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ScienceDirect

Vacuum 82 (2008) 529–534

VACUUM
SURFACE ENGINEERING, SURFACE INSTRUMENTATION & VACUUM TECHNOLOGY

www.elsevier.com/locate/vacuum

Study by AES and EELS spectroscopies of antimony and phosphorus evaporated on massive indium and on cleaned InP

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Received 23 April 2007; received in revised form 15 August 2007; accepted 15 August 2007

Abstract

In this paper, we give some results related to interaction mechanism between the elements V such as antimony or phosphorus with the metal indium. We used both powerful spectroscopy methods the Auger electron spectroscopy (AES) and the electron energy loss spectroscopy (EELS) for which the spectra were recorded in direct mode N(E). The antimony was evaporated on pure In metal or on cleaned InP surface involving the In metal because of its cleaning by the argon ion bombardment at low energy 300 eV. The antimony flow composed of Sb_4 species arrived with a thermal energy on the In metal surface. Such an energy was sufficient to their diffusion into the In matrix because of the low melting point of In metal (123 °C). A nucleation phenomenon occurred between Sb_4 and the In metal to form small islands of antimony metal in bulk. Further antimony evaporation enabled to increase the size of these islands towards the surface. However, the antimony evaporated on cleaned InP reacted chemically with the In metal distributed on the InP surface to form a thin layer of InSb. The inner stoichiometric layers of InP and the size of Sb_4 species and also the stability of InP versus the temperature impeded the interdiffusion phenomenon of antimony to occur deeply into the InP matrix. The InSb layer played the role to stabilise the surface of the InP compound versus the heating at 450 °C and the electron irradiation of 4 KeV energy. But, the phosphorus evaporation on In metal or on cleaned InP led to form chemical bonds InP. The phosphorus flow included chemical species P and P_2 with a thermal energy able to stimulate the chemical reactivity process between indium and phosphorus to form the InP compound.

Keywords: Surface; Evaporation; Antimony; Phosphorus; Electron energy loss spectroscopy; Auger electron spectroscopy; Heating

1. Introduction

The evaporation of group V over layers on III–V compounds and III metal surfaces is of large interest for fundamental studies of interfaces. This is essential in realizing advanced optical and electronic devices. However, many works have been done about the growth methods to form thin layers on substrates. These methods are based on the interaction process between the evaporated matters and the substrate. Feenstra and Martensson [1] had performed a study about the evaporation of antimony on III–V compounds to show the growth nature. On the other hand, the antimony played the role of electrical passivation layer for InP [2–6]. Recently, the growth method MOVPE was used to evaporate the trimethyl antimony on the indium phosphide [7]. But, many problems had been encounted about the crystallisation process [8]. In this paper, we are interested in evaporating the element V such as antimony or phosphorus on the metal indium substrate or on the cleaned InP. We used in this study the spectroscopy methods well appropriate to characterize the material surfaces such as the Auger electron spectroscopy (AES) and the electron energy loss spectroscopy (EELS). Our purpose is to understand the interaction mechanism between the element V and the element III and to show their settlement mode.

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0042-207X/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.vacuum.2007.08.002

2. Experiments

The In and InP samples were cleaned chemically ex situ by using H_2SO_4, acetone and dionized water. After their introduction into the spectrometer chamber, the recorded AES spectra showed the presence of contamination layer composed of carbon and oxygen. We used the argon ion bombardment at low energy 300 eV to remove them. In order to characterize the surface of those materials, we used a hemispherical spectrometer operating in direct mode N(E). The pass energy between the deflectors was of about 80 eV, corresponding to a good compromise between the transmission and the resolution of the apparatus [9]. The pressure in the spectometer chamber was of about 10^{-9} Torr.

2.1. Evaporation of antimony on massive indium

The metal antimony put in a Knudsen cell was heated until evaporation. We note that antimony is known to sublimate to give species Sb_4. They were deposited on the indium metal. The interaction phenomenon depended on the thermodynamic rules related to energy transfer between the antimony flow and the substrate. Furthermore, the In metal is known by its low melting point (123 °C). The heat brought by the Sb_4 species was sufficient to allow their diffusion through the surface to locate beneath the outmost layers of the In metal. We give in Fig. 1 the EELS spectra recorded at different primary energies E_p of the electron beam to study the surface. We discuss the results given by Fig. 1 as follow:

The first spectrum a is related to pure In metal recorded at $E_p = 250$ eV. The main energy loss peaks are located at 8.6, 11.6 and 19 eV. They concern the surface plasmons, bulk plasmons and interband transitions of In metal, respectively. The spectra b, c and d were recorded at the primary energies E_p (1000, 500 and 250 eV) to characterize the In surface previously submitted to an antimony evaporation on In metal during a short time. At low E_p energy as shown on spectrum d, the energy losses are due mainly to the In metal. We give spectrum e of pure Sb metal showing the energy loss peaks due to bulk plasmons and to the interband transition of Sb metal located at 16 and 33 eV, respectively. According to the comparison of spectra b, c and d with EELS spectrum e of pure antimony metal so recorded in the same experimental conditions, we deduce that this step of antimony evaporation on In metal led to form small islands of antimony metal without covering the In surface because the energy loss peaks related to bulk and surface plasmon of In metal remained still visible. We suggest that through the comparison of spectra b, c and d with the EELS spectrum f of InSb taken for comparison, there was no chemical reactivity between the antimony and the In to form the InSb compound. The In metal, because of its low melting point constituted a smooth surface to hot and heavy Sb_4 groups of antimony which went down into In matrix without any chemical

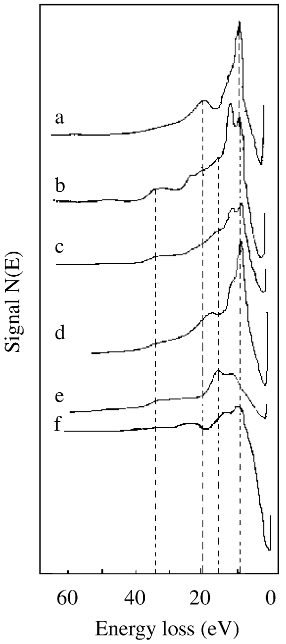

Fig. 1. EELS spectra of: (a) pure metal indium; spectrum recorded at the primary energy $E_p = 250$ eV. (b)–(d) Spectra recorded at the primary energies $E_p = 1000$, 500 and 250 eV, after short antimony evaporation on In metal. (e) Pure metal antimony, spectrum recorded at the primary energy $E_p = 500$ eV. (f) Cleaned InSb compound; spectrum recorded at the primary energy $E_p = 250$ eV.

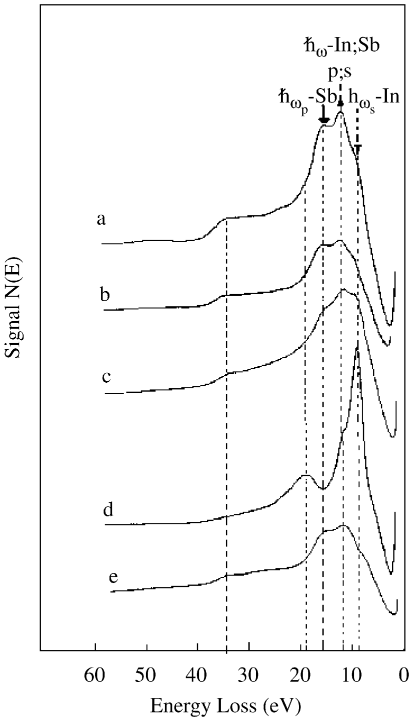

Fig. 2. EELS spectra of In metal submitted to excessive antimony evaporation. The spectra were recorded at different primary energies E_p: (a) 1000 eV; (b) 600 eV; (c) 400 eV. The EELS spectra (d) and (e) are related to pure In and Sb metal. They were recorded at the primary energy $E_p = 250$ eV.