described. Second, the i-layers in an optimized, multijunction cell are thinner than in single-junction cells [147, 148]; as can be seen in Figure 12.20, this "junction thinning" means that each individual junction will have a somewhat better fill factor than in the optimized single-junction device, and there will be less change from the initial to the stabilized efficiency of the cell. Third, a multijunction cell delivers its power at a higher operating voltage and lower operating current than a single-junction cell; the lower current reduces resistive losses as the current flows away from the junctions and into its load.

On the other hand, it is more challenging to fabricate multiple-junction solar cells than single-junction cells. The performance of a multijunction cell is more sensitive to the spectrum of the incident light due to the spectrum-splitting feature. This makes it even more critical to control the band gaps and thicknesses of the individual layers. In addition, most multijunction cells incorporate a-SiGe alloys. These alloys are made using germane gas as the germanium source. Germane is several times more expensive than silane and is highly toxic. Manufacturers need to implement strict safety procedures to handle these types of gases. Overall, the advantages and benefits of higher stabilized output power for multiple-junction cells do outweigh the difficulties in the fabrication.

12.5.2 Using Alloys for Cells with Different Band Gaps

As was mentioned in Section 12.2.7, when a-Si is alloyed with other elements such as Ge, C, O, and N, amorphous alloy materials with different band gaps can be obtained. This allows the selection of appropriate band gap combinations for high-efficiency solar cell fabrication. Since the band gap of the a-SiGe alloy can be continuously adjusted between 1.7 and 1.1 eV when different amounts of Ge are incorporated in the alloy, it can be used as the low band gap bottom cell absorber layer for a multijunction solar cell. It is desirable to select a band gap near 1.2 eV to achieve the maximum efficiency according to the contour plot in Figure 12.22. Unfortunately, the optoelectronic quality of a-SiGe degrades rapidly when the a-SiGe band gap is reduced below 1.4 eV, and these materials have not proven useful for PV application.

Figure 12.23 shows the J–V characteristics of a series of a-SiGe solar cells with different Ge concentrations in the i-layer (of constant thickness, and without a backreflector) [149]; the band gaps are indicated in the legend. As the band gap is reduced by incorporating more Ge in an i-layer, V_{OC} goes down and J_{SC} goes up (for a constant thickness), in agreement with trends for the calculations in Figure 12.20. In Figure 12.24, we plot the QE curves of these same a-SiGe cells (along with one curve for a cell with a back reflector, and one curve for a cell with a microcrystalline Si i-layer). Consistent with the increase in J_{SC}, the QE is increased for longer wavelengths (smaller photon energies) as the band gap decreases.

The fill factors of the cells also decrease as the band gap decreases. This effect is due to the increased defect density in the alloyed materials. We have not included this important effect in the discussion previously. As the defect density in the i-layer increases, a given cell's performance will ultimately be dominated by the trapping of photocarriers on defects instead of by bandtail trapping. Roughly speaking, one can think of defect trapping as reducing the "collection length" that determines the useful thickness of the intrinsic layer (cf. Figure 12.17). Naturally, one is principally interested in these effects for the "light-soaked" state achieved by operating cells.