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Dislocations and Defect Structure around Micro-indentations and Te Precipitates in CdTe

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Dislocations and Defect Structure around Micro-indentations and Te Precipitates in CdTe

V. Babentsov, F. Sizov, J. Franc, P. Fochuk, G. Yang, A. Bolotnikov, and R. B. James

***Abstract* – We investigated dislocation-related electronic states induced by dislocation motion in CdTe-based semiconductors. Dislocations cause various types of electronic defect states in the bandgap of semiconductors, namely, defects created by different types of dislocations, and those due to an impurity or native defect segregated around the dislocations. The aim of this work was to further clarify, on the basis of an analysis of the lattice deformation, whether these defects belong to either the Te or Cd sublattice and to formulate a model describing such defects**.

I. Introduction

CdTe-based compound semiconductors are leading candidate materials for fabricating room-temperature radiation detectors [1-5]. Several researchers reported studies of dislocations in CdTe-based semiconductors (see, for example, references 1-5). The presence of different defects can degrade the crystal quality and deteriorate the performance of devices [1,2]. Especially, dislocations are one representative type of defects in these semiconductors [3,4]. It is important to correlate dislocations with the corresponding changes of electronic states and use this understanding to investigate their effects on device performance. Different techniques were used to investigate the dislocations in CdTe and CdZnTe. For example, cathodo-luminescence was used to probe the distribution of dislocations around indents on CdTe [3]. Photoluminescence was employed to investigate the dislocations caused by plastic deformation of CdZnTe [4, 5]. In this work, we investigated dislocation-related electronic states induced by dislocation motion in CdTe-based semiconductors. Dislocations cause various types of electronic defect states within the band-gap of semiconductors. In some cases the defects are created solely by the presence of the dislocations, while in other cases the origins of the defects are related to either impurities or native defects segregated to the dislocations. The aim of this work is to further clarify, on the basis of an analysis of the lattice deformation, if these defects belong to the Te or Cd sublattice, and to formulate a model describing such defects.

II. Experimental

As a means of introduction of fresh dislocations, we used room-temperature indentation with a diamond indenter. Old dislocations were also studied around as-grown Te precipitates. Fig. 1 demonstrates an optical image of the indenter fingerprint on the initial unindented (110) surface of the CdTe sample.

III. Results and discussions

Crystallographic orientation of dislocations around the micro-indentation

Indented (110) surface. The development of the tangential and tetrahedral glide deformation on the (110) surface in the vicinity of the indenter fingerprint is illustrated in Fig. 2. Tangential deformation arises at the surface of the CdTe sample from the load of the indenter tip, and it develops plastic flow of the segment of the crystal lattice parallel to the surface in the inclined (111) and (11□1) glide planes. Two sides of the moved segment represent (111) Cd (dark color) and (111) Te (gray color) planes. Intersections of such planes form prisms, which develop inside the crystals at an acute angle to the surface. Fig. 3 demonstrates that the CdTe volume under an indenter is highly disordered due to the intersections of various dislocations. In such a defective region various recombination channels for non-equilibrium carriers can be realized. As shown in Fig. 4, one can see the chemical etching rosette (left panel) and luminescence map of the 841-nm PL intensity at 80 K (right panel) in the area of the indenter fingerprint on the (110) surface. Fig. 5 gives the PL spectra from the (001) surface of the CdTe crystal at 4.2 K before (1) and after the indentation (2, 3).

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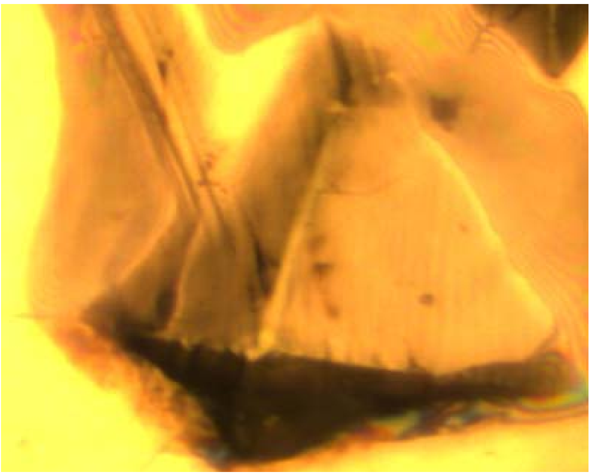

Fig. 1. An optical image of the indenter fingerprint on the initial unindented (110) surface of a CdTe sample

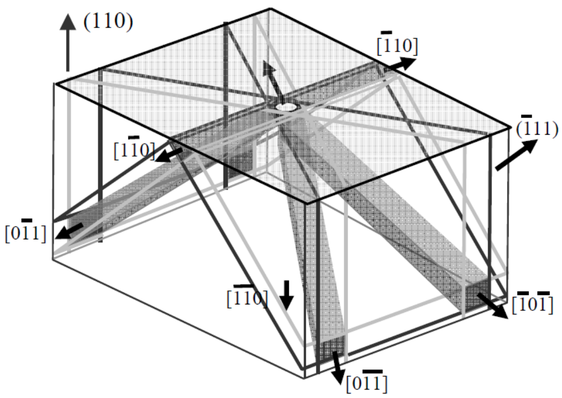

Fig. 2. Development of the tangential and tetrahedral glide deformation on (110) surface in vicinity of the indenter fingerprint

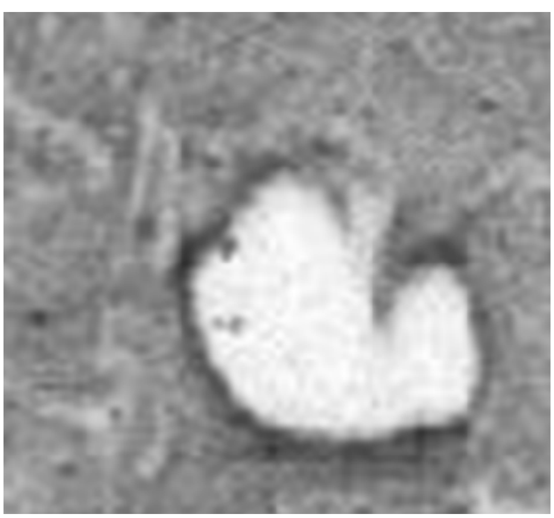

Fig. 3. CdTe volume under an indenter. Results of white beam X-ray diffraction tomography of the area under an indenter.

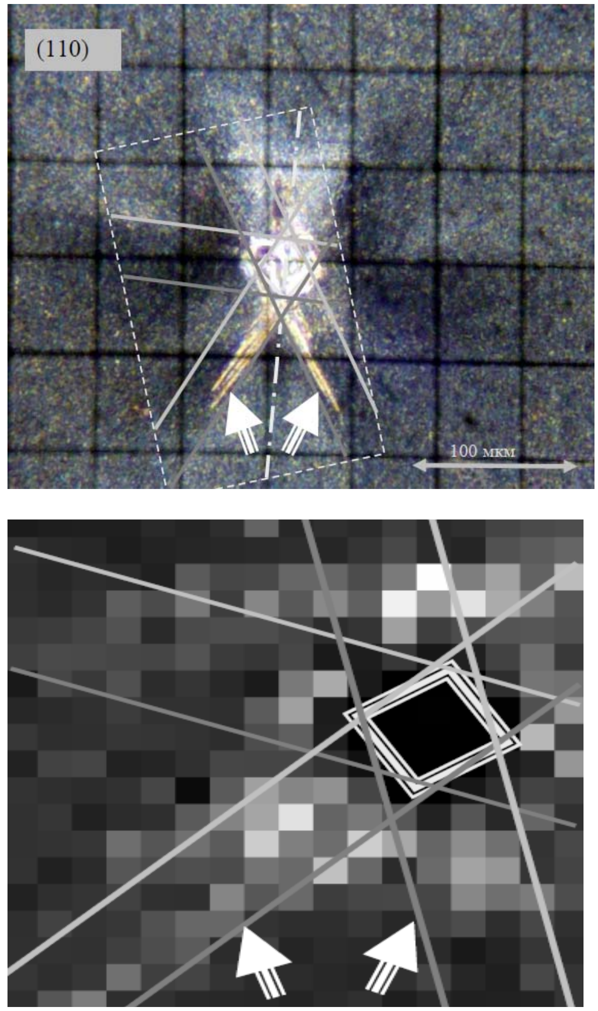

Fig. 4. Chemical etching rosette (left panel) and luminescence map of the 841-nm PL intensity at 80 K (right panel) in the area of the indenter fingerprint on the (110) surface. White arrows show the Te dislocation branches, and lines demonstrate the crystallographic orientation as shown in Fig. 2.

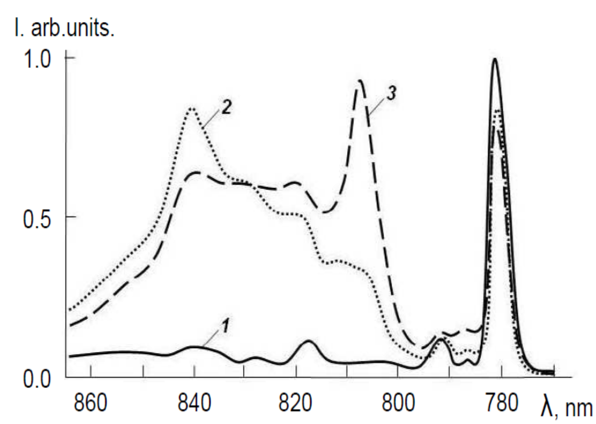

Fig. 5 The PL spectra from the (001) surface of the CdTe crystal at 4.2 K before (1) and after the indentation (2, 3).

IV. CONCLUSIONS

We conclude that the "dislocation" emission is a characteristic emission in CdTe. This emission develops according to the crystallography of the rosette around the indentation point. It has relatively narrow PL lines, which have different dependences on the temperature and excitation intensity. It is reasonable to consider that these bands refer to the different types of deformation defects, namely, nano-defects existing in the region of the dislocations.

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