test and light soaking. PV modules that are sold for commercial use have generally been qualified by these testing programs.

12.7 CONCLUSIONS AND FUTURE PROJECTIONS

12.7.1 Status and Competitiveness of a-Si Photovoltaics

Over the last quarter of a century, significant progress has been made in the understanding of properties and of deposition processes for a-Si-based materials and solar cells. There have been impressive achievements both in increasing the conversion efficiency of solar cells and in reducing the cost of fabrication. In 1997, a-Si-based solar cells with 15.2% initial efficiency and 13% stable efficiency were demonstrated [8]. The manufacturing volume of a-Si solar modules has increased more than tenfold over the past 10 years, and capacity is presently more than 85 MW_p/year. There are now seven a-Si PV manufacturers with production capacity of 2 MW_p/year or more.

In the pipeline for the future, significant progress has been made in the development of rapid deposition processes (>5 Å/s) that achieve essentially the same quality as the present slow processes, as discussed in Section 12.3. As rapid deposition and high gas utilization processes are incorporated into production, further cost reduction will be achieved.

Additionally, the use of microcrystalline silicon as the narrow band gap absorber layer in an a-Si-based tandem solar cell has been demonstrated, and cells exceeding 12% conversion efficiency (stabilized) have been produced in different labs. The cells incorporating μc-Si show superior light stability over extended light soaking.

Amorphous Si-based PV technology is unique compared with other PV technologies. Amorphous Si absorbs sunlight more strongly than c-Si and poly-Si because it is amorphous; the selection rules that weaken absorption in c-Si (an "indirect band gap" semiconductor) do not apply to a-Si. A rather thin layer of a-Si is sufficient to absorb sunlight. Amorphous Si can be made at a low temperature on inexpensive substrates. The product is made through a low-cost process. The energy payback time (the time required for an a-Si module to generate the energy used in its production) was estimated as one to two years in 1989, and has probably shrunk substantially since then [194]. One expects that the cost will continue to decline as the production volume is increased. When deposited on selected substrates, the product can be made lightweight and flexible, which is important for many applications. The output power of a-Si PV products also has a positive temperature coefficient: at higher ambient temperature, for example, in areas with more sunshine, the efficiency is higher.

Compared with other types of thin-film PV technologies, such as CdTe and copper-indium-diselenide (CIS)-based PV technologies that have demonstrated higher efficiency in small-area R&D type cells, a-Si photovoltaics looks attractive because (1) it has been developed for approximately 20 years and the production process is more mature and proven and (2) the product does not contain any hazardous materials such as Cadmium as in CdTe photovoltaics or a large amount of expensive metal such as indium as in CIS-based photovoltaics. The materials in amorphous silicon–based cells originate in raw materials that are abundant on earth.