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GROWTH OF CdTe/α-Sn/CdTe/InSb MULTILAYER STRUCTURE BY MBE

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Grey-tin thin films confined by CdTe films were successfully grown on InSb(100) substrate. α-Sn grown on InSb(100) substrate at high temperature was higher in quality than those grown under lower temperature. The quality was examined using double-crystal X-ray diffraction. Above the critical temperature, the movements of the boundary between α and β phases were observed using a microscope. The thickness for the α-Sn layers was 30–1000 Å. Finally, an α-Sn/CdTe supperlattice structure has been grown up to 15 periods. During the growth of the superlattices, each layer showed a streak RHEED pattern. Even at interfaces, no spotty pattern was observed. The growth temperature was around 170 °C.

1. Introduction

The band gap of bulk grey tin is nearly zero. However, the band gap opening can be expected by one-dimensional quantum well confinement. Takatani et al. [1] demonstrated the band gap opening of grey tin thin films grown on CdTe (111) without a cap layer. If one can grow a CdTe/α-Sn superlattice, effective band gaps in the range of 0.1 to 0.5 eV can be obtained. Potential application as an infrared optical device covering the range of 2.5 to 10 μm, may be realized.

As is well known, semiconductor α-Sn undergoes a phase transition at 13.2 °C. However, the increase of transition temperature up to 70 °C by substrate stabilization effect, when the thickness is less than 0.5 μm, was reported by Farrow et al. [2]. Recently, higher transition temperatures were reported by Menedez et al. [3], Iwai et al. [4] and Seno et al. [5]. However, there is no report on the growth of InSb or CdTe on top of the α-Sn layer. Thus we tried growing an α-Sn/CdTe multilayer structure.

2. Experimental

Epitaxial growth was carried out in an MBE system equipped with a quadrupole mass spectrometer and analytical apparatus for reflection high energy electron diffraction (RHEED).

Polished (100) oriented InSb wafers were used in all experiments. Prior to loading, they were chemically etched and then were thermally etched for approximately 30 min at 415 °C. After cleaning, the surfaces revealed well defined RHEED patterns.

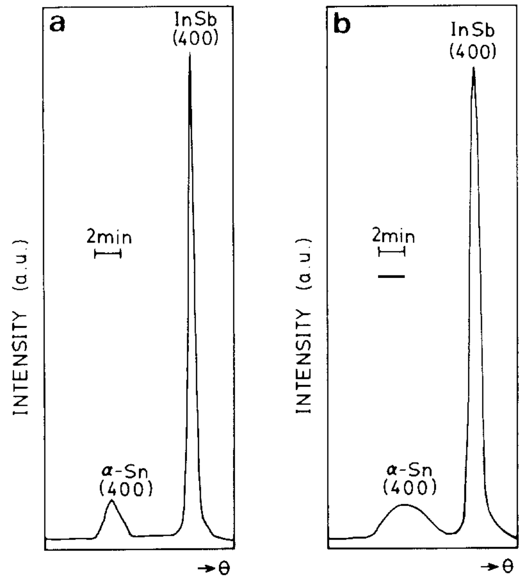

Fig. 1. X-ray rocking curve for α-Sn grown on InSb (100): (a) growth temperature of 75 °C (thickness of α-Sn = 1070 Å); (b) growth temperature of 50 °C (thickness of α-Sb = 1150 Å).

The growth rates of CdTe and Sn were 0.06 and 0.1 μm/h, respectively. During growth, the total pressure was in the order of 10^{-9} Torr. The growth temperatures were 50–170 °C.

3. Results and discussion

The difference in quality due to different growth temperature was examined by using double-crystal

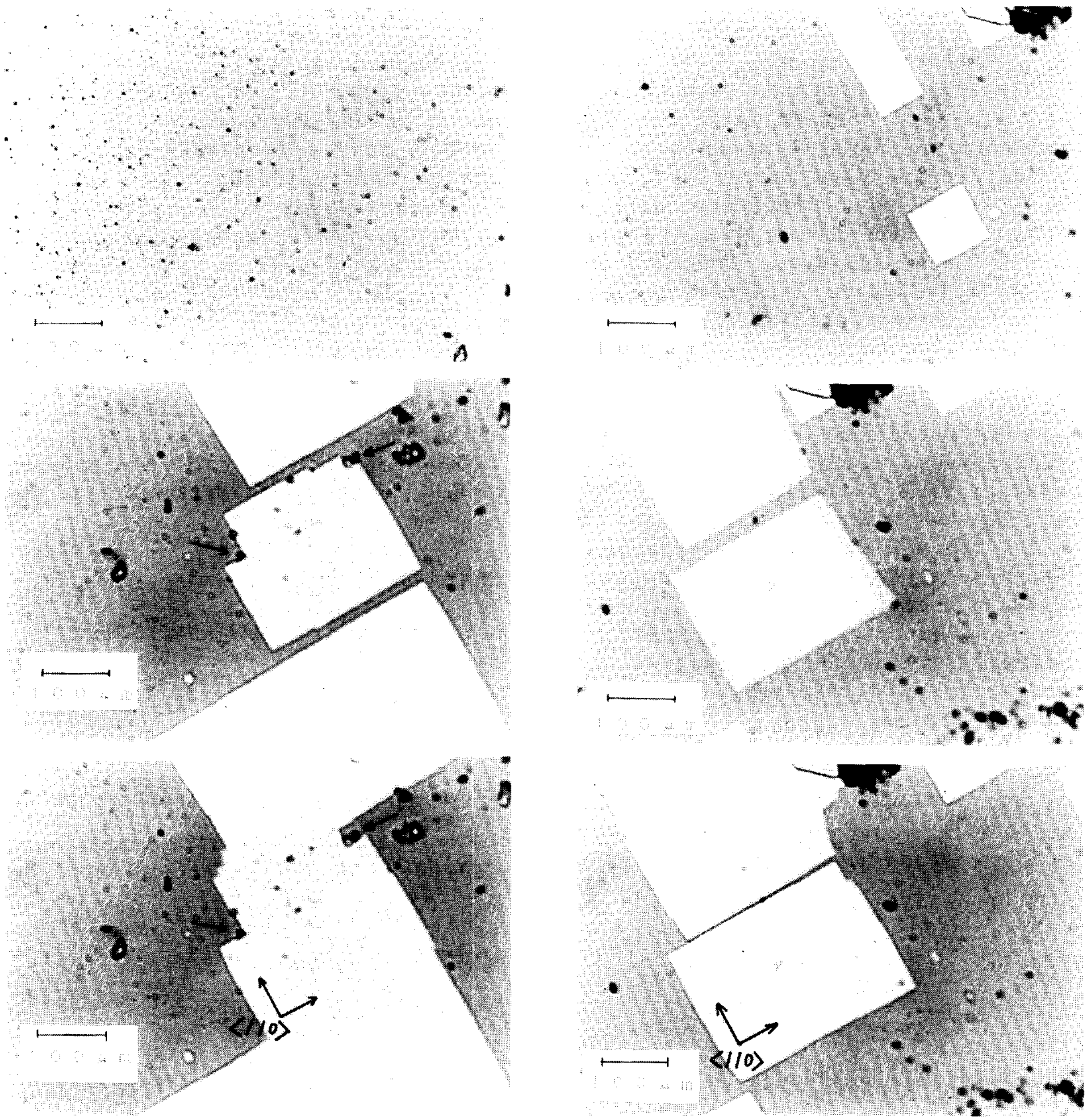

Fig. 2. Time dependent distribution of α and β region of Sn; (a) and (b) show different parts of the sample used in fig. 1a.

X-ray diffraction. As can be seen from fig. 1, at the growth temperatures of 75 and 50 °C, the full width at half maximum (FWHM) of the substrates was 30 and 55 arc sec, respectively, while the FWHM of the α-Sn films was 85 and 220 arc sec, respectively. We can conclude that as the growth temperature increases, the migration effect becomes more effective and the quality is improved.

When the temperature of the sample grown at 75 °C rose to 91 °C, transition from α to β phase took place, even when the temperature of the sample was kept constant. The movement of the boundary between α and β phases can be seen in fig. 2. Figs. 2a and 2b show the time dependent changes in different places on the sample, top to bottom. The transition seems to originate at some nucleus such as a defect. Even so, the movement of the boundary stopped at the points shown in the figures by arrows.

When the temperature of this sample was decreased by 10 °, the velocity of the boundary movement slowed down. This is the result of the thermodynamical instability of the crystals. The critical thickness h, calculated using Matthews and Blakeslee's equation [6], is about 1000–1300 Å. Due to insufficient data on the elastic moduli [7], only an approximate range can be calculated. At this thickness, it becomes energetically favorable for misfit dislocations to be made for α-Sn/InSb. This h must be decreased by the thermodynamical instability of α-Sn and by the defects at an interface.

α-Sn/CdTe superlattice structure could be grown up to 15 periods. The growth temperature was 160–170 °C, and the thickness of each layer was 30 Å. During the growth of the superlattices, each layer showed streak RHEED patterns. Even at interfaces, no spotty pattern was observed. This means that each layer underwent two dimensional growth.

4. Conclusion

CdTe layers have been successfully grown on α-Sn layers for the first time. α-Sn/CdTe superlattice structure has also been grown up to 15 periods. For the growth of α-Sn, there exists an optimum growth temperature due to the balance between thermodynamical instability and migration effect. In our case, it was around 160–170 °C. In addition, the movement of the α and β phase boundary towards ⟨110⟩ direction was observed.

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