18A/2005G089

Electronic properties of Manganese adsorbates on Si(111) √3×√3-Ag surface

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Introduction

Metal or semiconductor surfaces have provided various fascinating systems for exploring low dimensional physics. Also they have attracted many researchers' attention in terms of application, since surface superstructures have worked as good templates for adsorption of atoms or molecules. Among them, Si(111)7×7 and superstructures brought about by metal adsorption on that surface have been intensively studied, aiming at application for Si-based nano-devices. The Si(111) √3×√3-Ag surface, generated by one-monolayer-Ag termination of Si(111) 7×7 dangling bonds, shows good inertness and has free-electron-like electronic states, which are in good contrast to Si(111) 7×7. Recently, small amounts of alkali-/noble- metal adsorption on Si(111) √3×√3-Ag under 200 K have been found to exhibit novel superstructures [1]. Such adsorption condition is expected to be useful in studying the growth on .the inert surface, Si(111)√3×√3-Ag, while growths of other metal atoms on this surface under this condition have not been reported. In particular, transition metal atoms on this surface can be a prominent candidate for nano-spintronics devices. Motivated by this, we have recently studied the morphology of the initial growth of manganese (Mn) adatoms on Si(111) √3×√3-Ag at ~65 K[2]. We found coexistence of novel three types of Mn nanoclusters with the different probabilies of occurrence at different Mn coverages. This indicates that different Mn nanoclusters have different valencies.

In this work, in order to reveal the electronic states of Mn nanoclusters and Mn-adsorbed Si(111) √3×√3-Ag , we performed core-level photoemission spectroscopy (CL-PES) and angle-resolved photoemission spectroscopy (ARPES) for Si(111) √3×√3-Ag with various Mn coverages.

Experimental

A Si(111) wafer with its resistivity of 1-10 Ωcm at RT was used as a substrate. A clean Si(111) 7×7 was obtained by applying direct current under the ultra-high vacuum (~ 2×10^{-10} mbar) repeatedly, and was checked by low-energy-electron diffraction (LEED). The Si(111) √3×√3-Ag surface was fabricated by depositing one monolayer of Ag atoms onto the heated Si(111) 7×7 (~450ºC) and also confirmed by LEED. Mn atoms were deposited on the Si(111) √3×√3-Ag substrate at 100 K. The Mn deposition rate was calibrated beforehand by making a series of Mn films and Mn silicides [3]. The CL-PES and ARPES were performed at BL18A in PF, KEK. For the CL-PES, the photon energy was set at 110 eV to measure the Mn 3p spectra with the analyzer of VG CLAM1. ARPES of the surface states was done with VG ADES 400 at the photon energy of 30 eV.

Results and Discussion

Figure 1(a) shows the Mn 3p spectra of Mn / Si(111) √3×√3-Ag surface. The Lower spectra (0.1 ML of Mn adsorption) show a chemical shift compared to the upper spectra (6 ML of Mn adsorption). This indicates that the Mn nanoclusters at initial growth stage exhibit larger charge transfer to the substrate Si(111) √3×√3-Ag, compared to the bulk-like Mn. Similar behaviors were observed at different initial coverages (not shown here). Figure 1(b) displays band diagram of the Si(111) √3×√3-Ag surface with 0.033 ML of Mn obtained at 100 K. The original band of Si(111) √3×√3-Ag is known to be parabolic[4], while this band shows a splitting. The splitting was also observed at different initial Mn coverages. This can be understood by hybridization of the parabolically-dispersing band of Si(111) √3×√3-Ag and Mn-induced impurity band. In addition, another finding of the increase of Fermi wave number according to the increase of Mn coverages at initial growth supports the occurrence of charge transfer suggested from the analysis of Mn 3p spectra.

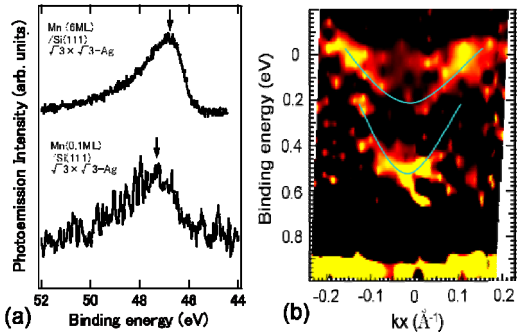

Fig. 1 (a) Mn 3p spectra and (b) surface states of Mn/Si(111) √3×√3-Ag.

References

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