MBE GROWTH AND CHARACTERIZATION OF CUBIC MnTe(111) ON BaF₂ SUBSTRATES

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We report on growth by molecular beam epitaxy of cubic MnTe(111) layers on $BaF_2(111)$ substrates. Layers as thick as 0.2–1.0 μm were grown. Basic characterization by X-ray diffraction shows that the cubic crystal structure is deformed to orthorhombic symmetry.

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Growth of cubic MnTe is only possible by non-equilibrium techniques such as molecular beam epitaxy (MBE) [1–4]. Here, zinc-blende MnTe epilayers were grown by MBE in EPI-620 system on (111) oriented BaF_2. The bars of 5 × 5 or 15 × 15 mm² were cleaved in order to provide slices of 0.5–1.0 mm thickness. Surfaces of such substrates had almost some of cleavage steps. The substrates were soldered to molybdenum blocks with gallium. MnTe epilayers were grown from Mn and Te sources, at Te rich conditions, either directly on the substrate or after a deposition of a very thin (10–15 monolayers) CdTe buffer. The growth was monitored by in situ RHEED which showed diffraction streaks corresponding to a six-fold symmetry; no evidence of twinning was observed during all stages of the growth process. The growth was realized at about 300 or 400°C while changing the beam equivalent pressure (BEP) of Mn and Te fluxes in order to establish optimum growth conditions (BEP Te/Mn ratio was varied between 5 and 20). The layer thickness, determined by scanning electron microscopy, ranged from 0.4–1.1 μm, corresponding to the growth rate of about 0.2 μm/h.

MnTe layers deposited on (111)-oriented BaF_2 were characterized by (a) Nomarski contrast microscopy, (b) scanning electron microscopy, (c) X-ray analysis and (d) optical transmission measurements at 12 and 300 K.

In the first stage of X-ray diffraction studies we determined the crystal phase composition of the layers using a conventional powder diffractometer. In all investigated layers three crystallographic phases were detected: hexagonal MnTe, cubic MnTe and traces of cubic $MnTe_2$. The relative abundance of hexagonal to cubic MnTe changes from sample to sample without any evident correlation to the growth parameters (T_{subst}, BEP). In majority of examined samples the main phase was cubic MnTe in the form of a single crystal layer with (111) crystallographic planes parallel to BaF_2 (111) substrate. The interplanar spacing d, measured in

the grow.th direction, was evidently larger than the lattice parameter of cubic MnTe grown on GaAs(001) [1, 6]. Detailed measurements of different interplanar spacing were made using Bond spectrometer with Bartels monochromator. It enabled us to determine the absolute lattice parameters with accuracy of 1×10^{-4} Å. Measurements and calculations made for 333 symmetrical reflections showed that MnTe layers have an orthorhombic crystal structure with unit cell parameters: $a = 6.3440$ Å, $b = 6.3402$ Å, $c = 6.3716$ Å. The unit cell volume is slightly larger than in the case of cubic MnTe grown on GaAs(001) substrates by about 0.7%.

In order to investigate the crystal perfection of the layers we carried out measurements of the double crystal rocking curves as well as the reciprocal space maps (RSM). The full width at half maximum (FWHM) of 333 rocking curves were found to be equal to 47 arcsec for the substrates and to 720-1500 arcsec for cubic MnTe, depending on the sample. Such large values of FWHM are connected with defect structure of the layers, mainly with a mosaicity and the lattice parameter fluctuations. Aiming at a separation of the two contributions we determined the RSM using a high resolution triple-axis diffractometer. RSM of the symmetrical 111 reflections and non-symmetrical 440 reflections were obtained (see Figs. 1 and 2). The maps in the vicinity of symmetrical reflections give a direct information concerning the mosaicity and the lattice parameter fluctuation, while the maps around asymmetrical reflections allow us to determine the strain state of the layer. The analysis of the RSM for symmetrical and asymmetrical reflections showed that the rocking curve broadening is caused mainly by the mosaic structure and that the layers are almost fully relaxed [7]. The relaxation process in the epilayers is accompanied by an increased mosaicity directly visible on the RSM for symmetrical reflection. Since our substrates are transparent to the light in
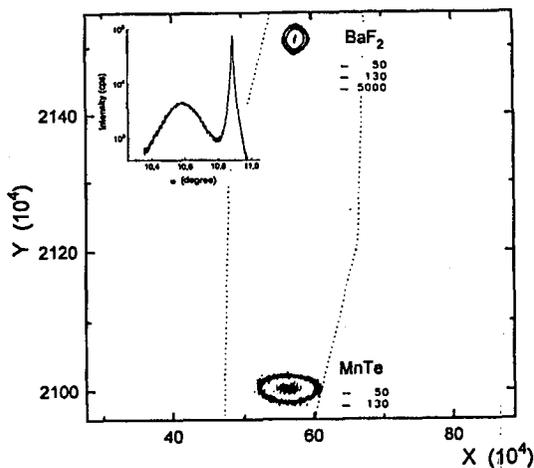
Fig. 1. Reciprocal space map in the vicinity of the symmetrical 111 reflections due to the substrate and layer. Inset shows the 111 reflection rocking curve. Both axes are in units $\lambda/2d$.
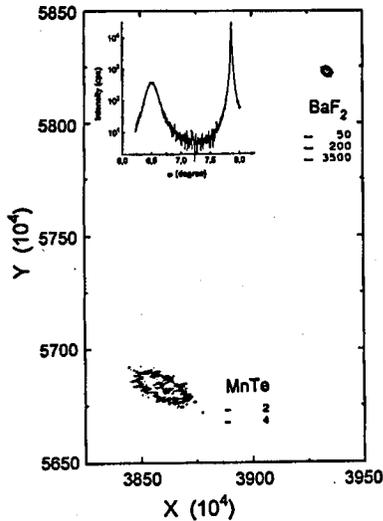
Fig. 2.   Reciprocal space map in the vicinity of the asymmetrical 440 reflection due to the substrate and the layer. Inset: the 440 rocking curve. Both axes are in units $\lambda/2d$.

the region corresponding to the fundamental band gap of MnTe, it was possible to perform direct absorption measurements. It will be the subject of another publication.

Acknowledgments

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