After the semiconductor deposition, the roll is then loaded into the TCO deposition machine, which uses either reactive evaporation of indium in oxygen ambient or sputtering from an ITO target in an argon atmosphere. The thickness of the ITO is carefully monitored to achieve antireflection properties.

The four roll-to-roll steps are currently not integrated into one machine. This design reflects the different pressure ranges for the four machines: atmospheric pressure for the washing, a few mTorr for back-reflector sputtering, around 1 Torr for PECVD, and a few mTorr for TCO sputtering.

At this point, the SS roll is a giant solar cell, 700 m long, which needs to be converted into many smaller series connected cells to get higher voltage for the modules. The semiautomatic back-end process for cell interconnect and module assembly includes the following steps. The roll of TCO coated a-Si solar cells is first cut into slabs of selected sizes with a slab cutter. Etching paste is then applied to the edge of the slab and activated through a belt furnace to remove ITO around the perimeter of the slab and to define effective solar cell area. Selected small samples (coupons) are collected throughout the run for quality-assurance and quality-control (QA/QC) evaluation. The standard slabs then go through a shunt passivation process in an electrolyte bath to remove and isolate small shunts by converting the TCO at the shunting point into an insulator [188]. The grids, either carbon paste or copper wire coated with carbon paste, are then applied to the slab to complete a strip cell, which is a big cell that generates $\sim$2.3 V voltage and $\sim$2 A current. Different numbers of strip cells, depending on the module specification, are connected together in series with the grids/bus bar of one strip cell connected to SS substrate (the opposite electrode) of the neighboring strip cell. By-pass diodes are also installed at this step for the strip cell protection. The connected cells are then covered with ethylene vinyl acetate (EVA) and Tefzel, which are transparent encapsulating layers, and cured in an oven for appropriate time for lamination. This is then followed by selected module framing.

Despite the need for relatively labor-intensive module assembly process at the moment, the continuous roll-to-roll production of a-Si solar panels on SS substrate has a number of advantages. The product is lightweight and flexible. The front-end production process requires low maintenance and can be easily scaled up. The coated SS roll may be cut into slabs of various sizes to make different products. For example, small sizes are suitable as battery charger, and large sizes as metal roof shingles (more than 5 m long). A high production yield can be maintained. The disadvantage is the need for labor-intensive cutting, gridding, and interconnecting individual cells to create a module.

In the process at Iowa Thin Films, Inc., a flexible Kapton[14] substrate is used. The cell interconnect is achieved by laser scribing, similar to the process at BP Solar for superstrate-type solar cells, as to be described below.

12.6.2 a-Si Module Production on Glass Superstrate

The manufacturing of a-Si solar panels on glass superstrates is being developed by several companies including BP Solar, Inc. (USA), Energy Photovoltaics, Inc. (USA), and

[14] ®Registered trademark of the Dupont Corporation.