

Hydrogen Adsorption Studies on Superlattices of Co/Ni

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We studied the adsorption of H_2 by superlattices of Co/Ni in an ultra-high vacuum system equipped with a mass spectrometer. Superlattice samples are dosed with 1000 Langmuir of H_2 and the desorption of the gas is measured with the mass spectrometer while the samples are heated from room temperature up to 800 K. The superlattices are made by alternating deposition of Ni films of 4.2 nm with Co films of either 3.0 or 4.0 nm until reaching a total superlattice thickness of 100 nm. Adsorption of hydrogen by the superlattices is described and discussed considering possible electronic effects arising from the superlattices' structure.

Introduction

There are some issues related to gas adsorption by surfaces that have not yet been extensively studied. One of these issues is the connection between adsorption and the electrical conductivity of the bulk. We have demonstrated that the adsorption of gaseous molecules by metallic surfaces modifies the surface electrical conductivity of a metal [1, 2]. We are interested to study now how the electronic band structure of unique materials (superlattices) modifies the adsorption properties of their surfaces. Thus, we hope that by studying adsorption properties of superlattices we will be able to correlate them with their unique transport properties [3, 4]. To prove this, we selected two superlattice structures of alternating Ni and Co layers which display oscillatory resistivity behavior. We studied the adsorption of H_2 and CO on two superlattices of Co/Ni with a fixed Ni thickness of 4.2 nm which show a maximum and a minimum value of the superlattice resistivity along the layers. The thickness of the Co layers corresponds to about 3.0 nm for a resistivity of $5 \mu\Omega cm$ and to about 4.0 nm for a resistivity of about $3 \mu\Omega cm$. The adsorption results are presented and discussed in this paper.

Experimental

Thermal desorption was measured for Co/Ni superlattices and also for pure Co and Ni films exposed to H_2 or CO in a modified AMETEK (Thermox Instruments Division) system designed for gas analysis. The experimental chamber consists of a 6-way stainless steel cross (base pressure around 1×10^{-9} torr) mounted on a pumping system, equipped with a sample manipulator, an Ar ion sputtering gun, a quadrupole mass spectrometer, a variable leak valve and a glass viewport.

Superlattices of alternating layers of $Co_{3.0}/Ni_{4.2}$ and $Co_{4.0}/Ni_{4.2}$ which repeated until a total thickness of 100 nm was reached, were prepared by a Molecular Beam Epitaxy technique on top of sapphire substrates ((110) orientation). For simplicity we will refer to the

first sample as S3042 and the second sample as S4042. The superlattices had fcc structure and grew along the (111) direction. Films of Ni and Co of 200 nm thickness were prepared by a Sputtering technique. The films also had fcc structures and grew in the (111) direction. The sputtered films covered an area of $\approx 0.9 \times 0.3 cm^2$ of the $1 \times 1 cm$ sapphire substrates. The superlattice covered a smaller area of the substrate than the sputtered films. The superlattice structure, the film thickness and the film orientation was determined from small and high angle X-ray diffraction (XRD).

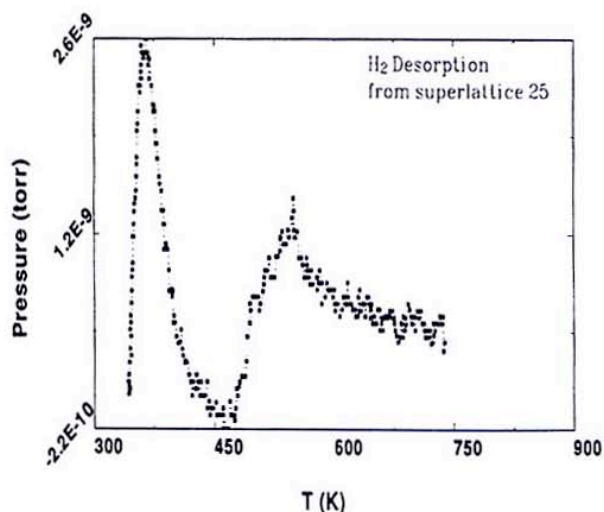


Figure 1. H_2 desorption from superlattice S3042 ($Co_{3.0}/Ni_{4.2}$)

Results and Discussion

Desorption of CO from the sputtered Co or Ni films displayed two peaks at 450 and 600 K which corresponds

to the typical desorption from either metallic surfaces. The peak at 450 K correspond to molecular adsorbed CO and the peak at 600 K corresponds to dissociated CO. The amount of gas adsorbed on either surface (Co or Ni), after dosing with 500 Langmuir, are also comparable in quantity. These experiments showed that surface properties of these sputtered films are identical to any comparable surface of a crystal of Co or Ni.

Desorption of CO from the superlattices S3042 and S4042 was similar to that of the single metal films but the molecular CO adsorption was highly diminished. The surface of the superlattices is more reactive than that of a single metal film.

On the other hand, the process of hydrogen absorption-desorption by a film or a superlattice is expected to be different from the adsorption by a single crystal surface due to the unique diffusion properties of hydrogen. We measured the hydrogen desorption spectra (TDS) for a variety of single metal surfaces: Pd, Pd alloys [5], Ni and Co foils [6]. From these studies we can differentiate between surface H_2 adsorption and bulk absorption. The desorption of hydrogen from Pd showed a TDS spectra typical of bulk absorption (a H_2 peak at 650 K), whereas in the case of Ni and Co, the hydrogen is confined to the surface (two peaks between 400-480 K).

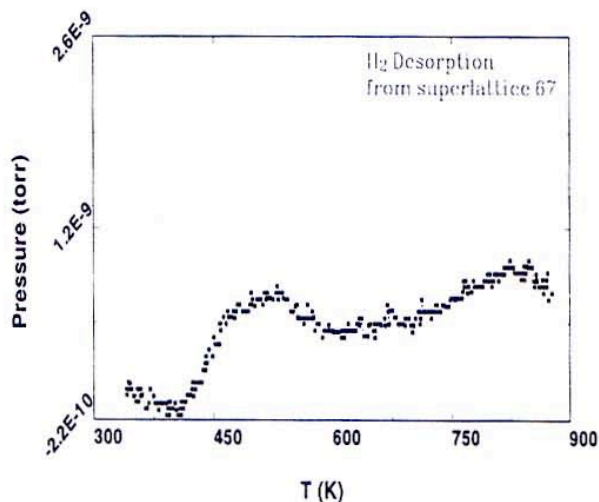


Figure 2. H_2 desorption from superlattice S4042 ($Co_{1.0}/Ni_{4.2}$)

A H_2 TDS spectrum from sample S3042 reveals the presence of H_2 adsorbed on the surface of the superlattice (peak around 375 K). Some diffused hydrogen is

also observed due to the presence of a peak around 550 K. This TDS is displayed in Figure 1.

A H_2 TDS spectrum from sample S4042 reveals the absence of H_2 adsorbed on the surface of the superlattice. Some diffused hydrogen is also observed due to the presence of a peak around 550 K and a peak around 800 K. This TDS is displayed in Figure 2.

The behavior of these two superlattices towards the adsorption of H_2 is totally different and it might be related to their electronic band structure since they display different resistivity. These preliminary results need to be confirmed with more rigorous experiments which we are planning to do in the near future.

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