Vol. 88 (1995) *ACTA PHYSICA POLONICA A* No. 5

Proceedings of the XXIV International School of Semiconducting Compounds, Jaszowiec 1995

MBE GROWTH OF YbTe ON GaAs(100) AND BaF_2(111) SUBSTRATES

J. SADOWSKI, E. DYNOWSKA AND L. KOWALCZYK

Institute of Physics, Polish Academy of Sciences
Al. Lotników 32/46, 02-668 Warszawa, Poland

The structural properties of MBE grown YbTe layers were investigated by X-ray diffraction methods and photoluminescence measurements. YbTe films were grown on the ZnTe and CdTe buffer layers crystallised on the GaAs(100) 2° off oriented substrates and on the BaF_2(100) substrates. In the case of GaAs substrates the two-dimensional growth mode of YbTe was observed on reflection high energy electron diffraction picture. Results of the X-ray rocking curve and photoluminescence excitation measurements indicate that the structural properties of YbTe films are comparable to the properties of the MBE grown ZnTe and CdTe layers on the GaAs(100) substrates. The measured values of the YbTe lattice constant parallel and perpendicular to the growth plane show that the 1 μm thick layers are partially strained. The full width at half maximum values of the X-ray rocking curves are the smallest (900 arc seconds) for the YbTe films crystallised on the 2 μm thick CdTe buffer layer grown on the GaAs(100) substrate. In the case of BaF_2(111) substrate the two-dimensional MBE growth mode of YbTe was not observed.

PACS numbers: 81.15.Gh, 61.14.Hg.

1. Introduction

Rare earth telluride thin films can be grown by molecular beam epitaxy (MBE) with high crystallographic perfection [1]. These compounds crystallise in the rock salt crystallographic structure and using the MBE system it is easy to obtain ternary compounds (in the whole composition range) of rare earth chalcogenides with rock salt lead chalcogenides, what is important for semiconductor laser structures based on these compounds [2]. The relatively high energy gap (up to 2 eV) and the lattice constant values of 6.2 to 6.6 Å allow to crystallise laser structures in this material system, which work in the 1–8 μm wavelength range. From the rare earth chalcogenides the MBE grown europium (Eu) chalcogenides have been studied for several years [1]. MBE crystallization and the properties of thin films of the other rare earth compounds like Yb, Sm, Tm chalcogenides have

not been investigated so extensively. In this work we study the structural properties of ytterbium telluride (YbTe), 1 μm thick films crystallised on the CdTe and ZnTe buffer layers MBE grown on the GaAs(100) vicinal substrates and on the BaF_2(111) substrates.

2. Experiment

MBE growth processes were performed in the MBE system designed and manufactured in the Institute of Physics of the Polish Academy of Sciences in Warsaw. Samples 1 and 2 were grown on the GaAs(100) 2° off oriented epiready substrates, purchased from American Xtal Technology (AXT). Sample 3 was crystallised on a cleaved BaF2(111) substrate. YbTe was grown from the elemental Yb and Te sources. The MBE growth was monitored by the 10 keV reflection high energy electron diffraction (RHEED) system. To control the thickness of YbTe layers we have measured the intensity of He–Ne laser beam reflected from the growing film. Due to the interference of laser beam in the film we observe the periodical changes in the reflection intensity, which allow to control the thickness with about 300 Å (in the case of YbTe) accuracy.

As the lattice constant of YbTe ($a_{\mathrm{YbTe}} = 6.365$ Å) is relatively close to the CdTe lattice constant, for substrates we have chosen the MBE grown ZnTe and CdTe buffers crystallised on the GaAs(100) surface 2° off oriented towards [110] direction.

Three kinds of samples were grown as follows:

(i) 1 μm YbTe grown on the 1200 Å ZnTe buffer layer on the GaAs(100) — sample 1,

(ii) 1 μm YbTe grown on the 2 μm CdTe buffer layer on the GaAs(100) — sample 2,

(iii) 1 μm YbTe grown on the BaF_2(111) substrate — sample 3.

3. Results

The YbTe layers of samples 1 and 2 were grown in the tellurium rich conditions at the substrate temperature of about 360°C and the growth rate of 0.4 μm/h. For samples 1 and 2 the streaky RHEED diffraction patterns were observed during the YbTe crystallization process. In the case of MBE growth on the BaF_2 substrates, after 2 minutes of YbTe deposition spotty RHEED patterns appeared and up to 1 μm thick films the streaky RHEED patterns were not observed. X-ray rocking curves for samples 1 and 2, measured on the computer controlled single crystal DRON diffractometer are shown in Fig. 1. As the incident beam the Cu $K_{\alpha 1}K_{\alpha 2}$ radiation was used. The two neighbour diffraction peaks result from the X-ray diffraction on the same set of the layer crystallographic planes, but are taken in the different azimuthal angle sample positions (turned by 180° one to another). The angular separation of these two curves is proportional to the disorientation angle of the layer (100) crystallographic planes versus substrate (100) planes. From Fig. 1 we see that the disorientation angles of the epilayers versus GaAs(100) substrates are as high as 1.9° — for the YbTe layer crystallised on

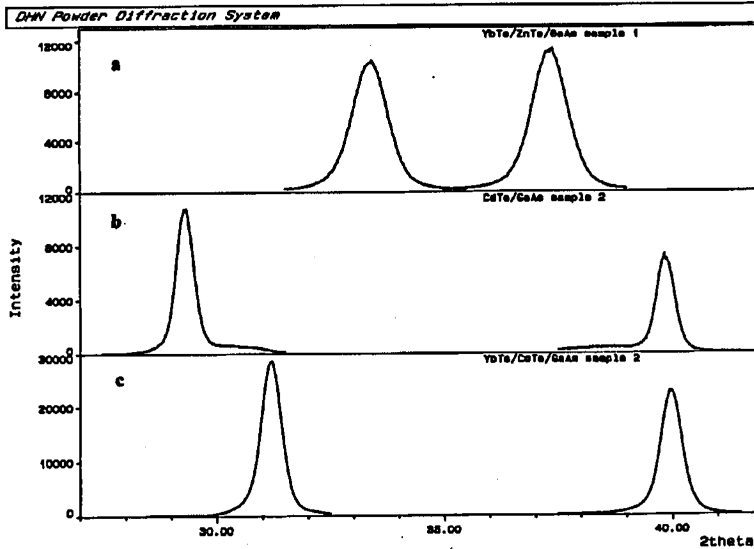

Fig. 1. X-ray rocking curves of the 1 μm thick YbTe films grown on the ZnTe and CdTe buffer layers: (a) (400)YbTe reflex from sample 1, (b) (400)CdTe reflex from sample 2, (c) (400)YbTe reflex from sample 2.

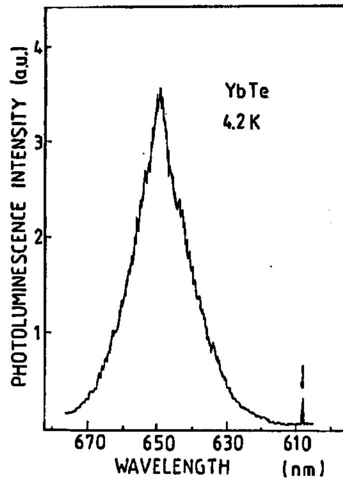

Fig. 2. PL spectrum from 1 μm thick YbTe film MBE grown on the CdTe/GaAs(100) buffer, excitation energy — 2.056 eV.

the ZnTe buffer and 4.4° — for the YbTe layer crystallised on the CdTe buffer. The full width at half maximum (FWHM) values of the X-ray rocking curves are 1600 arc seconds for sample 1 and 930 arc seconds for sample 2. The better structural perfection of sample 2 follows from the much smaller lattice mismatch value between the CdTe buffer and YbTe epilayer ($f_2 = 2\%$) in comparison to the ZnTe

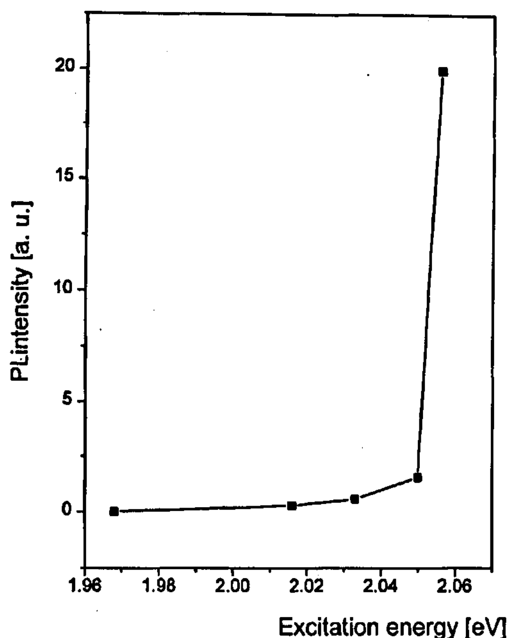

Fig. 3. Photoluminescence excitation spectrum of YbTe (sample 1).

buffer and YbTe epilayer ($f_1 = 4\%$). For sample 2 the lattice constant values in the directions parallel and perpendicular to the growth surface were measured from the symmetric 004 and asymmetric 422 brag reflections. These values are slightly different: $a_\perp = 6.3580$ Å, $a_\| = 6.3685$ Å, which means that the 1 μm thick YbTe layer is partially strained.

In the case of $BaF_2(111)$ substrates we have not obtained high quality single crystalline YbTe films. X-ray diffraction measurements of sample 3 indicate the textured YbTe epilayer structure with preferential (111) orientation and with small admixtures of YbTe and Te polycrystalline phases.

For sample 2 the photoluminescence (PL) excitation measurements were performed at liquid helium temperature (4.2 K). PL was excited by a dye laser pumped by the second harmonic of Nd:YAG laser (532 nm). The laser operated in the pulsed mode, with the duration of single pulse of 5 ns and 10 Hz repetition frequency. The energy of the dye laser radiation was changed from 1.96 to 2.1 eV. A single PL peak was detected at 1.916 eV, (the energy gap value of YbTe at 10 K reported in Ref. [3] is 1.97 eV) with the FWHM value of about 30 meV (Fig. 2), when the excitation energy was higher than 1.968 eV. The intensity of luminescence increases drastically when the excitation energy approaches 2.056 eV (Fig. 3).

4. Conclusions

YbTe thin films can be crystallised by molecular beam epitaxy on the GaAs(100) substrates with a quality similar to the quality of II–VI compounds MBE grown on these substrates. The results of X-ray diffraction measurements

show that YbTe films of the best quality were crystallised on the CdTe buffer layers. The structural parameters of YbTe layers crystallised on the BaF_2(111) substrates were inferior to the parameters of the layers grown on GaAs(100) substrates with ZnTe or CdTe buffers. The low temperature luminescence peak of YbTe was detected at 1.916 eV and the dependence of luminescence intensity on the excitation energy was measured.

Acknowledgments

This work was partially supported by the State Committee for Scientific Research (Republic of Poland) through grant No. PBZ-Z011/P4/93/01.

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