by thermal stress that is originated from temperature non-homogeneities during crystallisation and cooling of the ingot. The reduction of these temperature variations while keeping high process speed is therefore considered one of the most important issues for the further improvement of multicrystalline silicon.

An optimal process scenario for the production of multicrystalline silicon from both the crystal defect and the productivity point of view starts with a small crystallisation speed and minimal temperature gradients in order to secure a low-defect density bottom region of the ingot. After that, crystallisation speed should be largely increased for productivity reasons while keeping the solidification front planar and thermal gradients within the solidified silicon low.

6.3.4 Impurities

Despite boron being the standard dopant and thus an intentionally introduced impurity, even higher impurity concentrations in multicrystalline silicon are observed for both oxygen and carbon.

The interstitial oxygen concentration in multicrystalline silicon is affected by two processes, which are oxygen incorporation via the quartz crucible during melting and oxygen loss through evaporation of SiO, that is, the evaporating gaseous silicon monoxide that is stable at high temperatures only.

Because the segregation coefficient >1, the oxygen content decreases with increasing block height. Typical concentrations of the interstitial oxygen content of Bridgman and block-cast material are given in Table 6.2. Obviously, although the silicon melt never stays in direct contact with the quartz crucible, lower oxygen concentrations with Bridgman-type material compared to silicon from the block-casting process are not feasible. We therefore conclude that there also has to exist an oxygen release from the Si_3N_4 coating (containing some percentage of oxygen) into the silicon melt during the Bridgman process. In addition, we observe a much more rapid decrease of the oxygen concentration with increasing block height for block-cast material, which is attributed to the normally employed lower ambient pressure and enhanced gas exchange during this process.

Table 6.2 Typical concentrations of interstitial oxygen $[O_i]$ for block-cast material from the Freiberg production plant of Deutsche Solar GmbH and for typical material coming from a Bridgman process. For the determination of the oxygen concentration by Fourier Transform Infrared Spectroscopy (FTIR), a conversion factor of $2.45 \times 10^{17}/cm^2$ was used

Ingot position	Interstitial oxygen concentration $[O_i]$ $[10^{17}/cm^3]$	
	Block-casting process	Bridgman process
Bottom	6.5	6
Middle	0.9	3.5
Top	0.5	2