that is, below approximately $10^{12}/\text{cm}^3$. The importance of metal impurities for multicrystalline silicon solar cells is, however, based on metal impurities controlling the activity of extended defects, specifically that of crystal dislocations.

We anticipate that metallic impurities are, for example, responsible for the observed systematic changes of the lifetime of multicrystalline silicon wafers after high-temperature steps in the range of 800 to 1000°C (e.g. the phosphorous diffusion step for fabrication of the solar cell *pn*-junction). The wafer lifetime quite commonly decreases in annealing steps above 900°C, where this decrease is even more significant at enhanced cooling speeds after the anneal. The proposed mechanism behind this lifetime degradation is a release of metal atoms from extended defects like dislocations into the wafer bulk material and a subsequent quenching of the metal atoms as highly recombinative point defects.

Another hint of an extensive interaction between extended defects and metal impurities is given in Figure 6.13 that depicts the theoretical segregation profile of iron in an intentionally contaminated multicrystalline ingot (mean iron concentration: $7.9 \times 10^{17}/\text{cm}^3$) as compared to the experimental one. We clearly can state a reduced experimentally determined segregation effectiveness most probably caused by iron segregation into extended defects competing with the segregation process in the liquid silicon phase during crystallisation.

In order to prevent such defect–metal interaction processes leading to enhanced recombination activity, a very effective segregation of metallic impurities into the ingot top region has to be assured. This segregation effectiveness, however, decreases with both increasing crystallisation speed and increasing concentration of extended defects.

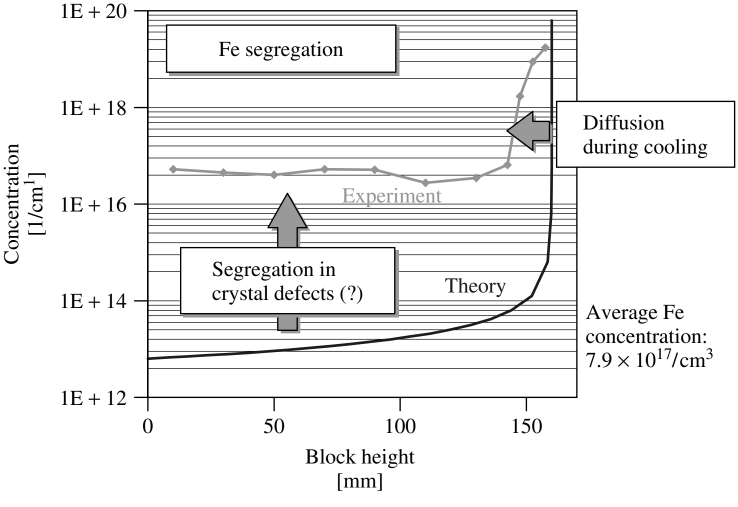

Figure 6.13 Experimentally determined iron concentration of an intentionally contaminated multicrystalline silicon test ingot (mean Fe concentration: $7.9 \times 10^{17}/\text{cm}^3$). The experimental data is given as a function of the block height and in comparison to the theoretically expected profile. The much higher than theoretically predicted concentration in the bottom and middle part of the ingot is attributed to a segregation not only into the silicon melt but also into extended crystal defects during solidification