12.5.3.1 Current matching

In a triple-junction cell, the three component cells are stacked monolithically. Since these component cells are connected in series to form a two-terminal device, the cell with minimum current density during operation will limit the total current of the triple-junction stack. Therefore, the current densities of each of the component cells need to be *matched* (made the same) at the maximum power point for each cell in sunlight. The short-circuit currents J_{SC} of the component cells are only a rough guide to this matching. For an a-Si/a-SiGe/a-SiGe triple-junction cell, the bottom a-SiGe cell usually has the lowest *FF* and the top a-Si cell usually has the highest *FF*. Therefore, the J_{SC} of the bottom cell needs to be slightly greater than the J_{SC} of the middle cell, which in turn needs to be slightly greater than the J_{SC} of the top cell. For an optimized triple-junction cell, the differences in J_{SC} between the bottom and the middle and between the middle and the top cells are each about 0.5–1 mA/cm^2. This is referred to as an intentional "mismatch" in the J_{SC} values designed to match the cells at the operating point. To obtain the highest stabilized solar cell efficiency, the triple cell needs to be designed, by adjusting the band gaps and thicknesses of the component cell i-layers, such that the component cell currents are matched at the maximum power point in the light-soaked state.

While adjusting for current matching, one needs to consider that the bottom cell benefits from the light enhancement from the back reflector, as can be seen from Figure 12.24, while the middle and top cells receive little benefit from the back reflector.

12.5.3.2 Tunnel junctions

Another area that needs attention in fabricating a multijunction solar cell are the *tunnel junctions* at the interfaces between adjacent *pin* cells. These interfaces lie between n-type and p-type layers, and one might think that they would have electrical properties like classic *pn* junction diodes. However, researchers take advantage of one of the special properties of a-Si material that was discussed in Section 12.2.6: dangling bonds are generated when doping is increased. Carriers that are trapped on defects on one side of the interface can move to traps on the other side simply by quantum mechanical tunneling. This process is sufficiently efficient that it "short-circuits" electrical transport involving the conduction band and valence band states [169]. For this reason, the doped layers at the tunnel junction, particularly the sublayers near the interface, are made with very high doping. The large density of dangling bonds permits the efficient recombination[13] (by tunneling) of holes from the cell below and electrons from the cell above, as illustrated in Figure 12.25. This tunnel junction is reverse-biased under normal operation; it must generate negligible V_{OC} and have negligible resistance and optical absorption [169].

12.5.3.3 I-V measurement

In measuring the $I-V$ performance of a multiple-junction, spectrum-splitting solar cell, researchers need to pay particular attention to the spectrum of the illuminating light

[13] One can consider this as a neutralization process.