Owing to the reaction between the liquid Si and the quartz crucible, the crucible is of considerable importance to the growth. The silica of the crucible supplies considerable amounts of oxygen to the melt and, owing to the high purity of the silica, only small amounts of other impurities. However, the crucible tends to dissolve after a long-standing time so that the risk for particles in the melt from the crucible is increased with increased pulling time. The oxygen of the melt adds up to 10^{18} oxygen atoms/cm^3 to the growing crystal, whereas carbon is usually $<10^{17}/cm^3$ and has only little impact on the solar cell performance. Oxygen effects like thermal donors and precipitates can be well controlled in Cz cell processing.

6.2.2 Tri-crystalline Silicon

The mechanical properties of tri-crystalline silicon (tri-Si) allow slicing of ultra-thin wafers with higher mechanical yield than monocrystalline silicon (see [5, 6]). Tri-Si is a crystal compound consisting of three mutually tilted monocrystalline silicon grains [5, 6]. The crystal compound has a (110) surface orientation in all grains in contrast to the standard (100) orientation of wafers for today's solar cell production. While two of the grain boundaries in a tri-crystal are $\sum 3$ classified, that is, first-order twins, the third grain boundary is a $\sum 9$ structure, that is, a second-order twin. All boundaries are perpendicular to the (110) wafer plane and meet at the ingot centre forming a characteristic tri-star. Tri-Si growth is fully compatible with standard Cz monocrystalline growth, but it is faster. Using a tri-crystal seed that contains the complete generic information, tri-Si ingots of 100 to 150 mm diameter and up to 700 mm length are grown in standard commercial crystal pullers using optimised growth parameters for neck, crown and body (see Figure 6.2).

As the pulling axis is parallel to the common <110> orientation of all three grains, the dislocations often cannot be completely eliminated during necking, resulting in ingots that are not dislocation-free. The maximum local dislocation densities are about 105/cm^2 in the ingot top and about 107/cm^2 in the ingot bottom. The dislocations are often arranged

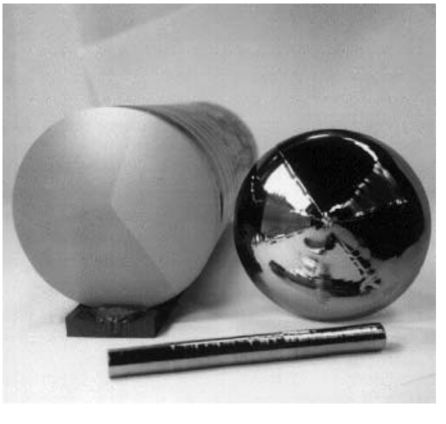

Figure 6.2 Tri-crystal seed (front), tri-crystal with cropped crown (left) and tri-crystal crown (right) with typical facets