When the Ge content is increased such that the band gap of a-SiGe is reduced below 1.4 eV (see the J–V curve for the 1.37-eV cell in Figure 12.23), the FF deteriorates rapidly. In this case, the short-circuit current density does not increase compared to the 1.50-eV cell even though more photons are absorbed. This lack of increase in J_{SC} with further decrease in the band gap occurs because the fraction of photocarriers that recombine has become more significant than the increase in the rate of photocarrier generation.

Similar to the deposition of a-Si, a-SiGe films and devices made with high hydrogen dilution show improved quality and light stability [151]. Optoelectronic properties of narrow band gap a-SiGe material are nonetheless inferior to those of a-Si.

12.5.2.1 Band gap grading

To enhance the fill factor of cells made using a-SiGe, band gap *grading* is used to enhance the collection of holes [152, 153]. In such a design, an asymmetric "V"-shaped band gap profile is created by adjusting the Ge content across the i-layer. Wider band gap material lies closest to the n- and p-layers. The plane of narrowest band gap lies closer to the p-layer (through which the photons enter into the device). Such a grading scheme allows more light to be absorbed near the p-layer so that "slower" holes do not have to travel far to get collected (see Figure 12.10). Also, the tilting of the valence band assists holes generated in the middle or near the n-side of the i-layer to move toward the p-layer. With appropriate hydrogen dilution during growth and band gap grading, a-SiGe cells can be made to generate up to 24.4 mA/cm^2 (27 mA/cm^2 as the bottom cell in a triple cell) when a light enhancing back reflector is used [154].

12.5.2.2 a-SiC alloys

The band gap of a-SiC can be adjusted between 1.7 and 2.2 eV, depending mainly on the C concentration [155]. After extensive research, most workers decided that a-SiC is not suitable for use as the i-layer of the uppermost cell in a multijunction structure. After light soaking, a-SiC material that has an appreciable band gap increase over a-Si is fairly defective and must be used in very thin layers; these layers do not absorb enough sunlight to be optimal. The wide band gap material presently used in triple-junction cells is a-Si with a relatively higher concentration of H (achieved by using lower substrate temperature and H dilution) [8].

12.5.3 a-Si/a-SiGe Tandem and a-Si/a-SiGe/a-SiGe Triple-junction Solar Cells

Several types of multijunction solar cells have been used in a-Si photovoltaics. Dual-junction a-Si/a-Si (same band gap tandem) solar cells have lower material cost than tandem cells using a-SiGe, but have lower efficiencies than more advanced structures [156]. Dual-junction a-Si/a-SiGe cell and triple-junction a-Si/a-SiGe/a-SiGe cells, which use a spectrum-splitting approach to collect the sunlight, achieve higher conversion efficiencies. Some additional details and references may be found later in Table 12.4. Among these, a-Si(1.8 eV)/a-SiGe(1.6 eV)/a-SiGe(1.4 eV) triple-junction solar cells have been used to obtain the most efficient a-Si-based cells today [8]. Figure 12.25 shows the structure of