Crystal defect dynamics at the solid-liquid interface in silicon – Investigation by X-ray topography and rocking curve imaging.

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Controlling defect formation during silicon solidification is essential for improving its crystalline quality for photovoltaic solar-cell applications. In particular, understanding how defects are transmitted from the seed crystal into the regrown region, and how they reorganize at the solid–liquid interface, remains a key challenge. In this work, in-situ X-ray radiography and topography are combined to directly visualize the evolution of the solid–liquid interface and follow defect dynamics in real time. In addition, rocking curve imaging (RCI) is used ex-situ to quantify local lattice distortions, misorientation, and possible sub-grain formation during the early stages of silicon regrowth. This approach is applied to different seed materials, including float-zone, Czochralski, and cast-mono silicon, in order to assess the influence of the initial seed quality on defect propagation and reorganization during regrowth.

The observations reveal a characteristic two-stage evolution of defects revealed by their contrast on the X-ray topographs recorded during regrowth. At the initial stage, diagonal contrast features are observed above the first solid–liquid interface. These features are attributed to dislocation glide along {111} characterized only in the first stages. As growth proceeds and the interface becomes more stable, the linear contrasts progressively reorient and become nearly perpendicular to the solid–liquid interface moving upward. This latter contrast type is interpreted as grown-in dislocations expanding along the growth direction, intersecting with the solid-liquid interface to minimize their line tension.

Interestingly, the quasi-perpendicular contrast does not appear in the same form in all samples. In some cases, it appears as sharp, intense, and well-defined individual lines, whereas in others it appears weaker, broader, and more diffuse. Comparison with the RCI peak-position maps suggests that regions showing broadened topographic contrast are often associated to local lattice misorientation and thus to sub-grain formation. This indicates that, in these regions, dislocations may rearrange collectively ultimately polygonising and creating dislocation networks or low-angle boundaries, leading to broadened contrast and measurable local lattice tilt. In contrast, when sharp individual perpendicular contrast is observed, no significant lattice tilt or misorientation is detected in the corresponding RCI maps indicating that the linear contrasts are due to the strain field created by independent propagating dislocations.

These results suggest that the solid–liquid interface plays an active role not only in the transmission of seed defects into the regrown crystal, but also in their reorganization during the transition from the transient stage to the stationary growth regime.