## 6.2 BULK MONOCRYSTALLINE MATERIAL

The dominant issue of the photovoltaic industry is to fabricate solar cells in large volumes that are both highly efficient and cost-effective. An overall industrial goal is to significantly lower the costs per watt. The dominant absorber material used today for the majority of the commercially produced solar cells is the Czochralski-grown crystalline silicon (c-Si) in monocrystalline and block-cast material in multicrystalline form (mc-Si). Up to now, a lot of effort has been undertaken to increase the electrical efficiency of solar cells reproducibly towards and even above 20% [1], whereas much higher efficiencies were indeed claimed [2] but were most probably never reached [3]. Unfortunately, efficiency improvements are often reached only with the help of cost-intensive process steps so that most steps cannot be directly implemented into industrial products but have to be reengineered for low-enough cost. Hence, there still remains a significant efficiency gap between monocrystalline laboratory cells with efficiencies up to 24% and cost-effective, commercial Cz solar cells that are presently produced and sold in high volume at approximately 14 to 17% efficiency.

While some years ago the cost of a module was driven almost equally by the cost of the wafer (33%), the cell process (33%) and the module making (33%), this well-known ratio has changed significantly – both for C-Si and mc-Si. Today, in most products the wafer attributes to sometimes more than 50% (!) of the module cost, whereas the cell process and the module process attribute to the rest with similar portions of ∼25%. The main reason for this is on one hand a steady cost reduction in the cell and module processes and on the other hand a significant increase in feedstock price together with an almost unchanged wafer thickness of 250 to 350 μm in production.

One way to meet today's demand of lower wafer cost is to (1) reduce the cost of crystal growth by improvement of productivity and material consumption at constant wafer quality, (2) reduce the cost of the wire-sawing process and (3) cut thinner wafers. While commercial Si solar cells still have a present wafer thickness of 250 to 350 μm for reasons of mechanical stability, a thickness of only 60 to 100 μm has been calculated to be the physical optimum thickness for silicon solar cells [4]. In this thickness regime the maximum theoretical efficiency for c-Si solar cells can be reached. In this optimum thickness regime, however, monocrystalline silicon becomes very fragile so that not only the electronic but also the mechanical properties of the wafer as well as the handling and processing techniques become of utmost importance for a good overall fabrication yield. Besides the mere mechanical wafer stability, manufacturing processes have to be adapted, redesigned or newly developed to avoid bending and breaking of ultra-thin wafers. With reduced wafer thickness, the necessity for surface passivation has to be taken into account. Since this cannot be done without adding to the cost, any added process step has to add adequate efficiency to remain cost-effective. Other important issues to get as much efficiency as possible out of the "valuable" wafer are improvements in anti-reflection (AR) coating, grid shadowing, "blue" response of the emitter and both surface and volume passivation.

The demand for high-quality polysilicon feedstock in the world market grew quickly not only in the microelectronic but also in the photovoltaic industry. In 1980 the worldwide production of single-crystal silicon amounted to approximately 2000 metric tons per year. This number was equivalent to ∼100 000 silicon crystals every year