Growth dynamics of lattice dislocations and small-angle grain boundaries in multicrystalline silicon during directional solidification

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Grain boundary (GB) and dislocations are both critical factors influencing the solar cell performance. Dislocations are harmful to photovoltaic effect due to electrical activity, and small-angle GBs (SAGBs), which are well-known dislocation arrays, have been confirmed electrically active as well [1]. It has been reported that SAGBs can be generated by dislocation aggregation during solidification [2]. The growth behavior of SAGBs and their interplay with dislocations remain poorly understood. A thorough knowledge of SAGBs and dislocations during solidification would lead to more applications of defect engineering with SAGBs.
In this study, experimental methods include *in situ* observation of Si growing directional in a quartz crucible, determination of grain orientations and GB structures by SEM-EBSD, and dislocation delineation by preferential etching. The combination of *in situ* observation and *ex situ* characterization enable the studies of growth behaviors of SAGBs and dislocations.
We have found three different behaviors between dislocations and SAGBs during solidification: (i) lattice dislocations aggregated into a linear array during solidification and eventually formed a SAGB [2]; (ii) dislocations terminated at SAGBs (Fig. 1) and increased GB's misorientation, which implies dislocation absorption by SAGBs; (iii) twist SAGBs growing along {111} split and released tons of dislocations (Fig. 2), which suggests that a twist {111} SAGB is not a stable structure during solidification. Lattice dislocations are able to be generated and eliminated by SAGBs, and they can also create SAGBs by aligning themselves together. Growth dynamics depends significantly on the growth orientation. Our findings could partly explain the inhomogeneous distribution of dislocations in multicrystalline Si.

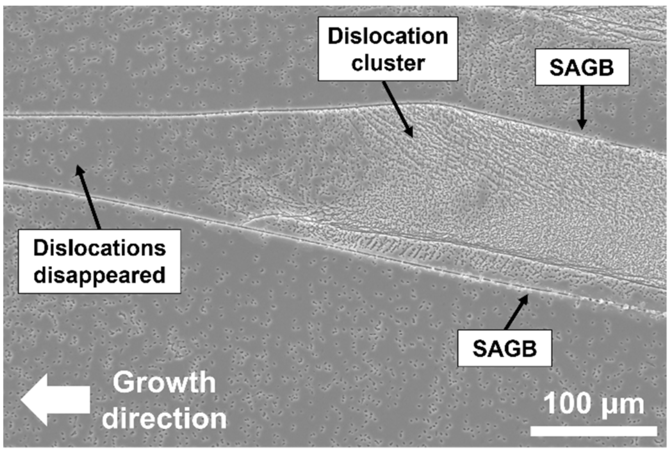

Fig. 1 Dislocation cluster gradually disappeared between two non-twist SAGBs, resulting in a significant decrease in dislocation density. Sample surface was etched by Sopori etchant.

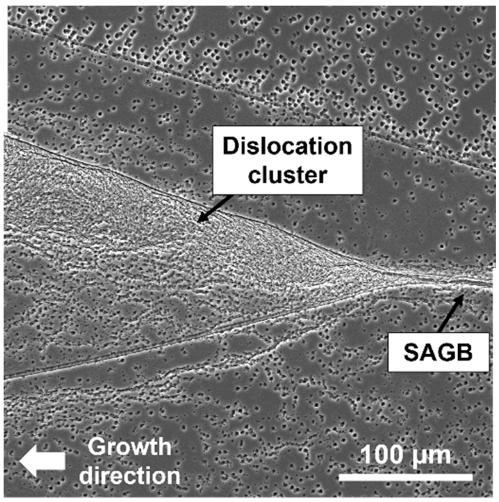

Fig. 2 One twist {111} SAGB split during solidification and released tons of dislocations. Sample surface was etched by Sopori etchant.

References:
[1] J. Chen, T. Sekiguchi, *Jpn. J. Appl. Phys.* 46 (2007) 6489–6497
[2] L.-C. Chuang, K. Maeda, H. Morito, K. Shiga, K. Fujiwara, *Materialia* 3 (2018) 347–352