are made by introducing atoms of phosphorus to one surface of the wafer, making it the *n*-type partner in the *pn* junction. This is done by locating the wafers in a phosphorus rich atmosphere at high temperature so that these atoms penetrate slightly (~0.2 μm) into the silicon wafer.

Then metallic grids are printed on the boron and phosphorus-doped zones (some tricks, sometimes proprietary, are used to separate boron- and phosphorus-doped regions properly) and the solar cell is thus finished. The grids make it easier to collect the electricity without resistance losses and are commonly applied with low cost screen-printing methods. But a solar cell is brittle and produces low voltage (about 0.5 V) so that some 36 cells (or multiples of this number) are interconnected with tinned copper ribbons and encapsulated in a sandwich formed of a sheet of tempered glass, an embedding polymer that surrounds the solar cells, and a back sealing plastic layer. The reason for multiples of 36 cells is so that their output voltage ~15 V will be compatible with most DC battery charging applications.

The lowest (publicly offered) module selling prices in 2002 were about $3/W_P$. The breakdown of costs, as given in Chapter 6 are presented in Figure 1.12. The wafer itself represents about 65% of the module cost, approximately equally divided between purification, crystallization, and sawing. This hyperpure silicon is found today as a scrap or waste product from the microelectronics industry at a price of ~$50/kg. The increase of the PV market in the 1990s has nearly exhausted this market. Additional supplies are coming from the former Soviet Union, whose microelectronic industry has disappeared due to western competition. The Siemens method is considered ultimately too expensive for photovoltaics, but the purity it provides seems necessary for the fabrication of solar cells. Attempts in the 1980s to fabricate a low-cost solar silicon (SolSil) did not succeed due in part to the scarce interest generated by the small markets of the time. Today, new attempts are being made. These might include purification in the MG silicon production steps and in the crystal growth steps avoiding the expensive chlorination procedure and using the molten step of the crystal growth for further purification, or alternately, reducing the chlorosilanes in the molten phase prior to the crystal growth. It is not clear whether they can achieve the needed purity level. Even if feasible it is uncertain whether such wafers would be less expensive than the standard Siemens process or some simplified versions of it. There are fears that a shortage of hyperpure polycrystalline silicon availability might seriously hinder the growth in cell production demanded by the market. Chapter 5

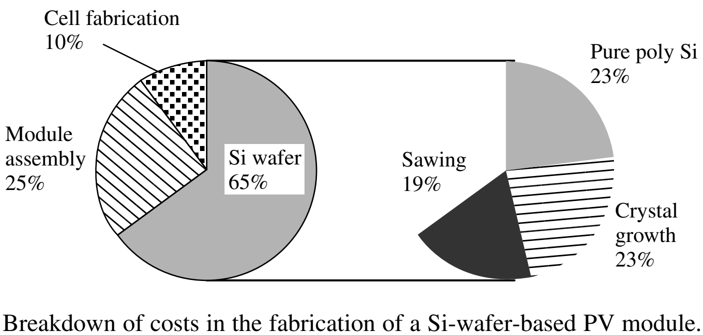

Figure 1.12 Breakdown of costs in the fabrication of a Si-wafer-based PV module. The right side presents the wafer costs