by either the Czochralski technique (80%) or the floating-zone technique (20%). The PV industry used both the high-quality tops and tails of the microelectronic crystals for less than 5$/kg to fit the feedstock demand and the depreciated Cz pullers of the "big brother" microelectronic industry. Since the microelectronic industry was and is still driven by continuously increasing ingot diameters, the "small" Cz machines became available for the PV-industry at interesting prices. During the last expansion phase of the microelectronic industry (1993–99), the PV industry had to struggle with a severe shortage of affordable feedstock. To reach the production volume, even pot scrap Si material had to be used. New and demanding techniques were developed in a hurry to separate the Si from the quartz crucible parts and to pre-select and pre-clean this material. Also, fine grain material had to be made usable. However, the annual world requirement for solar quality silicon in 2010 is estimated at 8000 to 10 000 metric tons for PV use, that is, the silicon demand will be roughly as high in volume as today's world production for microelectronics. A dedicated Si feedstock supply only for PV is therefore a necessity.

It can no longer be denied that the growing of silicon crystals has matured from an art into a scientific business. In today's PV-business, some of the bigger companies convert more than ~1 to 2 tons of silicon per day into solar grade Cz crystals and solar cells. Since PV has different main requirements for crystal growing from the microelectronic industry, the focus of machine and process development differ.

6.2.1 Cz Growth of Single-crystal Silicon

Solar cells made out of Czochralski (Cz)-grown crystals and wafers play – together with multicrystalline cells – a dominant part in today's PV industry. This is due to the following advantages.

Cz crystals can be grown from a wide variety of differently shaped and doped feedstock material. This enables the PV industry to buy cost-effective feedstock Si with sufficient quality even on spot markets. Since the feedstock is molten in a crucible, the shape, the grain size and the resistivity of the different feedstock materials can be mixed for the required specifications, although a given feedstock alone would fail. However, special care must be taken to avoid any macroscopic particles (SiO_2, SiC) that would not be dissolved in the melt especially when pot scrap material is used.

The Cz process acts as a purification step with respect to lifetime-limiting elements. The effective distribution coefficients of the most dominant lifetime-limiting metals (Fe, Ni, Au, Ti, Pt, Cr) are in the range of 10^{-5} or below. Together with appropriate gettering steps during cell processing, highly efficient commercial solar cells can even be made out of ingots grown from low-grade pot scrap material. The targeted iron equivalent concentration in the finished cell must be $<10^{12}$ atoms/cm^3 to achieve a minority carrier diffusion length well above ~150 μm.

The Cz process itself acts as a quality control step since proper crystallisation, that is, dislocation-free growth of an ingot, can only take place in a well-defined process window. The homogeneity of a well-grown solar grade Cz ingot for PV application is excellent with respect to the bandwidth of electronic and structural properties, whereas mc-Si block casting produces specifications with higher variances in most parameters. Cell