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Investigation of Defect Reduction in Solution-grown SiC with Synchrotron X-ray Topography and Etching Method

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Introduction

Silicon carbide (SiC) is an attractive semiconductor material for power device applications. Presently, commercial SiC wafers are grown by sublimation method. However, in these crystals, there are a lot of defects, e.g. threading edge dislocations (TED), threading screw dislocations (TSD), basal plane dislocations (BPD), and stacking faults (SF) which drastically lower the performance of SiC power devices. Therefore, a crystal growth technique to grow a high quality bulk crystal is strongly required.

Solution growth presents several highly interesting features, particularly for high structural perfection [1]. This is because the low growth temperature and the thermodynamic conditions close to equilibrium should lead to improved crystal quality (no micropipe [2], a lower dislocation density, and a lower residual strain). In our previous study, we grew high quality single crystals by solution growth [3-5]. In this study, we evaluated the defects in SiC crystals grown by solution method with the synchrotron X-ray topography and chlorine thermal etching method.

Experiments

SiC crystals were grown by the top-seeded solution method with pure silicon solvent. 6H-SiC on-axis wafers by the sublimation method were used as seed crystals. The growth temperature was at around 1800 °C. The growth rate was varied from 11 µm/h to 70 µm/hr to investigate the effects of the growth rate on crystal quality. The thickness of all samples was adjusted to 100 µm. Synchrotron X-ray topography measurements were carried out under the reflection condition at BL-15C at Photon Factory. Monochromatic X-ray wavelength was 1.26 Å. The applied **g** vector was 11-2·12. In this case, the penetration depth was about 2 µm. Chlorine thermal etching was carried out for evaluation of the density of dislocations [6].

Results and Discussion

Fig. 1 (a) shows X-ray reflection topographic image of a seed crystal. The white spots enclosed with orange circles and red circles are TED and TSD, respectively. The bended lines are BPD. Fig. 1 (b) shows X-ray topographic image of the crystal grown on the seed crystal by solution growth. No BPD was observed in the crystal grown by solution growth. Moreover, TED and TSD densities of grown crystal were lower than those of seed crystal.

The etch pits can be categorized to two with different size. Comparing to X-ray topographic image, the small hexagonal pits and the large ones are TED and TSD, respectively. By counting the number of etch pits in the area of 0.76 mm^2, TSD density of the grown crystal by solution growth was by 20-80% lower than that of the seed crystal (we evaluated 4 areas per sample). In addition, the improvement of crystal quality did not depend on the growth rate.

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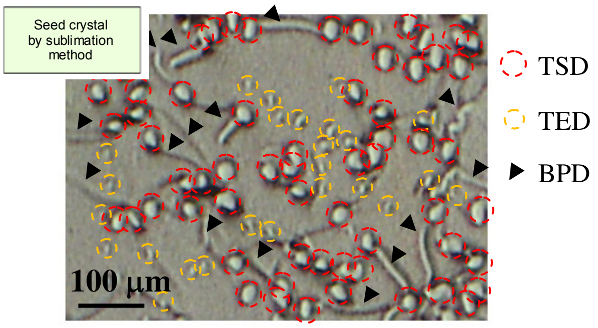
(a) Crystal grown by sublimation method



(b) Crystal grown by solution method

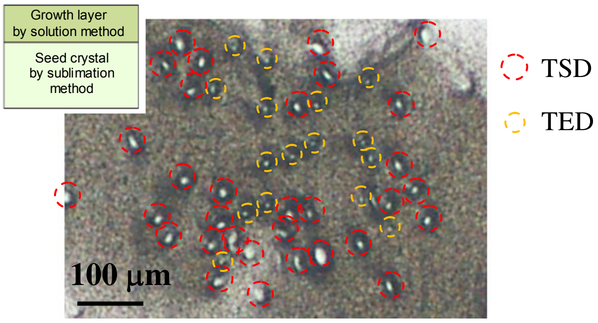


Fig. 1 X-ray topographic images of SiC crystals (a) grown by sublimation method and (b) grown by solution method.