Effect of macrostep height on formation of solvent inclusion in SiC solution growth

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In SiC solution growth, proper control of macrosteps is crucial for growing a high-quality crystal. As macrosteps develop, threading dislocations are converted to defects on the basal plane [1]. Then, converted defects laterally propagate to the edge of the crystal [2]. On the other hand, overdeveloped macrosteps make the interface unstable, leading to the formation of solvent inclusions [3]. In this research, the effect of macrostep height on solvent inclusion formation was investigated experimentally and numerically.
The relationship between macrostep height and solvent inclusion was analyzed through a solution growth experiment, and the macrostep shape for different step heights was simulated by the phase field method. A 4H-SiC single crystal was grown for 3 h by the solution growth method on a 1.6 inch off-axis seed crystal. The growth temperature was 1900 ℃, and the growth rate was 300 μm/h. Step height, step shape, and solvent inclusion were observed with a laser scanning confocal microscope (LSCM). Mass transport and surface kinetics were numerically calculated by the phase field method, which can reproduce macrostep development [4].
Fig. 1 shows typical crystal surface morphology. White lines are solvent inclusions that formed along the groove of the Y-shape macrostep (cellular structure). The critical step heights of the formation of cellular structure and solvent inclusion were investigated. The cellular structure and solvent inclusion formed at minimum step heights of 0.99 μm and 1.85 μm, respectively. The phase field simulation results agreed well with these results. As the step height increases, the step shape changes from nearly straight (Fig. 2(a)) to a cellular structure with a short groove (Fig. 2(b)), and then to that with a deep groove (Fig. 2(c)). Phase field calculations revealed that higher macrosteps promote the formation of cellular structures due to a thinner solute concentration in the groove, which is caused by more solute consumption. Once a groove is formed, it is difficult to prevent further groove development, which forms solvent inclusions, because most solutes are absorbed before being transported to the groove. Therefore, proper control of step height that suppresses cellular structure is key to suppressing solvent inclusion.

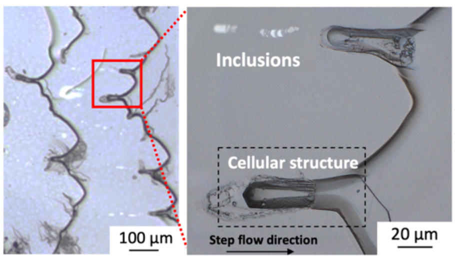

Fig. 1 LSCM image of a cellular structure and solvent inclusions.

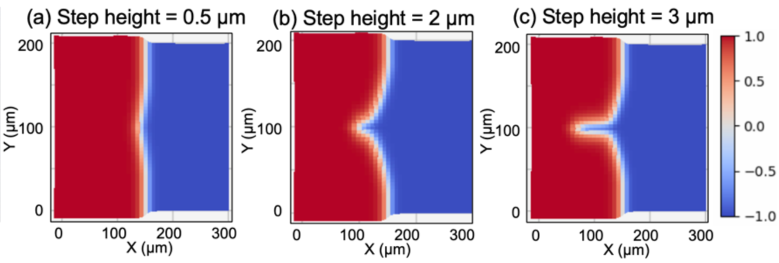

Fig. 2 Phase field simulation results for step height of (a) 0.5 μm, (b) 2 μm, (c) 3 μm.

References
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