Phototronics Solartechnik GmbH (Germany) [189]. A typical process is that of BP Solar's 10-MW plant (TF1) in Toano, Virginia, (USA) [190].

The process begins with large sheets of "float" glass, 3 mm thick, with a typical size of 1 m by 0.5 m. A textured tin oxide TCO layer is deposited using an APCVD process either at the glass supplier's plant or at the PV plant. The substrate is edge-polished and cleaned before silver frits are applied as bus bars and cured in a belt furnace. This TCO layer is "scribed" by a laser into strips about 9 mm wide. The substrates are then loaded in the PECVD machine for the deposition of the six semiconductor layers for an a-Si/a-SiGe *pin*/*pin* tandem structure. The semiconductor deposition is followed by the deposition of a ZnO buffer layer. Another laser scribing is done at this point adjacent to the first scribe lines. This second scribing is done at a lower laser power so that, while the ZnO and a-Si layers are scribed, the underlying tin oxide layer remains intact. An aluminum layer is sputter-deposited as the back reflector and back contact. A third scribing of the Al adjacent to the second completes the interconnection of neighboring cells in series, as shown in Figure 12.28. A fourth, high-power laser scribing around the perimeter of the solar panel isolates the active area from the edges. The panel is then finished by bonding a second glass plate onto the cells with EVA. This second piece of glass is needed for encapsulation, which unfortunately adds weight and cost to the module.

12.6.3 Manufacturing Cost, Safety, and Other Issues

An important aspect of any manufacturing process is cost, which generally consists mostly of raw materials, labor, capital depreciation of the machines, and administration. The overall production cost per unit of product is reduced as the production volume goes up. At a high production volume, perhaps 100 peak megawatts/year, 100 MW_p/year, (under illumination yielding peak power production), the cost is expected to be lower than \$1/Wp. Currently, for a-Si modules intended for outdoor use for extended time, the major costs are the module framing, encapsulation, and the substrates (glass or SS). As an example, for the materials cost, the current breakdown at BP Solar's 10-MW plant is 33% for framing and packaging, 38% for TCO/glass, 17% for germane, 7% for encapsulation, and 5% for silane and other feedstocks [63].

Another important aspect with regard to a-Si PV manufacturing is the plant safety. Although there is no toxic material in the final product, the manufacturing processes do involve toxic and pyrophoric gasses such as germane, phosphine, trimethylboron, silane, hydrogen, and so on. Amorphous Si PV manufacturers, who have learned and borrowed

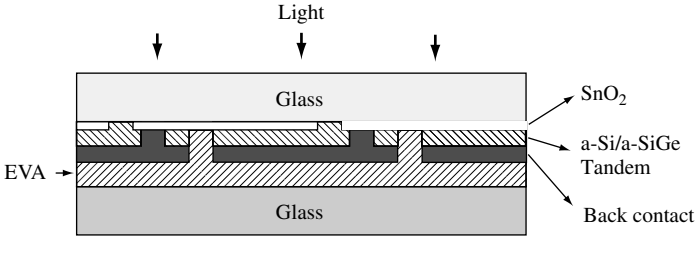

Figure 12.28 Cell interconnection of superstrate-type solar cells, used at BP Solar