The most striking difference between the best and the ideal solar cell is the difference in design: thick and low injection *versus* thin and high injection. The PERL cell is surely the best design for the currently achievable levels of surface recombination, which limit open-circuit voltage and shift the optimum thickness to high values. The low resistivity follows then from transport considerations for the chosen structure. The very high fill factor of the ideal cell is characteristic of high injection, Auger-limited operation.

Reduction of surface recombination in the best laboratory cells relies on surface passivation and the restriction of very heavily doped regions to a minimum. In the end, this is possible because of the possibility of defining and aligning very small features on the surfaces.

The very heavily doped emitter, along with lower substrate lifetimes, is responsible for the reduced short-circuit current and open-circuit voltage in the industrial cell. The fill factor is affected by the large device area in conjunction with the limitations of the metallization technique, which further reduces the current because of shading.

Continuous improvement in material quality and cost-driven thinning of the substrates will increase the need for industrial cells to implement surface passivation schemes. This will require the refinement of the metallization technique; another issue is that substrate lifetimes in an industrial environment depend on the gettering action of very heavy diffusions, which are not compatible with optimum surface performance. The PERL approach – high-temperature processes and delineation of fine features – is the most successful path to high efficiency, but it is not the only one that can inspire the forthcoming developments in industrial cells. It is worth noting, in this respect, that heterojunction with intrinsic thin-layer (HIT) solar cells have entered the exclusive club of more than 20% efficiency with a different approach (see Section 7.7.2).

7.4 MANUFACTURING PROCESS

7.4.1 Process Flow

Figure 7.6 shows the main steps of a simple process for solar cell fabrication based on screen printing. With more or less minor modifications, this process is currently used by many manufacturers. The main virtues of this 30-year-old PV technology are easy automation, reliability, good usage of materials and high yield. The drawback, as explained in preceding sections, is the efficiency penalty derived from the coarse and aggressive metallization technique. Some specific treatments worked out for mc-Si will be explained in Section 7.6.

Each step is briefly described in the following text with illustrative purposes: values of temperature, time and so on will only be indicative.

1. *Starting material*: The industry uses so-called solar grade Cz-Si wafers, round in origin but very often trimmed to a pseudo-square shape, or multicrystalline square wafers. Wafer dimensions are between 10- and 15-cm side and between 200- and 350-μm thickness. Doping is *p*-type (boron) to a resistivity of around 1 Ω·cm.
2. *Saw damage removal*: The sawing operation leaves the surfaces of “as cut” wafers with a high degree of damage. This presents two problems: the surface region is of