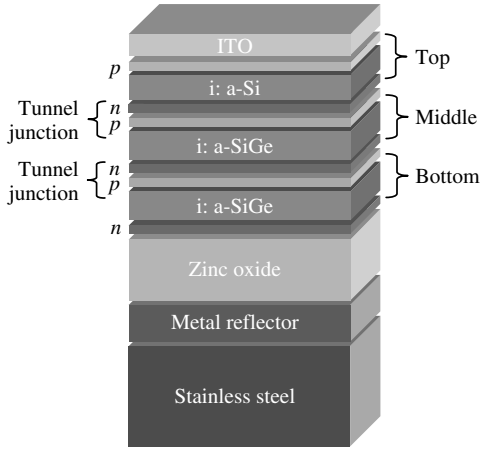

Figure 12.25 Structure of triple-junction *nip* substrate-type solar cells

a triple-junction substrate cell[12] grown on SS foil; a superstrate-type tandem cell (glass substrate) was illustrated previously in Figure 12.4. In both cases, light enters from the *p*-layer so that holes need to travel less distance to get collected than electrons. In the following, we will briefly describe the two designs and typical deposition processes that are most broadly used today.

In *nip* cells deposited on an SS substrate, a reflective metal layer is deposited first on the substrate by sputtering or evaporation, followed by the sputter deposition of a ZnO buffer layer. Usually, silver is used as the reflective layer for research cells because of its high reflectivity, whereas aluminum is used in production because of difficulties with production yield for silver. The metal layer is deposited at high temperature (300–400°C); self-segregation in the metal film forms the texture needed for light trapping. The sample is then moved into a RF PECVD deposition system for the deposition of semiconductor layers. The bottom *nip* with an a-SiGe *i*-layer (1.4–1.5 eV band gap) is deposited first. A second a-SiGe-based middle cell (1.6–1.65 eV *i*-layer band gap) is then added. Finally, the top a-Si-based cell (1.8–1.85 eV *i*-layer band gap) is added; the intrinsic layer is made using high H dilution at relatively low temperature. An indium-tin-oxide (ITO) layer is deposited on top via evaporation or sputtering. This layer is approximately 70-nm thick and serves as both the top electrode and an antireflection coating. Metal grids are evaporated or sputter-deposited on top of ITO to further reduce contact resistance.

In *pin* superstrate cells deposited on glass, the glass substrate is first coated with a textured transparent conducting oxide, usually SnO_2 or ZnO, using one of the several methods such as atmospheric pressure chemical vapor deposition (APCVD) [167, 168]. A *pin* top cell having an a-Si *i*-layer is then deposited, followed by the a-SiGe middle cell, and finally the narrow band gap a-SiGe bottom cell. The vertical structure is finished with the deposition of a ZnO buffer layer and metal reflector in the back.

[12] Substrate and superstrate cells were illustrated in Figure 12.3. The substrate-type cells are also called *nip*-type cells, and superstrate-type cells are also called *pin*-type cells, corresponding to the sequence in which the layers are deposited.