Introduction of H after impurity gettering can help improve solar cell efficiency by as much as 3 to 4 absolute points. Generally, such a passivation results in a significant decrease in the dark current and an improvement in the illuminated cell parameters. However, the degree of improvement can vary significantly over the wafer in a manner very similar to impurity gettering [96–98]. It has been determined that better-performing regions improve more than the poorer regions. This behavior can be explained by the dependence of H diffusion on the structure of defects, such as defect clusters and impurity precipitation. The defects and impurities act as trapping centers for atomic H, reducing its effective diffusivity [99–102].

Several methods have been used for incorporating H in solar cells. These include ion implantation, plasma processing, and, more recently, a process in which hydrogenation is combined with deposition of a Si_3N_4 layer by a PECVD process. The nitride layer is used as an AR coating. Another advantage of the nitride coating is that the front metal can be fired through the nitride using an RTP-like process, typically 800 to 850°C for about 10 s.

In a wafer-based cell, passivation of impurities and defects requires a deep diffusion of H into the bulk of the solar cell. In addition, it is important that H interacts with only those impurities that degrade device performance. For example, H should not deactivate dopants because that would lead to a change in the resistivity of the device. These considerations dictate a careful design of a hydrogenation process. A deep diffusion of H may appear to be quite trivial because a high value of diffusivity of H in Si is often assumed. However, the effective diffusion of H in Si is primarily controlled by its defects and impurities. H can associate with impurities and defects to form complexes, leading to “trapping” of H during its diffusion into Si – causing a greatly reduced diffusivity of H at low temperatures (e.g. $<400°C$ typically used for hydrogenation by plasma or ion implantation). To minimize the effects of trapping, it is necessary to use a high-temperature process step. At higher temperatures, the complexes begin to dissociate, causing the H to diffuse with intrinsic lattice diffusivity.

Trapping of H is also expected in poly TF-Si solar cells because of the abundance of GBs. However, by incorporating suitable process design, the trapped H can be released for impurity-defect passivation. This feature may be valuable for TF-Si solar cells because many a-Si or poly-Si deposition techniques result in copious amounts of H in the thin film.

8.4 CONCLUSION

The thin-film Si solar cell was envisaged during the infancy of solar-cell technology as a potential candidate to reduce the amount of Si needed for an efficient solar cell. Although it was recognized that the quality of the material needed for a TF-Si solar cell does not have to be very high, experimental work on cell fabrication had to await technologies in two different areas – a lift-off type of technology for making single-crystal cells, and low-temperature processing of large-grain polycrystalline deposition to make thin films on low-cost substrates. Clearly, this is just the beginning of thin-film Si solar-cell technology, but there has been astounding progress in a very short time frame. In addition to vigorous research, there is also interest in commercial production of such