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The Influence of Antimony Interlayers on the Formation of CdS Epitaxia Layers on InP (110) Studied by Raman, Photoluminescence, and Ellipsometry

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Abstract

CdS layers were grown on InP(110) substrates by molecular beam epitaxy (MBE). The interface was modified by introducing antimony layers of single or several monolayers thickness. The interfacial reaction usually leading to the formation of In_2S_3 and liberated P is found to be suppressed at the Sb terminated interface. Surprisingly, however, the crystalline quality of the CdS layer deteriorates if the Sb monolayer (ML) is present. The thicker Sb interlayers lift the substrate stabilised zincblende growth of CdS and the layer is hexagonal immediately. In addition, a transition from the cubic to the hexagonal modification is observed by *in situ* photoluminescence at about 200nm for the first time.

1 Introduction

The growth of CdS on clean cleaved InP(110) as an example of II-VI/III-V heterointerfaces has recently been investigated [1]. It has been shown that CdS grows in the metastable zincblende modification and a chemical reaction takes place at the interface resulting in an interlayer of In_2S_3 . The influence of metal interlayers on the interface properties, in particular the valence band offset and chemical reactivity, was also studied in a photoemission experiment [2]. While aluminium was found to enhance the reactivity, Sb leads to a suppression. Sb ML on InP(110) is known to produce significant Raman signals [3]. The growth of CdS on Sb terminated InP can therefore ideally be monitored by Raman spectroscopy using resonance condition for either the CdS layer or the Sb at the interface.

2 Experimental

CdS layers were grown on InP(110) substrates using single source MBE in ultra-high vacuum (UHV) at a base pressure of $\leq 2{\cdot}10^{-10}$ mbar. The substrate temperature during growth was 190°C. CdS was deposited stepwise at a rate of 3.2Å/min on either the clean cleaved InP or after pre-deposition of a Sb interlayer. In the latter case single epitaxial monolayers of approximately 5 ML of crystalline Sb were prepared

as decribed elsewhere [3]. *In situ* Raman and photoluminescence (PL) spectra were taken after each evaporation step at 90K using the same experimental setup as in ref.[1]. Additional information was obtained from ex situ spectroscopic ellipsometry (SE) from 1.5 to 5.5eV and low temperature (1.6K) PL measurements.

3 Results

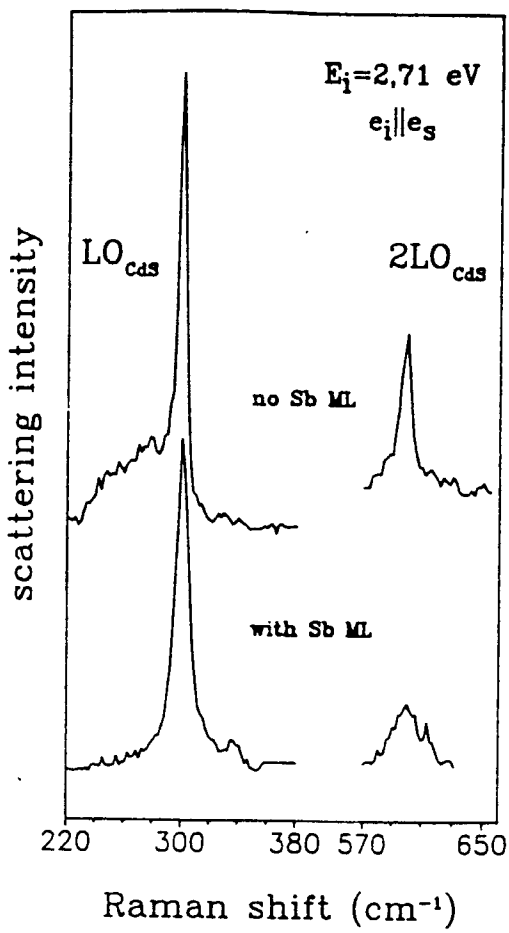

Figure 1: Raman spectra of 150Å thick CdS layers on clean and Sb ML terminated InP.

Figure 1 shows the Raman spectra obtained after the deposition of 150Å on the clean cleaved InP substrate as well as on a InP surface terminated by a single Sb ML. They are in both cases dominated by the Fröhlich induced longitudinal (LO) and 2LO phonon scattering stemming from the CdS layers. Without Sb termination an additional feature centered at about $250cm^{-1}$ is present in the spectrum. It was suggested that this feature is due to scattering from the interfacial reaction product of In_2S_3 [1]. The absence of this structure in the spectrum obtained for CdS/1 ML Sb/InP justifies this previously made assignment and shows the suppression of the interfacial reaction in accordance with the photoemission results. Due to the limited electron escape depth the interface could only be probed up to a few nanometers of CdS layer thickness by photoemission. Raman spectroscopy, on the other hand, allows the interface to be investigated over a much wider range of film thickness. As a result the chemical reaction at the interface is detected even for the CdS/1 ML Sb/InP case at coverages beyond the 150Å of figure 1. This is in agreement with the destruction of the Sb ML observed by Raman as well as photoemission spectroscopy. Consequently the Sb termination does not lead to an entire suppression of the interfacial reaction but delays it until the Sb ML is dissolved by a reaction with the impinging CdS.

Considering now the *in situ* PL measurements for CdS deposition on clean InP figure 2 shows the evolution between approximately 600 and 10000Å. The additional shoulder appearing at 2500Å on the high energy side indicates the presence of the hexagonal phase of CdS having a band gap which is almost 100meV larger than that of the cubic modification [4]. This naturally preferred modification then takes over and obscures the underlying cubic part of the layer. The structural transformation is

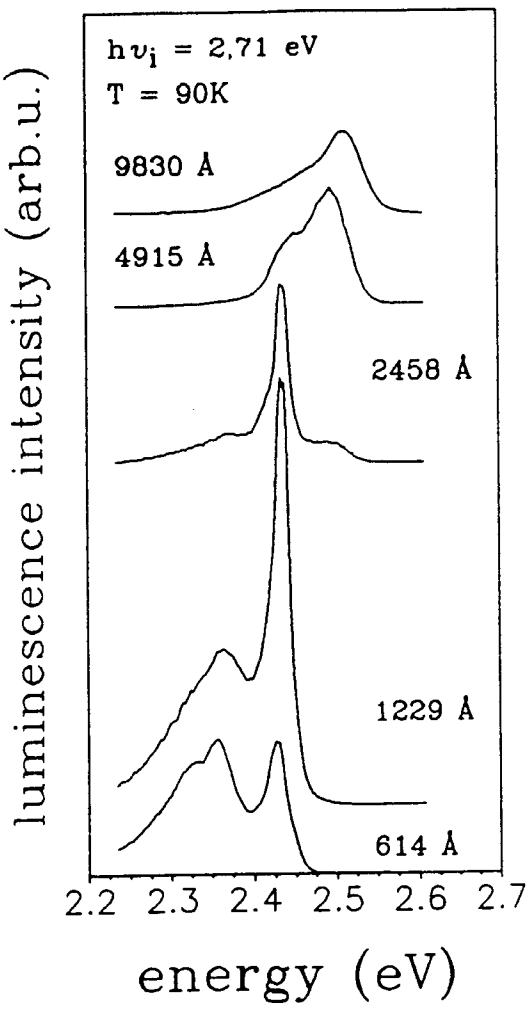

Figure 2: *In situ* PL spectra taken at various CdS coverages on the clean InP.

observed by ex situ SE and PL measurements in samples having thicknesses around 2000Å. It is suggested that dislocations formed during growth beyond the critical thickness of about 250Å lead to increasing roughness at the growth front and finally to a decoupling of the substrate stabilised zincblende growth. The PL of the layers of figure 1 reveals that both layers are cubic. Then the LO and 2LO full width at half maximum (FWHM) is a good measure for the crystal quality of these CdS films. It is apparent that the FWHMs are larger in the CdS/1 ML Sb/InP spectrum. Consequently the Sb ML leads to a deterioration of the crystal quality even though the interface reaction is suppressed. It may thus be argued that the presence of the In_2S_3 reacted layer is preferable for good epitaxial growth rather than an obstacle.

Considering the few ML thick crystalline Sb interlayer (c-Sb) the substrate stabilisation of growth is lifted and CdS grows solely in the hexagonal phase as judged from the PL spectra. For the hexagonal modification the LO and 2LO FWHMs are expected to be broader since two LO phonon modes overlap at the Brillouin zone centre. The evolution of the LO FWHM can be seen in figure 3 for all three kinds of interfaces. The initial decrease mirrows the evolution from the two dimensional to the bulk like material. The FWHM is lowest for CdS on clean InP over the entire coverage range. The increase observable at larger coverages is consistent with the partial transformation into the hexagonal modification. The FWHM for the CdS/c-Sb/InP case represents the hexagonal growth. The much larger FWHM for CdS/1 ML Sb/InP is, however, directly related to bad crystallinity in the cubic modification. Furthermore, when annealing this type of sample the layer also transforms into the hexagonal phase as judged from both PL spectra and the increase in FWHM towards the hexagonal value. In addition, the LO and 2LO scattering intensity (not shown) is also found to be correlated with the structure of the CdS layers.

4 Summary

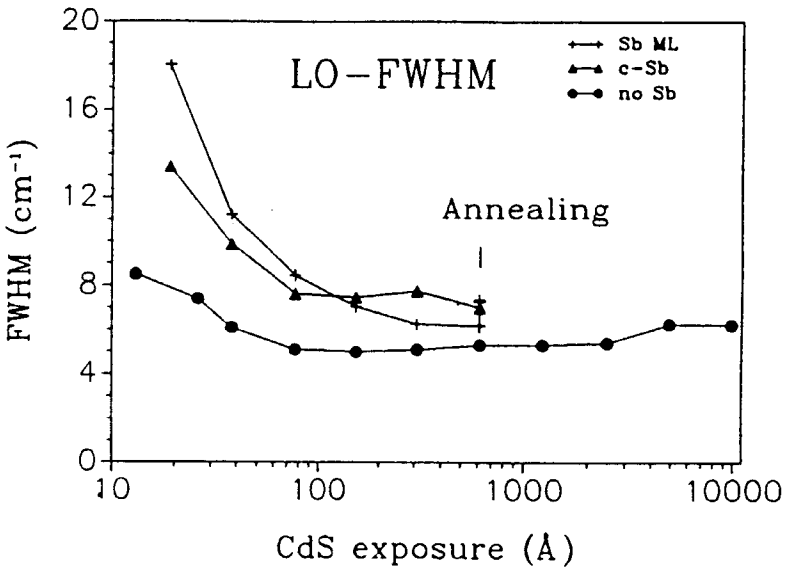

Figure 3: LO FWHM as a function of CdS exposure for the three different interfaces. CdS/1 ML Sb/InP was annealed at 680K after the final CdS deposition.

The results of this study provide a interesting insight in the interface formation between CdS and InP. Sb interlayers can partially suppress the chemical reaction at the interface but does not lead to improved crystal quality. The results may thus be relevant for the whole field of II-VI/III-V heteroepitaxy.

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