Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 586 (2008) 439–443
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Effects of mosaic structure on the physical properties of CdZnTe crystals

Dongmei Zeng[a,b,*], Wanqi Jie[a,b], Tao Wang[a], Gangqiang Zha[a], Jijun Zhang[a]

[a]State Key Laboratory of Solidification Processing, Northwestern Polytechnical University, Xian 710072, China
[b]School of Materials Science and Engineering, Northwestern Polytechnical University, Xian 710072, China

Received 4 November 2007; received in revised form 10 December 2007; accepted 17 December 2007
Available online 31 December 2007

Abstract

Mosaic structure in CdZnTe crystals was identified by using scanning electron microscopy (SEM), then the effects of mosaic structure on the physical properties were studied by means of high resolution X-ray diffraction (HRXRD), *I–V* characterization, and Fourier transform infrared (FT-IR) measurements. X-ray studies suggest that mosaic structure has a slightly different orientation from the main part of the sample. In FTIR measurements, IR transmittance of CdZnTe wafer with mosaic structure in the wavenumber between 500 and 1100 cm^{-1} is only about 4%. From 1100 to 4000 cm^{-1}, it increases gradually to about 50%. Analysis of the low IR transmittance is discussed using the theory of free carrier absorption. *I–V* curve of CdZnTe wafer with mosaic structure exhibited piezoresistance characteristic. This characteristic can be considered as a transition to the space charge limited regime due to carriers injecting at the mosaic structure. By analogy with Schottky barrier behavior, we calculated interface barriers of CdZnTe wafer containing mosaic structure and the mosaic structure free wafer, which are 0.78 and 0.98 eV, respectively.

PACS: 51.70.+f; 61.10.−i; 73.25.+i; 81.05.Dz

Keywords: CdZnTe; Mosaic structure; High resolution X-ray diffraction (HRXRD); IR transmittance; *I–V* characteristic

1. Introduction

Cadmium zinc telluride (CdZnTe) is often considered as the preferred materials for room temperature X-ray and gamma ray detectors [1]. However, growth of CdZnTe single crystals suffers the problems, such as convection currents and constitutional supercooling [2–4], which could lead to the formation of dislocation net in the grain interior. The regions between the dislocation lines can be modeled as mosaic structure. Like other defects in CdZnTe crystals, the mosaic structure influences the physical properties of the crystals.

The effects of typical defects in CdZnTe crystal, i.e., dislocations, precipitations and grain boundaries, have been widely studied by means of optical, structural and electrical techniques [5–8]. Although mosaic structure has been observed and studied in other crystal materials, such as Al–Pd–Mn icosahedral quasi-crystals, InN films, and HgCdTe/CdZnTe heterostructures [9–11], the effects of mosaic structure on the physical properties of CdZnTe bulk crystals is still unknown.

In this work, mosaic structure in CdZnTe were identified by using scanning electron microscopy (SEM), then the effects of the mosaic structure on the physical properties were studied by means of high resolution X-ray diffraction (HRXRD), *I–V* characterization, and Fourier transform infrared (FT-IR) measurements.

2. Experimental

The boules of CdZnTe crystals were grown by the modified vertical Bridgman method in our lab [12]. The growth

*Corresponding author at: School of Materials Science and Engineering, Northwestern Polytechnical University, Xian 710072, China.
Tel.: +86 29 88486065; fax: +86 29 88495414.
E-mail address: zengdongmei1010@gmail.com (D. Zeng).

0168-9002/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2007.12.033

procedure is as follows: first, the raw materials of Cd (7 N), Zn (7 N) and Te (7 N) were loaded into the carbon-coated quartz crucible. The crucible was sealed under vacuum till 6×10^{-5} Pa and synthesized in a rocking furnace. Subsequently, the crystal growth was carried out in the same crucible in a five-zone furnace. The wafers were mechanically polished using diamond paste and MgO powders of 0.5 μm in diameter, and then chemically etched with 5% Br–MeOH, rinsed with methanol and dried with N_2. Before electrical properties measurement, the backside of the samples was sputtered with Au in a KYKY SBC-12 coating system immediately to avoid surface oxidation and ohmic contact was obtained.

The observations on CdZnTe crystal surfaces were carried out with JSM 6360-LV SEM at 20 kV. X-ray measurements were performed using a Philips X'Pert X-ray diffractometer equipped with Ge (2 2 0) analyzer. The electrical properties of the samples were measured at the room temperature using Agilent 4339B with the current resolution till to picoamperes. The IR transmission measurements were done at room temperature using a Nicolet Nexus FT-IR spectrometer over the wavenumber ranging from 500 to 4000 cm^{-1} under normal incidence.

3. Results and discussions

Two patterns of mosaic structure observed on (1 1 1) face by means of SEM micrographs are shown in Fig. 1. One is the pronounced globular type as shown in Fig. 1(a); the other is a strip-like structure with longitudinally extended dislocation walls as shown in Fig. 1(b). The two mosaic structures are all the formation of the dislocation walls, as the results of the rearrangement of the stored dislocations. The dislocation walls are usually not completely closed and the dislocations with the same Burgers vector are aligned into the mosaic structure. Mean dimension of the mosaic structure is in the range of 100∼200 μm. In the region of mosaic structure, dislocation density is much higher, coming close to $\rho = 10^6 \sim 10^7\,cm^{-2}$.

Dislocation cell patterns in semiconductor compounds were ascribed to the instable interface [13,14]. The driving force for mosaic structure formation is the reduction in strain energy resulting from the clustering of dislocations in cell and sub-grain boundaries [15,16]. The dislocation rearrangement into mosaic structure takes place under external or internal stress in the course of plastic relaxation.

In order to investigate the effect of mosaic structure on the physical properties of CdZnTe crystals, we compared CdZnTe wafer containing mosaic structure with mosaic structure free CdZnTe wafer.

3.1. *X-ray diffraction measurements on CdZnTe wafer with mosaic structure*

The representative reciprocal space map around (1 1 1) reciprocal lattice points for CdZnTe wafer with mosaic structure is shown in Fig. 2(a). Close to the maximum intensity peak from the matrix (peak A), we find a plateau peak (peak B). The plateau peak results from the defects of the grain. Fig. 2(b) shows the measured isointensity contours of the reciprocal space map, which extended along the central ω scan, indicating that the orientation of crystal has changed slightly [17]. Mosaic structure is a substructure in which neighboring regions are oriented slightly differently, i.e., the whole single crystal is likely "divided" into small pieces whose crystal orientations are not exactly coincident. The reciprocal space map from CdZnTe wafer with mosaic structure verified that the mean angle of disorientation is about 0.04°.

The double crystal rocking curve of CdZnTe (3 3 3) plane is shown in Fig. 3. A continuous plateau of side peak displays deviation from the narrow Gaussian profile. And then the side peak increases the full-width at half-maximum (FWHM) value of CdZnTe wafer, i.e., degrades crystalline quality.

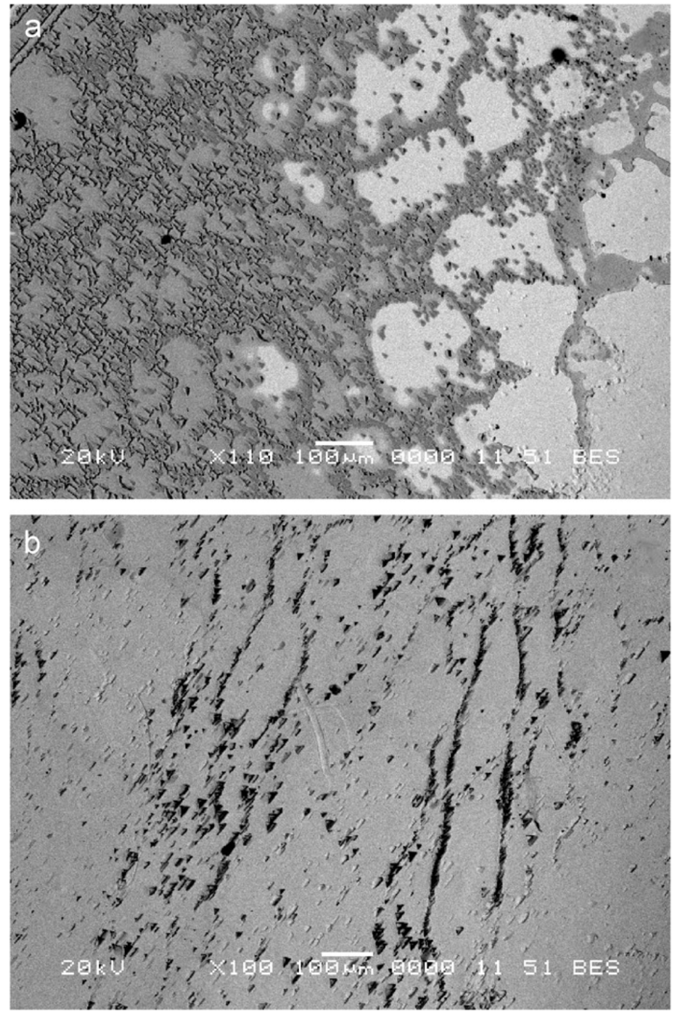

Fig. 1. SEM photographs of typical mosaic structure formed in CdZnTe crystal: (a) the pronounced globular type and (b) the strip-like structure with longitudinally extended dislocation walls.