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Kondo effect in transport on Co/Si(111)-$\sqrt{7}\sim\sqrt{3}$-In surface

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Surface superstructures formed by adsorption of metals on semiconductor surfaces are effective systems to study low-dimensional physics such as charge density wave, metal-to-insulator transitions, electron correlation, and quantum size effects. Among them, the Si(111)-$\sqrt{7}\sim\sqrt{3}$-In surface, which is brought about by interaction of indium with Si(111) dangling bonds, was found to have a nearly free-electron and metallic surface state with a parabolic band [1]. Thus, transition metal adsorption on this surface can be expected to be a good prototype to study the interaction of spins and two-dimensionally extended electrons. In this work, we have conducted temperature-dependent surface-sensitive transport measurements of Si(111) $\sqrt{7}\sim\sqrt{3}$-In with and without additional small amount of cobalt atoms adsorption. We have found minima and upturn in resistance with logarithmic behavior with very small amounts of Co adsorption, indicating the observation of Kondo effect [2]. Furthermore, we also found a resistance maximum at lower temperatures at higher Co coverages, which suggest a formation of a spin glass state mediated by RKKY interaction with surface-state electrons.

We have performed measurements of the temperature dependence of the resistivity of Si(111)-$\sqrt{7}\sim\sqrt{3}$-In from room temperature (RT) down to 10 K in UHV. The technique is the state-of-the-arts micro-four-point-probe method [3] with the probe spacing of 20 μm. The sheet resistivity of the pristine $\sqrt{7}\sim\sqrt{3}$-In monotonically decreased with cooling, indicating a metallic transport. The electron-phonon coupling constant obtained from the results was ~ 1.2, which is consistent with that derived from the recent photoemission spectra [1]. Successively, we have measured the resistivity of the $\sqrt{7}\sim\sqrt{3}$-In with tiny amounts of cobalt on it as a function of temperature. The resistivity decreased monotonically from RT to ~80 K while it turned to increase by further cooling. The upturn curve was well-fitted with a logarithmic function and estimation of its amount of increase in resistance made us believe that the weak localization picture is not reasonable. The temperature dependence of the resistivity within the measured range is reasonably explained by Kondo formula of dilute magnetic alloy.

In the presentation, we will show detailed data of transport measurements with various amounts of cobalt atoms and exhibit that descriptions by Kondo effect and RKKY interaction are reasonable.

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[2] J. Kondo, Prog. Theor. Phys. 32, 37 (1964).
[3] T. Tanikawa et al., e-J. Surf. Sci. and Nanotech., 1, 50 (2003).