Cross-sectional Analysis of Solvent Inclusions and Macrostep Dynamics In p-Type 4H-SiC Grown from Solution

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Introduction

In the solution growth of 4H-SiC, high-quality crystals with low threading dislocation density can be obtained. However, a critical issue is the formation of “solvent inclusion” defects in which the solvent is incorporated into the crystal. Previous studies have reported that macrosteps on the crystal surface promote their formation [1]. In addition, other studies on N-doped GaN and SiC have shown impurity inhomogeneity corresponding to the advancement traces of macrosteps during solution growth [2,3]. Based on these findings, this study focuses on impurity inhomogeneities and aims to clarify the height and advancement speed of macrosteps during the formation of solvent inclusions.

Experimental Procedures

First, we confirmed that impurity inhomogeneities also occur in Al-doped p-type 4H-SiC by combining SIMS analysis of cross-sectional impurity distributions with transmission optical microscopy. From these results, we established a method to evaluate the height and advancement speed of macrosteps from the observed inhomogeneities. Next, this method was applied to analyze the behavior of macrosteps at the time of solvent inclusion formation, and the mechanism of their formation was discussed.

Results and Discussion

SIMS analysis revealed the formation of layers with lower Al concentration (Figure 1 (a)). Transmission observations of the cross section showed that there were bright layers that transmit more light (Figure 1 (b)), and they corresponded to low Al concentration layers. Transmission observations near the crystal surface showed that these bright layers were found to connect to the step fronts of macrosteps. These results indicate that macrosteps incorporate less Al, and their advancement traces appear as bright layers in transmission images.

For macrostep evaluation, the thickness and inclination of the bright layers were analyzed. The thickness is considered to reflect macrostep height, while the inclination represents the advancement speed ratio of macrosteps relative to single steps. A larger inclination means that the macrostep advances more slowly relative to the single step.

Solvent inclusions were observed as continuous, point-like images that do not transmit light. The analysis showed that solvent inclusions preferentially form at higher macrosteps (Figure 2 (a), (b)). Moreover, even at the same macrostep height, inclusions were more likely to form when the relative advancement speed ratio of macrosteps was smaller. Such slower advancement is likely caused by surface-reaction-limited growth under low supersaturation. These findings suggest that solvent inclusions tend to form when macrosteps are higher and the supersaturation is lower.

To suppress the formation of solvent inclusions, it is essential to properly control the growth conditions, especially supersaturation. Cross-sectional observation of macrostep development provides a useful approach for exploring such optimal conditions.

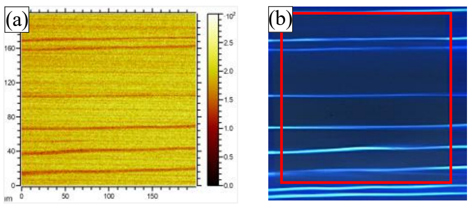

Figure 1 cross-sectional observation

(a) Al concentration distribution (b) transmission images

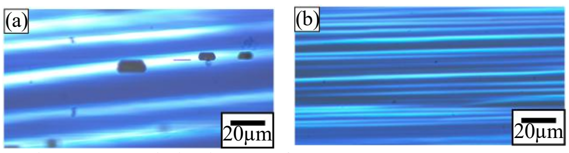

Figure 2 transmission images of macrosteps

(a) with solvent inclusion (b) without solvent inclusion

References

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