HIGH-RESOLUTION ELECTRON MICROSCOPY OF TWIN-FREE (111) CdTe LAYERS GROWN ON VICINAL (001) GaAs SURFACES

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ABSTRACT

We report here on a High-Resolution Transmission Electron Microscopy investigation of (111) epitaxial CdTe layers on (001) GaAs substrates where twinning is impeded by a suitable misorientation of the substrate surface. It is also found that the layer (111) growth planes are slightly tilted with respect to the (001) GaAs planes. This tilt is explained in terms of preferential nucleation at surface steps and of mismatch accommodation on the vicinal interface.

INTRODUCTION

CdTe epitaxial growth has been achieved on a variety of substrates, either almost lattice matched such as Cd$_{0.96}$ Zn$_{0.04}$ Te (Magnea et al., 1987) or non lattice matched such as GaAs (Otsuka et al., 1985). (001) CdTe growth on (001) GaAs is feasible but implies that the interface has to undergo a 14.6% mismatch in all directions, and one is left with a high-density of grown-in defects (Feuillet, 1988). On the contrary, it appears easier to grow CdTe in the <111> orientation. In this case, the [112] CdTe direction is aligned with the [110] GaAs direction and the misfit in this common direction is reduced to 0.7%: in the direction at 90° from the previous one, i.e. when [110] CdTe is parallel to [110] GaAs, the misfit is again 14.6%. But, due to the low stacking-fault energy in CdTe, twinning occurs parallel to the interface, the density of twins decreasing when going from the interface towards the top surface of the layer. We shall report on preliminary results obtained when (111) CdTe growth is initiated on vicinal GaAs (001) surfaces and demonstrate the possibility of eliminating twinning.

Observations

The vicinal GaAs surfaces, tilted by 6° around [110] were prepared as detailed elsewhere (Cibert et al., 1988). This tilt leads to
exposing Ga dangling bonds at the terrace edges as deduced from previous polarity determination experiments by ion channeling (Chami et al, 1988). T.E.M. samples were prepared in cross sections by Ar⁺-ion milling and subsequently observed in a JEOL 200CX microscope operating at 200 KeV.

Fig. 1 is a high-resolution lattice image of a typical portion of the CdTe/GaAs interface viewed along the common [110] direction. There are no more twins parallel to the (111) growth planes. In addition there appears to be extra half-planes (as indicated by arrows) parallel to the (111) growth planes, ending up at the interface. In addition, the (111) CdTe planes are no longer parallel to the (001) GaAs plane, the rotation angle being of the order of 5°. Other "inclined" (111) extra-half-planes are detected that correspond to the usual misfit dislocations.

Fig. 1. <110> lattice image of a vicinal (111) CdTe/(001) GaAs interface.

Discussion

The way epitaxial layers "rotate" when grown on vicinal surfaces has been observed a number of times, especially in the case of low misfit systems (cf. for instance (Ohki et al, 1988)). In these cases, one has to accomodate the misfit within the interfacial inclined plane which, in short, can be written:

$$\frac{a_L}{\sin(\theta+\delta)} = \frac{a_s}{\sin \theta},$$

where $\theta$ is the misorientation angle of the substrate, $\delta$ the layer "tilt" angle, $a_L$ and $a_s$ the respective layer and substrate lattice parameter in the growth direction. This means that lattice accommodation is possible by a rotation of the layer lattice planes without resorting to misfit dislocations even for layers with overcritical thickness. Coming back to our case, $a_L = a_{\text{CdTe}}/\sqrt{2} = 3.74$ Å, $a_s = a_{\text{GaAs}}/2 = 2.82$ Å, $\theta = 6°$ yielding $\delta=2°$, which is much less than...