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X-RAY AND SCANNING CATHODOLUMINESCEENCE IMAGING OF SMALL-ANGLE GRAIN BOUNDARIES AND DISLOCATIONS IN CdTe CRYSTALS

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Abstract - By employing the Reflection X-ray Topography (RXT), on one hand, and the cathodoluminescence (CL-IR) mode of operation of the Scanning Electron Microscope, on the other hand, we are able to visualize the lattice defects in CdTe single crystals. The possibility of defect identification is the advantage of the RXT technique. Moreover, the examined surface can be imaged as a whole. Cathodoluminescence however, guarantees higher resolution. The defects in CdTe crystals, observed in cathodoluminescence images, have been identified as small-angle boundaries and screw dislocations.

1 - INTRODUCTION

Complementary employment of Reflection X-ray Topography (RXT) and Scanning Cathodoluminescence (SCL) can successfully serve for identification of imaged defects, which is shown clearly in the present paper. At it has already been reported (KLIMKIEWICZ, AULEYTNER, WARMINSKI, 1981), a correlation can be found between the images of defects, obtained by using the above-mentioned techniques, provided the required experimental conditions are preserved.

The acknowledged advantage of the RXT technique consists in the fact that the image of the sample surface, as a whole, is obtained with distinguishable structural defects. However, the resolution of electron microscopic images is considerably higher although they offer an insight into a small section of the tested sample only.

1. Sample characterization.

The paper presents the results of investigations of CdTe crystals prepared by Bridgman method from solution with excess of tellurium. The sample to be examined had a form of a slice cut along the (110) plane. It was subjected to mechanical polishing with a diamond paste, washed in alcohol in an ultrasonic desintegrator, and finally chemically polished in 2% bromine solution in methanol. The investigations were performed on the samples not thicker than 200 μm. The sample shapes were, in consequence, reasonably irregular but X-ray topographs could satisfactorily be obtained.
2. Experimental arrangements.

Reflection X-ray topographs (RXT) were obtained in an oscillating slit camera (AULEYTNER, 1971) by using an X-ray tube with iron target. FeKα radiation has been used for imaging crystal surface structure. Which refers to the transmission X-ray Topographs (TXT) they were possible with the Lang method employing Ka Cu radiation. Microscopic observations were carried out using the SCL operation mode of EPMA JXA - 50A. The remaining modes, including SEI and BEI, served for surface control only.

3. Results and discussion.

Upon inspection of transmission X-ray topographs numerous defects have been recognized in the crystals tested, some of them being the small-angle boundaries and the other acting as single dislocations. A number of defects could hardly be identified owing to their high density. SCL picture exhibited a distinct contrast in a form of a disorder of dark spots together with dark lines arranged in networks. Under higher magnifications the latter can be recognized as rows of more or less densely distributed spots (Fig.1 and 2). When correlating the SLC images with RXT topographs obtained it can be stated, beyond any doubts, that the lines observed in cathodoluminescence pictures exactly correspond to those in X-ray images (Fig.1,2,3). The network of white and dark lines, appearing in X-ray topographs, represents the system of small-angle boundaries. When the RXT geometry, beam width, magnification, and crystal-film distance are known, the misorientation angle between the adjacent regions of the crystals, demarked by the given small-angle boundary, can be evaluated. The linear density of dislocations at the boundary can thus be determined. It ought to be noticed, however that the space electronic charge at the dislocation implies the CL-IR image of its cross-section to be a spot of diameter at least 1 μm. On the other hand, it has been found from practical X-ray topography that a misorientation of at least 15° is required to visualize the contrast of a boundary present experimental conditions. Let us exemplify it considering the arrow-marked boundary in the cathodoluminescence picture: the determinable spacing between the spots equals 5.2 μm/ the misorientation angle of the regions equals 18°. The above considerations make clear that this particular sector of the boundary gives a weak contribution to the RXT image, and only the other parts get clearly visible. Which refers to the region with higher dislocation density contained within the boundaries, a random distribution of dislocations is observed of density 10⁶ cm⁻².

Concluding, the defects imaged in the cathodoluminescence pictures are undoubtedly recognized as the small-angle boundaries of the tilt-twist type and the dislocations nearly normal to the crystal surface. It becomes thus evident that the RXT and SCL techniques are complementary ones and, when employed in the examination of the same object, they can provide a univocal interpretation of imaged defects if only the required experimental conditions are preserved.

References.


Fig.1 Scanning cathodoluminescence /C1-IR/ and X-ray topographic /RXT/ images of grain boundaries and dislocations in a thin CdTe sample. The arrows indicate the same vector of a boundary.

Fig.3 Low angle grain boundary with individual dislocations visible as dark spots; C1-IR image. The arrow in here and those shown in Fig.1 are pointing out the same sector of the boundary.
Fig. 2. Grain boundary in CdTe as seen in the CL-IR and RXT images, respectively.