contributions include Si-metal (Si-M) interface(s) and edge leakage (e.g. from the mesa edge). Many approaches are used to minimize the effective surface recombination at each surface. A prudent approach to minimize the Si-M contact area (both at the front and back) is through appropriate grid design. This consideration has led to the design of point-contact and buried-contact cells [20, 21]. This feature will also minimize the shadow loss for the incident light (except for back-contact cells). Another means of reducing the effect of Si-M interaction on the carrier loss is to employ a minority-carrier reflector consisting of a high–low field (such as $n^+/n$ or $p^+/p$) under the metal. Several schemes have been developed for forming the back contact of wafer-based cells that include either a partial or total diffusion of the back surface. For a TF-Si cell fabricated by deposition, these features can be accomplished by tailoring the dopant profile during deposition.

Surface passivation of unmetallized regions can be further improved by oxidation. It has been shown that such passivation can reduce the surface-recombination velocity to about 100 cm/s [22, 23] – values that are essential for high-efficiency TF-Si cells. In wafer-based cells, passivation schemes are embodied in various configurations called *passivated emitter rear locally diffused* (*PERL*) and *passivated emitter rear totally-diffused* (*PERT*) as described in Chapter 7. Application of wafer-based passivation methods to TF-Si solar cells may not be straightforward. For example, oxide growth at conventional temperatures (>1000°C) is not feasible for cells deposited on low-cost substrates like glass. However, it has been shown that low-temperature oxides grown by rapid thermal processing (RTP)-like processes can have excellent passivation properties [24]. Another approach to produce effective surface passivation can be the use of low-temperature plasma-enhanced chemical vapor deposition (PECVD) nitride. It is now well known that SiN (or oxy nitrides) produces a positive charge at the Si interface that results in excellent passivation characteristics for $p$-type Si [25, 26].

It is fruitful to briefly review some preliminary work that was instrumental in establishing the advantages of TF-Si solar cell structures and promoting further research. The capability of a thin cell to yield high performance with effective incorporation of light-trapping and surface passivation was demonstrated by a number of researchers. Table 8.1 compares the cell parameters of three devices of different thickness. One of them is a typical high-efficiency thick cell with light-trapping and surface passivation; the other two are thin cells fabricated by different processes. These cells include light-trapping, as well as oxide passivation. Figure 8.6 illustrates the structure of the devices.

The first device is a 44-μm-thick cell with $n^+pp^+$ structure [27]. Its surfaces are not well passivated, but include a good light-trapping design. The second device is a PERL cell fabricated on a 47-μm single-crystal, float-zone (FZ), wafer. The wafer was chemically thinned, and $NF_3$ was used during the oxidation step to reduce wafer-bending

**Table 8.1** Parameters of two types of thin cells and comparison with a thick cell

| Structure | Thickness [μm] | $V_{OC}$ [mV] | $J_{SC}$ [mA/cm$^2$] | Fill Factor [%] | Efficiency [%] |
|---|---|---|---|---|---|
| $n^+pp^+$ | 44 | 643 | 35.3 | 75.8 | 17.2 |
| PERL | 47 | 698 | 37.9 | 81.1 | 21.5 |
| PERL | 400 | 702 | 41.2 | 81.2 | 23.5 |