Finally, for space applications, $Cu(InGa)Se_2$ thin-film solar cells offer potential advantages since the radiation tolerance is high as compared to crystalline-silicon solar cells [4, 5]. The potential to use a lightweight plastic substrate could lead to solar cells with very high specific power, that is, power divided by mass, which is critical for some space applications (see Chapter 10 for a more complete discussion). However, $Cu(InGa)Se_2$ space solar cell technology has not yet reached a commercial stage.

13.6.4 Production Costs

Material costs have direct and indirect components, and depend on the material yield of the deposition processes. The direct material costs, that is, the cost of the feedstock, will not be reduced by an increased volume of the production, depending only on the feedstock market price and how much material is needed in the film. The indirect costs, including preparation of sputtering targets or other source materials, will be reduced when production volumes are sufficiently large. The material yield, or fraction of the source material that ends up in the film, may be less than 50% for various thin-film processes. For sputtering, typically 30% of the target material ends up in the films.

In addition to materials, the other main production cost for thin-film modules is the capital cost of the equipment. To first order, any large-scale automated deposition equipment will have comparable price. Therefore, the throughput or production capacity will be very important for determining the capital cost.

Costs around 20 $\$/m^2$ for each thin-film deposition or process step may be acceptable in pilot production, but clear pathways toward costs in the range 1 to 5 $\$/m^2$ for large-volume production need to be identified. Throughput has a direct effect on cost. In an in-line process, this will depend on the substrate width and linear speed, which fundamentally depends on the deposition rate and desired thickness of the layer. If the deposition rate is relatively low, it can be compensated by having a long deposition zone in the system, for example, by having multiple targets in a sputtering system with only a relatively small increase in capital cost.

All cost advantages for thin films are lost if the production is not completed with high yield. The overall manufacturing yield can be broken down into electrical yield and mechanical yield. The electrical yield reflects the module reproducibility since it is the fraction of the modules produced which fulfill minimum performance criteria. The mechanical yield is the fraction of the substrates entering the production line that make it to the end. Mechanical losses result from broken glass substrates or malfunctioning equipment. In general, the overall yield should be well over 80%.

Another manufacturing cost is the energy usage. The energy payback time for $Cu(InGa)Se_2$ modules is expected to be fairly low; four months has been estimated by Alsema and van Engelenburg [212], compared to three years for crystalline-silicon modules [213].

Production-cost analyses result in a range of projected manufacturing costs. There are predictions of 1.5 to 2 $\$/W_P$ for first-generation $Cu(InGa)Se_2$ plants with a few MW_P yearly capacity and projected costs of 0.4 to 0.6 $\$/W_p$ for large-volume manufacturing [214, 215].