layer. Finally, a "back" reflector is deposited onto the photodiode; the back reflector acts as an electrode to the *n*-type photodiode layer.

In the "substrate" design, sunlight enters the photodiode before it reaches the substrate. Starting with the substrate, the cell is fabricated in the reverse order compared to the superstrate design: first a back reflector, then the photodiode layers (starting with an *n*-type layer), and finally a TCO layer to act as an electrode to the topmost, window layer of the photodiode.

These two designs permit a very wide range of applications for amorphous silicon solar cells. The superstrate design (light enters through the substrate) is particularly suited to building-integrated solar cells in which a glass substrate can be used as an architectural element. The substrate design has generally been applied to solar cells using flexible, stainless steel (SS) substrates. The detailed construction of a deposition facility of course depends upon whether the substrate is rigid or flexible. Finally, it turns out that there is a profound effect of the substrate upon the properties of the first photodiode layers deposited upon it; this effect has led to fairly different photodiode structures for the superstrate and substrate designs.

12.1.2.3 Multijunction solar cells

The conversion efficiency of the relatively simple, amorphous silicon *pin* photodiode structure just described can be significantly improved by depositing two or three such photodiodes, one on top of another, to create a "multijunction" device. We illustrate a "tandem" device in Figure 12.4, which shows a combination of two *pin* diodes.[4] Note that the "bottom" cell is not based on a-Si:H, but rather upon an amorphous silicon–germanium alloy made by including germane (GeH_4) gas in the plasma-deposition recipe.

The main advantage of the tandem design over the simpler single-junction one is due to "spectrum splitting" of the solar illumination. Since the absorption coefficient of light rises rapidly with the photon energy, the topmost layer of a tandem cell acts

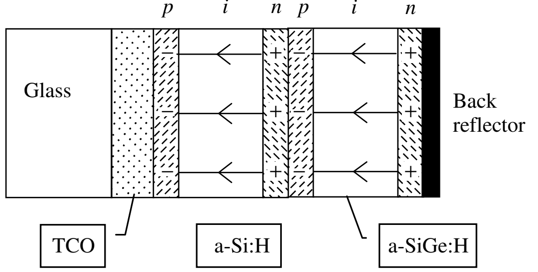

Figure 12.4 A multijunction solar cell consisting of two *pin* solar cells deposited in series. Double-junction (or "tandem," as shown) and triple-junction designs can be significantly more efficient than single-junction designs. Substrate texturing, which is important in real devices, is not indicated; see Section 12.4.5

[4] It is worth noting that the adjoining *p*-type and *n*-type layers do *not* form a *p-n* junction diode, but rather a simple Ohmic contact. We discuss the interesting physics underlying this fact in Section 12.5.3.