

Photoelectron spectroscopy of α -Sn film grown on an InSb(001)- $c(8\times 2)$ surface

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1. Introduction

The Sn film grown on an InSb substrate is known to show a semiconducting α phase at room temperature. This α -Sn film, which is only stable below 13.2 °C in the bulk phase, has great potential abilities to be used as semiconductor laser devices and high electron mobility transistors [1]. Regarding the stability of the α -Sn film on an InSb substrate at room temperature, two origins have been proposed. The first origin is almost the same lattice constant between the α -Sn and the substrate, and the second one is the strong chemical bonds between Sn atoms and surface atoms at the interface. However, there is no evidence about the chemical bond at the interface so far.

On an InSb(001) surface, a Sn film was reported to grow epitaxially and to have a Sn(001)-(2 \times 1) reconstructed surface with the dimer structure [1-4]. On the other hand, different growth modes were reported, i.e. island and layer-by-layer mode, and thus the mechanism of the initial α -Sn film growth is not determined. In order to elucidate the mechanism of the α -Sn film growth on an InSb(001)- $c(8\times 2)$ surface and to determine the origin of the stability of the film at room temperature, we have performed Sn coverage-dependent high-resolution core-level photoemission measurements. Photoelectron spectroscopy is one of most powerful techniques to probe the interface such as heterojunction of Sn/InSb.

2. Experimental details

The high-resolution core-level photoelectron and LEED measurements were performed at beamline BL-1C at Photon Factory of the High Energy Accelerator Research Organization, Tsukuba, Japan. The photoelectron spectra were obtained by using a SCIENTA SES100 spectrometer with a total energy resolution of 100 meV. The InSb(001) sample was cleaned by repeating annealing at 370 °C and Ar⁺ ion sputtering (500 eV) until a sharp $c(8\times 2)$ pattern was observed in LEED. After the cleaning, clear surface states were observed in the valence-band spectra, and neither the In 4*d* core-level spectra nor the Sb 4*d* core-level spectra showed any indication of contamination. Sn adsorption was performed using an effusion cell after cooling down the samples to room temperature. All LEED and core-level measurements were performed at room temperature.

3. Results and discussion

Figure 1 (a) shows the In 4*d* core-level spectra of the clean surface and after adsorption of the 0.4 monolayer (ML) Sn. Dots and solid lines, which overlap the dots, are the experimental data and the fitting curves obtained by

analyzing the spectra by a standard least squares fitting method using Voigt functions. The presences of the surface (S1, S2, and S3) and bulk (B) components were confirmed

by measuring the surfaces using different photon energies and different photoelectron emission angles. After adsorption of the 0.4 ML Sn, the intensity of the surface components of the clean InSb(001) surface (S1 and S2) become smaller and a new component (S3) appears. Taking the electronegativities of In, Sn and Sb (1.78, 1.96 and 2.05) into account, we assign the origin of this new component as In atoms bonded to Sn atoms. As shown in Fig.1 (b), two Sn 4*d* components are observed at a Sn coverage of 0.75 ML. Of these components, S is dominant below 0.75 ML, but its intensity becomes smaller while the other Sn component becomes prominent at higher coverages. This indicates that S originates from Sn atoms at the interface and the other one from Sn atoms of the film. By considering that the Sb 4*d* core-level spectrum of the clean surface was the same as those obtained after the Sn adsorption, we conclude that the interface component S originates from Sn atoms bonded to In atoms, and thus that the origin of the stability of the α -Sn film on an InSb surface is the strong bonds between In and Sn atoms. Concerning the mechanism of the film growth, we obtained that α -Sn films grow as islands with a uniform height and shape.

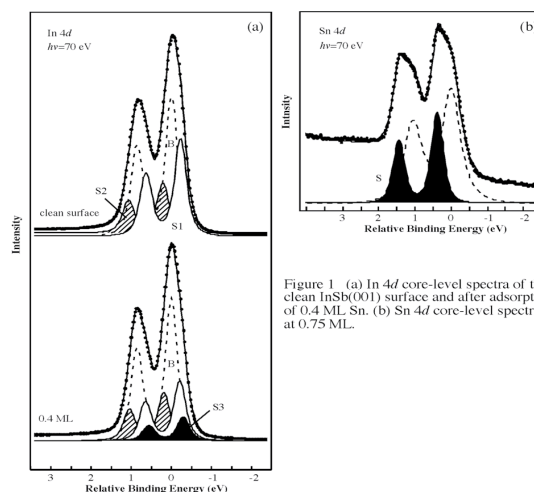


Figure 1. (a) In 4*d* core-level spectra of the clean InSb(001) surface and after adsorption of 0.4 ML Sn. (b) Sn 4*d* core-level spectrum at 0.75 ML.

References

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