopy (STM) while ones at semiconductor interfaces cannot [2]. Since Pd (111) surface has similar surface states but above the Fermi energy, one can expect that a Pd overlayer can modify the Au surface states and change its electron density.

Through an STM observation of electronic standing waves, whose period is a half of the Fermi wave length, we speculated that the binding energy of the Au surface states is shifted by 0.3 *eV* on the Pd overlayer and thus the electron density in the surface states of the overlayer is reduced from that of the substrate [2]. In the present work, we studied on the states using angle-resolved photoemission spectroscopy (ARPES) to confirm the speculation. The obtained spectra indicate the binding energy shift of 0.2 *eV*, consistent with the STM work.

Experimental

The ARPES measurement was performed at BL-18A using the attached UHV apparatus equipped with XPS, LEED and surface preparation tools. A (111)-oriented single-crystalline gold sample was cleaned by repetitive sputtering and annealing and Pd was deposited on the clean substrate by an electron bombardment heating while the sample was kept at room temperature. The amount of the deposited Pd was measured with a quartz thickness monitor and double-checked with the intensities of Au 4*p* and Pd 3*p* peaks measured by XPS. Alloying between the two elements does not seem to occur judging from an analysis of XPS peaks before and after intentional alloying by high temperature annealing. The energy of the incident light for PES measurement was set at 20.1 *eV*.

Results and Discussion

First, we measured energy dispersion of the Au surface states by ARPES. From the obtained quadratic curve, the binding energy and effective mass of the states were measured 0.43 *eV* and 0.27m_e, respectively, consistent with the reported values [1].

Normal emission photoelectron spectra taken on samples with the Pd coverage of 0.1 ML to 1.0 ML are shown in Fig. 1. On the dominant peak, which is obviously due to the Au surface states, a shoulder is found at its low binding energy side. As the shoulder feature becomes large with the Pd thickness, we assign it to a peak due to the surface states formed on the Pd overlayer. While both peaks due to the Au and Pd-overlayer surface states move to lower binding energy with the Pd coverage, which is presumably due to surface roughness, energy separation between the two peaks is constant around 0.2 *eV* regardless to the coverage. We thus conclude that the binding energy of the Pd overlayer formed on Au(111) is lower by 0.2 *eV* than that of the substrate.

A energy dispersion curve measured on 0.3 ML Pd / Au(111) surface shows a quadratic relation with an effective mass of 0.31m_e, same as that of the Au states within an accuracy of the measurement. With the energy dispersion curve shifted to the lower binding energy from that of the Au substrate, the surface states formed of the Pd overlayer occupy less number of electrons than the Au states.

References

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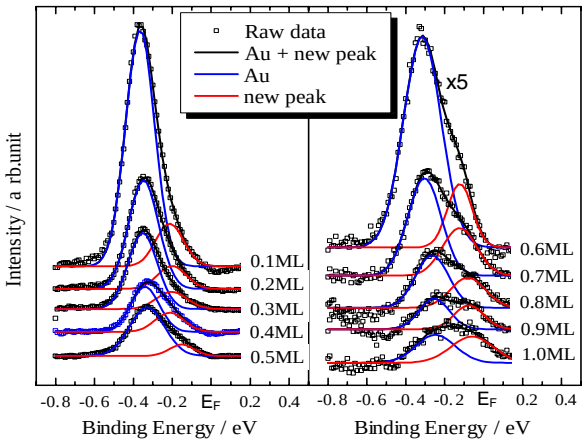

Fig. 1: Photoelectron spectra (normal emission) measured on the Pd-deposited Au(111) surfaces. The amount of Pd for each spectrum is written in the figure. The energy of the incident light is 20.1 *eV*.