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Observation of threading screw dislocations in 4H-SiC by means of the Laue-case weak-beam X-ray topography

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1 Introduction

X-ray topography is a useful tool for characterization of crystal defects, and it is suited for observation of large area without destructive preparation of specimen. Synchrotron radiation X-rays provide rapid and clear analysis of defects, but it has a limit in spatial resolution. For further detailed analysis, experimental setups for higher sensitivity to small strains are needed. Double-crystal diffraction method consists of the first crystal to collimate X-rays and the second crystal as a specimen. The diffraction intensity sensitively varies according to strains in the second crystal when the diffraction condition is deviated from the Bragg angle.

We have developed the X-ray topography using the double-crystal settings to analyze defects with high resolution. The diffraction contrasts were studied systematically, and it was found that when a specimen was set at a proper angle deviating from the Bragg condition, diffraction from locally-distorted regions due to defects was projected under suppression of intense diffraction from non-defect region[1,2]. Here the method under this condition is referred to as *weak-beam* X-ray topography.

Our observations are focused on threading screw dislocation (TSD) in silicon carbide (SiC), which runs threading a wafer along the *c*-axis of the crystal. SiC is a promising material for future power electronics applications. The SiC wafers, however, suffer from high density of dislocations, and therefore it is important to identify killer defects, which severely affect device performance. The TSD, of which Burgers vector is $\boldsymbol{b}_s=[0001]$, is often combined with an edge dislocation of $\boldsymbol{b}_e=(1/3)\langle 11\bar{2}0\rangle$ to form a mixed dislocation with the Burgers vector of $\boldsymbol{b}_s+\boldsymbol{b}_e$. The mixed dislocation is suspected of being a killer defect.

When $\boldsymbol{g}$ is perpendicular to $\boldsymbol{b}_s$, there should be no contrast from TSDs according to the $\boldsymbol{g}\cdot\boldsymbol{b}$ invisibility criterion. The criterion, however, does not hold true near the wafer surface due to extra surface strains. In this study, we have shown that the weak-beam technique distinguishes the strain at surface and that inside crystal originated from the threading dislocation.

2 Experimental

Experiments were performed at the beamline BL-15C and BL-20B. Monochromatic X-rays of wavelength 0.069 nm were collimated with the first crystal, Si 331 asymmetric reflection (asymmetric factor of 0.03). The second crystal was a 4° off-cut (0001) 4H-SiC wafer and the Laue-case diffractions of $\bar{2}110$, $\bar{1}2\bar{1}0$, $11\bar{2}0$, $\bar{2}020$, $\bar{2}200$ and $02\bar{2}0$ were observed. X-ray topographs were recorded on nuclear emulsion plates (Ilford L4) or high-resolution X-ray films (Fujifilm IX20).

3 Results and Discussion

Figure 1 shows TSD images taken under weak-beam condition for $\bar{1}2\bar{1}0$ reflection. Dislocations are projected along the X-ray paths, and the TSDs exhibit pairs of dot-shaped images near the incident and exit surfaces but no images from inside wafer (Fig. 1(a)). Line-shaped images between dots shown by arrows in Fig. 1(b) are the edge-component of TSDs. Thus the weak-beam images exhibited dislocation contrasts from screw and edge components separately. By comparing topographs with different g-vectors, each dislocation was identified as pure or mixed dislocation, and the Burgers vector of the edge component was determined using $\boldsymbol{g}\cdot\boldsymbol{b}$ criterion for the mixed dislocation.

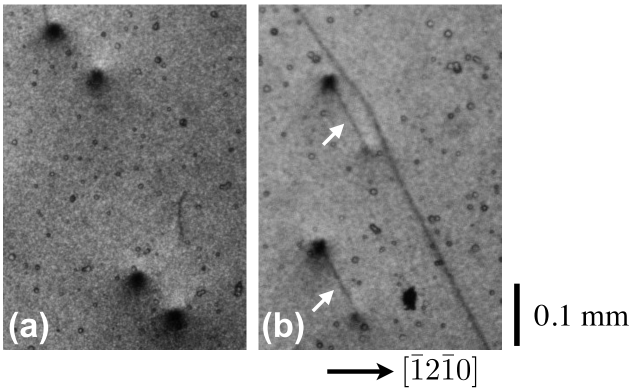

Figure 1 The Laue-case weak-beam X-ray topographs.

References
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