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Development of High-quality Multi-crystalline Silicon Ingots for Solar Cells

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Many new directional solidification (DS) technologies have been developed to meet the product quality requirements of the newly developed photovoltaic market. These technologies include growth for quasi-mono Silicon (QSC-Si) ingot, the granule silicon seeded and the heterogeneous seed-assisted growth for high-performance (HP) mc-Si ingot.

For the QSC-Si ingot, wafers with a large <100>-orientated area can be obtained and the cell efficiency had a great advantage in comparison with the conventional mc-Si by using alkaline texturing method. But high dislocation density and insufficient single orientated area yield were the main problems which restrained the solar cell efficiency and made a higher production cost. For the HP mc-Si ingot via the granule silicon seeded growth, the distribution of grain size was effectively controlled by the application of granule Si seeds (multi ones or single ones). Uniform grains with low dislocation density and high minority carrier lifetime were obtained in the HP mc-Si ingot in comparison with the conventional mc-Si ingot. About 0.5% absolute values in average solar cell conversion efficiency were higher with the same cell production process. However, for the above two methods, it is difficult to control the seeds at a suitable height during the melting stage, and the obtained ingots always have a longer low minority carrier lifetime zone at the bottom, almost twice as wide as that in a conventional mc-Si ingot, decreasing the production yield. On the other hand, the heterogeneous seed-assisted growth for HP mc-Si ingot is an effective approach for facilitating the nucleation of the uniform grains with low dislocation density, and the low minority carrier lifetime zone at the bottom of the ingot is as short as the conventional mc-Si ingot.