

Nowadays, the seed crystals used for Cz crystal growth are usually dislocation-free. However, each time the seed crystal is dipped into the melt, dislocations are generated by the temperature shock and by surface tension effects between the melt and the crystal. Normally these dislocations are propagated, or move into the growing crystal, particularly if the crystals have large diameters. The movement of dislocations is affected by cooling strain and faulty crystal growth.

The strain that occurs as a result of different cooling rates between the inner and the outer parts of the crystal is probably the main reason for the dislocation movement in the case of large crystals. At the usual $\langle 100 \rangle$ -crystal orientation, no (111) lattice plane, that is, no main glide plane, extends parallel to the crystal axis. All (111) glide planes are oblique to the crystal axis and as a result all dislocations that move only on one glide plane are conducted out of the crystal at some time. For movement in the pulling direction, the dislocations have to move downwards in a zigzag motion using at least two of the four different (111) glide planes. Dislocation-free crystal growth is relatively stable even for large crystal diameters, in spite of the higher cooling strain. This is so because it is difficult for a perfect crystal to generate a first dislocation. However, if a first dislocation has been formed, it can multiply and move into the crystal. In this way, numerous dislocations are generated and spread out into the crystal until the strain becomes too low for further movement of dislocations. Therefore, if a dislocation-free growing crystal is disturbed at one point, the whole cross section and a considerable part of the already-grown good crystal are inundated with backward-moving slip dislocations. The length of the slip-dislocated area is approximately equal to the diameter. Wafers and cells that show these types of dislocations can easily be hydrogen-passivated.

After losing the dislocation-free state, the crystal continues to grow with a high density of dislocations that usually are irregularly arranged. They are partly grown-in into the crystal and partly generated later by strain-induced processes. At high temperatures, climb processes take place that distort the dislocation array even more. This further increases the irregular shape and the distribution of the dislocations. In contrast to simple “slip” dislocations, these “grown-in” dislocations cannot be passivated well by a hydrogen-passivation step later in the solar cell processing. With crystal diameters above 30 mm, the monocrystalline but dislocated growth is not stable and in most cases changes to polycrystalline growth because of the tendency of a Si crystal to form twins in the presence of strain and dislocations. These twins also multiply and form higher-order twins and thus rapidly form a polycrystal. This fine-grained poly-Si material is not usable for solar cell production. Known causes for the generation of the critical first dislocation are either solid particles in the melt that move to the solidification front, gas bubbles that are trapped at the solidification front, impurities that exceed the solubility limit in the melt, vibrations of crystals and melt, thermal shocks or a too high cooling strain.

The growth of the seed cone is the most critical stage in the pulling of the Cz crystal. For productivity reasons very flat seed cones are preferable since the time for the making of the cone is not productive. However, the probability of introducing dislocations in the seed cone is lowest for tapered cones, although this means an increase in the pulling time by 15 to 25% for the same body length and additional loss in usable material. The loss of time and material gets worse for larger ingot diameters.