High-efficiency Spherical Si Solar Cell with Semi-light-concentration System

Chikao OKAMOTO

Si spheres that are the substrate of spherical Si solar cells can be directly produced from melt Si without cutting and polishing processes where Si material loss occurs in Si wafer production process. Moreover, spherical Si solar cells with semi-light-concentration system can reduce the Si quantity, because spherical Si solar cells are arranged in sparsity. Therefore, the spherical Si solar cell with semi-light-concentration system was expected to lead the further cost reduction. In this paper, we discussed the fabrication of spherical Si solar cells with semi-light-concentration system, electric and crystallographic characterizations of spherical Si solar cells based on Si spheres with a diameter of 1 mm produced by a dropping method, and high-efficiency technology of the spherical Si solar cell.

The crystal growth of the Si sphere produced by the dropping method is completed in the fall duration of about 2s. The crystal growth of the Si sphere, which is different from the crystal growth of the single-crystal Si ingot, is the seedless and high-speed cooling. Therefore, during the dropping, the generation of many crystal nuclei in the Si sphere occurs, and then the crystal growth of the Si sphere occurs in arbitrary directions. As a result, the Si sphere is generally polycrystalline. Moreover, Si spheres include many defects, because the stress is generated by high-speed cooling. The correlation between the defect distributions and spherical Si solar cell characteristics are evaluated by electron beam induced current (EBIC). By EBIC, we confirmed that a part of strong electrically active defects in the grain is the main factor of characteristics decrease, the strong electrically active defects on pn junction is the cause of leakage current, and the entire grain also has the weak electrically active defects. Moreover, the correlation between defect types and electrically active defects was directly identified by transmission electron microscope (TEM) after sampling a part of the electrically active defect by focused ion beam (FIB). As a result, dislocations and the grain with microcrystalline Si were observed. These crystal defects are determined to the main factor of spherical Si solar cell characteristics decrease.

It is necessary to inactivate and remove crystal defects in Si spheres for the high-efficiency spherical Si solar cells. At first, to inactivate electrically active defects, hydrogen passivation by RF plasma (H-passivation) was done. Spherical Si solar cell characteristics were improved after H-passivation. By EBIC, FIB, and TEM, H-passivation was found be effective in the grain with microcrystalline Si and grain boundaries, but be not effective at dislocations. Moreover, it is necessary to decrease the crystal defects for high-efficiency spherical Si solar cells. Therefore, to decrease the cooling rate of the Si sphere by decreasing the convection heat transfer to ambient, Si spheres are dropped in a free-fall tower at a low pressure state. In the low pressure spherical Si solar cell, dislocations and grains with microcrystalline Si which are observed in conventional spherical Si solar cells disappeared. As a result, we achieved the conversion efficiency of 11.1% under 100 mW/cm2 AM 1.5 illumination at 25oC. However, dislocations were still confirmed at the vicinity of the grain boundary in the low pressure Si sphere. The crystal growth of the Si sphere produced by the dropping method occurred in arbitrary directions, and the stress could not be relaxed completely in the vicinity of the grain boundary. To achieve the further high-efficiency spherical Si solar cell, it is necessary to control the crystal growth direction of the Si sphere.