多結晶シリコンインゴット中の転位発生点近傍の構造特性

Structural properties of generation sources of dislocations in polycrystalline Si ingots

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[Introduction] From a viewpoint of cost effectiveness, more than 50% of commercial solar cells are fabricated with multicrystalline silicon (mc-Si) with lower purity and perfectness, grown via high-throughput directional solidification at a low cost [1]. Many dislocation clusters acting as recombination centers are frequently generated during the crystal growth, and they degrade the macroscopic electric properties around them, which is much inferior to that in monocrystalline Si solar cells. One important issue to fabricate high quality mc-Si solar cells is, therefore, to control the generation of dislocation clusters during the growth. Even though the degree of dislocation generation in mc-Si would depend on the type of grain boundaries (GBs) [2], the generation sources have been hardly determined in commercial mc-Si ingots with complicated crystal structure. Recently, three-dimensional (3D) distribution of dislocation clusters is visualized in a high-performance mc-Si (hp-Si) ingot for commercial solar cells by photoluminescence (PL) image processing [3], and it is proposed that some triple junctions of GBs would be related to dislocation generation [4]. In the present work, we have examined the triple junctions to discuss the origin of the generation of dislocation clusters in terms of nanoscopic structural properties including the nature and distribution of GBs and dislocations, by using transmission electron microscopy (TEM) combined with PL image processing and etch-pit techniques [5].

[Results & discussions] As-sliced wafers cut from a hp-Si ingot were sequentially measured by PL imaging, and 3D distribution of dislocation clusters were visualized by 3D reconstruction with the PL images [3]. The electric properties around a generation source, such as the carrier recombination velocity, can be determined by analyzing the PL contrast. Dislocation clusters degrading the electric properties are frequently generated nearby triple junctions of GB, as reported [4]. Those dislocation clusters would be generated accompanied with the movement of the triple junctions. They propagate towards different directions, forming small angle tilt boundaries and dislocation networks on different atomic planes. Additional slip system may be operated when the complicated dislocation clusters are formed. The mechanism of their generation and propagation will be discussed.

References: [1] C.W. Lan, *et al.*, Cryst. Eng. Comm. 18 (2016) 1474; [2] T. Iwata, I. Takahashi, and N. Usami, Jpn. J. Appl. Phys. 56 (2017) 075501; [3] Y. Hayama, *et al.*, Sol. Energy Mat. Sol. Cells 189 (2019) 239; [4] K. Tajima, *et al.*, 79th JSAP Fall Meeting (2018) 20a-133-2; [5] Y. Ohno, *et al.*, 66th JSAP Spring Meeting (2019) 9a-W611-1.