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Threading dislocations in 4H-SiC observed by X-ray topography using collimated beams

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Introduction

Double-crystal X-ray topography has been applied to detection of micro-defects in dislocation-free silicon (Si) crystals[1]. In this study, the double-crystal method was used for dislocation analysis in silicon carbide (SiC) wafers with dislocation density of as high as 10^3-10^4 cm^{-2}. Using collimated beams, lattice distortions around a dislocation are projected on the topograph with fine contrasts because only the region suffering from a certain misorientation satisfies the Bragg condition. In our previous study[2], typical strain contrasts around screw dislocations threading across a wafer were observed by weak beam topography in the Bragg-case geometry, revealing their senses of screw and depth profiles. In this report, we show further study on dislocation contrasts by the Laue-case X-ray topography using collimated beam.

Experiment

Samples were 4H-SiC wafers with 4°-off {0001} faces. In an ideal double-crystal topography, the first crystal as beam collimator and the second one as specimen are identical planes. Since the dislocation-free SiC crystals were unavailable at present, however, Si was used for the first crystal. The Laue-case diffractions with $\boldsymbol{g} = 2\bar{2}00, 20\bar{2}0$ and $02\bar{2}0$, were observed using a beam of the wavelength 0.0657 nm collimated by a Si 224 asymmetric reflection. X-ray topographs were recorded on nuclear emulsion plates (Ilford L4).

Results and Discussion

Typical dislocations in SiC crystal are basal-plane dislocation (BPD), which is screw and/or edge dislocation lying in the *ab*-plane with the Burgers vector $\boldsymbol{b} = (1/3)\langle 11\bar{2}0 \rangle$, and threading edge- and screw-dislocations (TED and TSD, respectively) running along the *c*-axis with Burgers vectors $\boldsymbol{b}$: $\boldsymbol{b}_\mathrm{e} = (1/3)\langle 11\bar{2}0 \rangle$ and $\boldsymbol{b}_\mathrm{s} = \pm[0001]$, respectively. When the diffraction vector is tuned to the condition, $\boldsymbol{g} \cdot \boldsymbol{b} = 0$, the dislocation is invisible. According to this criterion, BPDs and TEDs are invisible in the topograph taken for one of the diffraction vector, $2\bar{2}00$, $20\bar{2}0$ or $02\bar{2}0$, thereby identifying their Burgers vectors. Since TSDs satisfy $\boldsymbol{g} \cdot \boldsymbol{b} = 0$ for these diffraction vectors, they should be always invisible in the topographs. On the contrary, TSD are clearly detected with strong contrasts, violating the invisible condition.

Using the collimated beam, the full width at the half maximum of the rocking curve was 8 μrad for the $02\bar{2}0$ reflection. Contrasts around each dislocation changed depending on the diffraction condition. At the rocking curve peak, a plan view of dislocations was projected on the topograph on which TSDs appear with strong contrasts. By deviating from the peak, the areas of the strong contrasts were reduced, and eventually pairs of smaller dot-shaped contrasts appeared. These were found to be a sectional view of dislocations. The dot-shaped contrast pairs were identified to the outcrops of TSDs at the wafer surfaces. TEDs were also observed with thin line-shaped contrasts. Some TSDs were found to accompany the edge component, forming mixed dislocations ($\boldsymbol{b} = \boldsymbol{b}_\mathrm{s} + \boldsymbol{b}_\mathrm{e}$).

Acknowledgment

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References

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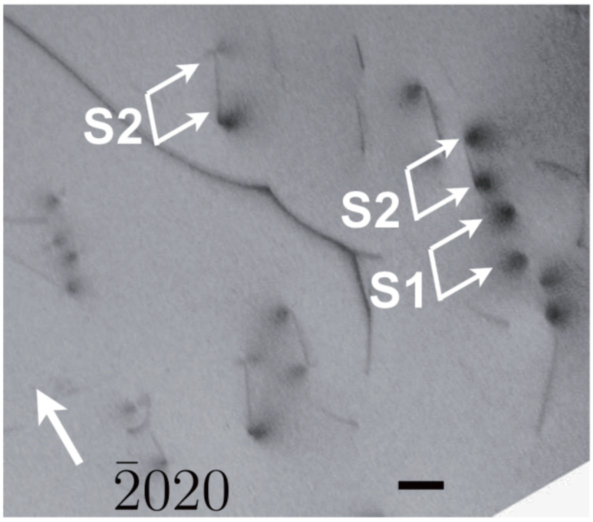

Fig. 1 Double-crystal X-ray topograph taken under an off-Bragg condition ($\boldsymbol{g} = \bar{2}020$). Thin short lines are threading edge dislocations, and large dot pairs are outcrops of threading screw dislocations; some examples are designated by arrows with S1 or S2. S1: pure screw dislocation, S2: mixed dislocation with screw and edge components. Scale: 0.1 mm.