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Strain-relieving ridge structure in a wetting layer on the W(1 1 0) surface

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Abstract

The growth behavior and atomic structure of the Ag wetting layer grown on the W(1 1 0) surface, was studied with scanning tunneling microscopy. Deposited Ag atoms preferentially adsorb at the step edges and reveal a step-flow growth behavior at room temperature. In the Ag wetting layer, a periodic bright ridge structure was observed along the $[\bar{3}\,3\,7]$ and $[\bar{3}\,3\,\bar{7}]$ directions. The atomic registry of the ridge structure is proposed on the basis of atomically resolved images.

Keywords: Scanning tunneling microscopy; Epitaxy; Nanostructures; Surface structure

1. Introduction

In heteroepitaxial systems, growth behaviors are determined by elastic strains and interface energies [1]. The balance of these two competing forces determines the atomic structure of the wetting layers. When the interface energy overrides the elastic strain, wetting layers show pseudomorphic (or commensurate) structures. Conversely, when the elastic strain overrides the interface energy, dislocation patterns are formed in metal on metal heteroepitaxy. An example of dislocation patterns is Moiré structures [2–8]. In heteroepitaxial systems, Moiré structures consist of periodic commensurate regions separated by incommensurate domain walls, which typically look brighter than commensurate regions in scanning tunneling microscope (STM) images. It was reported that several different Moiré structures are formed in the wetting layers of Cu on the hexagonal surface

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of Ru(0001), due to the equivalent choices between face-centered cubic (fcc) and hexagonal-close packing (hcp) stacking [2]. In the 2 monolayer (ML) Cu films on the Ru(0001) surface, for example, alternating fcc and hcp stacking (both pseudomorphic) regions are separated by the domain walls, where the Cu atoms occupy bridge (incommensurate) sites, just like the herringbone reconstruction on the Au(111)-$(22 \times \sqrt{3})$ surface [3]. On the body-centered cubic (bcc) surface of the W(110) substrate, strain-relieving Moiré structures have been reported on the wetting layers of Fe, Co, Ni, Cu, and Au [4–8].

In this paper, we report the growth behavior and atomic structure of the epitaxial Ag wetting layer grown on the W(110) surface, studied by STM. As a strain-relieving Moiré structure, the periodic ridge structure was observed along $[\bar{3}37]$ and $[\bar{3}3\bar{7}]$ directions. The atomic model of the ridge structure is proposed on the basis of atomic resolution images, ruling out the previous model based on diffraction studies.

2. Experiments

The experiments were performed with a home-built ultrahigh vacuum STM. The details can be found elsewhere [9]. The experimental setup consists of a preparation chamber connected to an STM chamber. The preparation chamber is equipped with two e-beam evaporation sources, a Knudsen-cell, low-energy electron diffraction and Auger electron spectroscopy instruments. The pressure of the preparation chamber was lower than 5×10^{-11} Torr and did not exceed 2×10^{-10} Torr during Ag deposition and substrate annealing. The W(110) substrate was cleaned by repeated cycles of annealing at 1800 K in O_2 pressure of 2×10^{-7} Torr and flashing at 2400 K to remove oxide layers. Ag (purity of 99.999%) was deposited with a Knudsen cell on the W(110) surface, while the substrate was kept at room temperature. The growth rate could be varied from 0.05 to 0.3 ML/min, as determined with a quartz thickness monitor and cross-checked by large-scale STM images. STM images were obtained in the constant-current mode at a tunneling current of 0.1–5.0 nA and the sample bias voltage of ±0.01 to 2.0 V.

3. Results and discussion

When an fcc metal is grown on a bcc(110) substrate such as W(110), there can be two possible growth orientations, Kurdjumov–Sachs and Nishiyama–Wassermann orientations. In the former, the close-packing direction of the films, fcc$[1\bar{1}0]$, is parallel to one of the close-packing direction of the substrate, bcc$[\bar{1}11]$ or bcc$[1\bar{1}1]$. In the latter, the fcc$[1\bar{1}0]$ direction aligns along the bcc[001] direction. The growth of Ag on the W(110) surface has been studied with low-energy electron and helium atom diffractions [10,11]. Ag forms several wetting layers with the Kurdjumov–Sachs orientation. Since this orientation is determined on the basis of a hard sphere model and ensemble averaged data, the real structure may be deviated from it.

Figure 1(a) shows an STM image of 0.05 ML Ag, grown on the W(110) surface at room temperature. Ag islands grow at the step edges of the W(110) surface. Ag islands are easily distinguished from the bare W(110) structure. Before Ag growth, the step edges of the W(110) are approximately straight and parallel. After Ag growth, previously straight step edges are irregularly decorated by Ag islands. Moreover, Ag islands look brighter in STM images than the nearby substrate terraces, probably due to their higher integrated electronic density of states. The atomic resolution images of the W-lattice were obtained at the bare terraces of the substrate, as shown in the inset of Fig. 1(a). The crystallographic orientation of the substrate is deduced from the atomic resolution images. As the coverage was increased, Ag-decorated irregular step edges grew further with a step-flow growth behavior. Figure 1(b) shows an STM image of a 0.8 ML Ag on the W(110) surface, after annealing at 350 K. The first wetting layer of Ag covers approximately 80% of the total area. The straight and parallel step edges of the substrate are in contrast with the relatively curved step edges of the Ag wetting layer.