Effect of {111} Polarity on the Growth Rate During the Solidification of Compound Semiconductor GaSb

The twin formation and propagation during the directional solidification of GaSb was directly observed, and the effect of twinning on the growth rate of the GaSb{111} plane was clarified. The growth rate parallel to the <111> direction decreased after twinning, indicating that the polarity reversal by twinning significantly influenced on the growth kinetics of the {111} plane.

Large-sized single crystals of compound semiconductors are difficult to grow because defects, such as twin boundaries and dislocations, are significant during solidification. As the defect formation mechanism remains poorly understood, a universal technique for the single-crystal growth of compound semiconductors has yet to be established. The sphalerite structure in compound semiconductors, such as GaSb and GaAs, exhibits polarity in the <111> direction; therefore, the {111}Σ3 twin boundary exhibits two possible atomic structures, and the difference between twin structures influences grain growth. However, the effect of the twin atomic structure on the growth dynamics of compound semiconductors is not completely understood. In this study, we directly observed twinning processes during the solidification of polycrystalline GaSb and clarified the effect of twinning on the grain growth rate [1].

The direct observation system consisted of a furnace and digital microscope. The furnace had two comb-shaped carbon heaters, between which a sample in a quartz crucible was placed and heated. The solidification of the sample was initiated by decreasing the currents applied to the heaters. The top surface of the sample was observed and recorded using a digital microscope. The moving distance of the crystal–melt interface was measured by tracing the position of the interface. The orientations of grains in the areas observed were determined by electron backscatter diffraction method.

Figure 1 shows the effect of twinning on the competitive grain growth of GaSb. Three grains were present in the crystal (Fig. 1(a)). The boundary between Grains 1 and 2 was identified as a Σ3 twin boundary, while that between Grains 2 and 3 was a random grain boundary. The shape of the crystal–melt interface remained the same before twinning. The twin nucleation was identified at the junction of the crystal–melt interface. The twin boundary between Grains 1 and 2, and the newly formed twin boundary propagated along the crystal–melt interface (Fig. 1(b)). The growth rate of Grain 2 along the direction parallel to <111> was reduced by half owing to the formation of the twin boundary, which resulted in the growth of Grain 2 being surpassed by adjacent grains (Fig. 1(c)). This indicates that polarity reversal occurred, and the growth direction turned to <111>A owing to the formation of a reflection twin. Thus, the {111} polarity significantly affected the grain growth rate during the solidification of GaSb.

References

[1] K. Shiga, K. Maeda, H. Morito and K. Fujiwara, Acta Mater. **185**, 453 (2020).

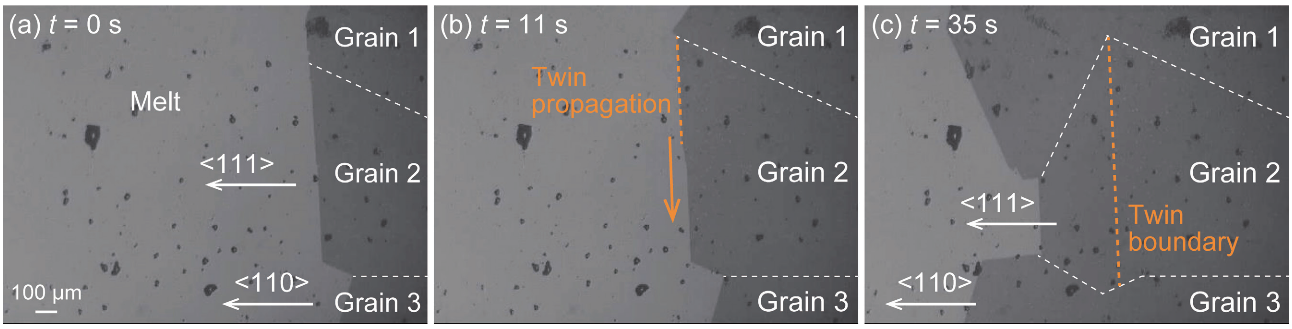

Fig.1 Photographic images of a moving crystal–melt interface during directional solidification of GaSb: (a) before twinning, (b) at twinning, and (c) after twinning.

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