co-workers [31] studied the precipitation and coarsening of $NiSi_2$ and the effect of precipitates upon the minority-carrier diffusion length in n-Si single crystals (FZ material). Scanning electron microscopy (SEM) using the method of electron beam–induced current (EBIC) revealed that $NiSi_2$ precipitates were efficient recombination centres and that the minority-carrier diffusion length, L_D, was related to the precipitate density, N_P, by

$$L_D = 0.7 \cdot N_P^{-1/3}$$

This relationship revealed that the diffusion length depends only on the density of precipitates and not on the concentration of impurities. Therefore, a suitable temperature process can increase the diffusion length, L_D. This occurs if during this process large precipitates grow at the expense of the smaller ones, increasing the free distance between the precipitates. This ripening process of precipitates is observed repeatedly during heat treatments.

5.7 ROUTES TO SOLAR GRADE SILICON

To design a specific route to solar grade silicon between the two existing commercial grades, that is, metallurgical and semiconductor (polysilicon), is not a new challenge. It was first seriously and massively addressed in the mid-seventies after the first international oil crisis. Considerable R&D efforts were made in the years 1975 to 1985 particularly in the United States under the guidance of the Department of Energy (DoE). During and at the end of this productive period, numerous specific articles, exhaustive review-studies and symposium proceedings devoted to these topics were published [38–40]. The following gives a summary and an update of these efforts. All approaches investigated are classified within four subgroups.

1. Crystallisation is generally an effective purification technique. Crystallisation is also a necessary step to produce the silicon device. The question is whether the crystallisation steps in the manufacturing chain to the solar cell can advantageously be combined with the purification.
2. Upgrading the purity of metallurgical silicon is a technique with the potential to produce millions of tonnes of silicon as we have demonstrated earlier in this chapter. The goal of and the challenge for this alternative are to achieve adequate purity at acceptable cost. A guiding number for this option has been and should remain less than 10 US$/kg.
3. The polysilicon process involving the synthesis, the purification and the decomposition to elemental silicon of volatile silicon hydrides is proven technology. This is presently the sole reliable source of silicon for solar cells. Simplifying it, exploring or revisiting related routes seems therefore an attractive alternative. The challenge in this particular case is to achieve sufficient output at acceptable cost.
4. Electrolysis, electrolytic methods, metallic reduction of silicon and so on are summarised in a fourth category of methods.

5.7.1 Crystallisation

The efficiency of the crystallisation processes may be predicted by the segregation or the distribution coefficient of each impurity element (see Section 5.6.1) between the solid and