Vicinal (111) surfaces at Si solid-liquid interface

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Silicon (Si) is a highly researched material because of its manifold applications in photovoltaics and semiconductor devices. Apart from its importance in applications, Si is also a suitable material for fundamental studies of crystal growth mechanisms, because it is a single-component material with a large degree of anisotropy. It has been well reported that Si {111} planes are atomically smooth and other planes are rough. However, the relationship between the growth rate of the {111} facet planes and the degree of undercooling obtained from experiments deviates from the theoretical one. Therefore, more precise studies on the growth at {111} solid-liquid interface are necessary. In this study, we carefully observed the {111} solid-liquid interface during directional solidification and found that a vicinal interface is often formed.

We investigated the growth behavior at different silicon planes and different cooling rates. Two high-purity 0-dislocation Si wafers having different crystallographic orientations along the growth direction were placed side by side and melted in a silica crucible. Combinations of wafers as ⟨110⟩/⟨111⟩, ⟨100⟩/⟨111⟩, and ⟨100⟩/⟨110⟩ were used with part of the seed left in the solid state for growth in desired orientations. The solidification process was recorded using a high-speed camera.

Fig. 1 shows snapshots of the interface growing in ⟨111⟩/⟨110⟩ direction. It is shown that a plane facet, which has a small terrace and step, is formed at the interface growing in the <111> direction. The length of this facet was found to be increasing in the lateral direction during the initial transient increase of growth rate. Simultaneously, the undercooling between the both growing grain increases as the length of (111) surface increases. These behaviors are not in agreement with a 2D nucleation growth law of the facet, which, at such growth rate, would need 1.5 K of undercooling. On the contrary, it is in agreement with the existence of a vicinal surface leading later to more perfect (111) facet after increase of undercooling.

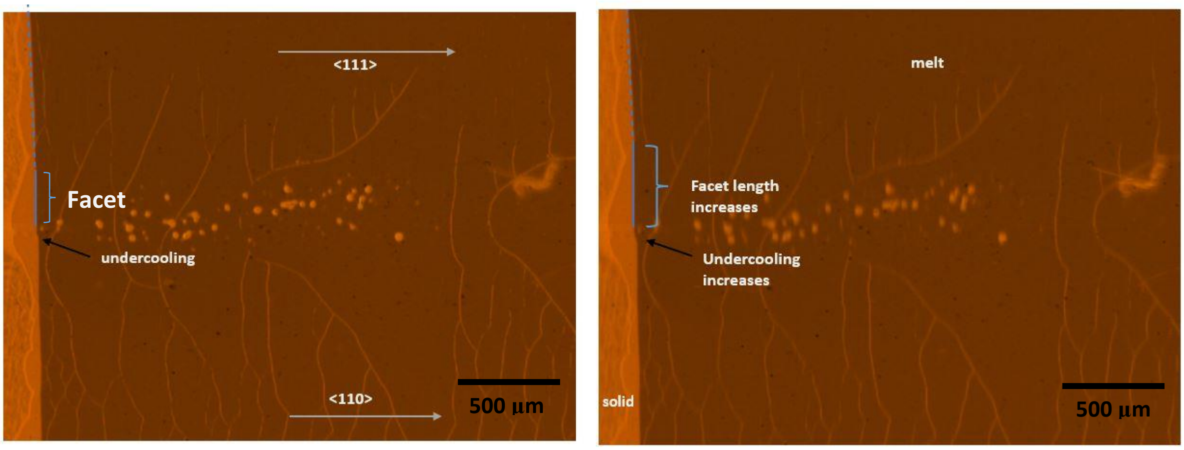

Fig 1: Snapshots of growing <111>/<110> interface with a 3 sec interval. Vicinal (111) surface was observed along <111> with increasing facet length during an increase in growth rate. The terrace height (measuring undercooling) also increases with time.