faces of silicon are (111) but in epitaxial films and polysilicon deposition (111) is the fastest growth direction. Vapour deposition below 500°C results in amorphous silicon. If reheated above this temperature, crystallisation will occur.

Unlike most of the compounds and elements, silicon contracts when melting or expands when solidifying.

Impurities incorporated in the silicon lattice during the crystal growth or during the post-treatment (diffusion, implantation etc.) ionise at low temperatures, thus providing either free electrons or holes. Impurities from the Group IIIA replace a Si atom in the atomic lattice to supply electrons and are called n-dopants or donors, whereas elements from the Group VA substitute for a Si atom to supply holes and are called p-dopants or acceptors (see Section 5.6.3). Phosphorus and boron represent these groups and are used in PV processing to control the semiconductor properties (doping levels) of silicon. Impurity concentrations are expressed in atoms of impurity per cubic centimeter of the host material (silicon). In silicon semiconductor devices, these vary from 10^{14} to 10^{20} atoms per cm^3 and can be directly measured by analytical instruments. An indirect measure of impurity concentration is the minority-carrier lifetime. This is the time that elapses before a free electron in the lattice recombines with a hole. The transition metals, Fe, Cr, Ni, degrade the minority-carrier lifetime and the solar cell performance. High-purity silicon crystals with metal content less than 10 ppb(w) have minority-carrier lifetime values as high as 10 000 μs. Semiconductor wafers with phosphorus and boron dopants have values from 50 to 300 μs. Solar cells require minority-carrier lifetime value of at least 25 μs.

The relatively high refractive index limits the optical applications of silicon. The absorption/transmission properties in the 0.4 to 1.5 μm wavelength spectra are important in the performance of PV cells and photoconductive devices. In PV applications antireflective layers applied to silicon are commonly used.

Silicon even when alloyed with small quantities of impurities is brittle. Shaping silicon for PV applications requires sawing and grinding. Microelectronic applications require polishing. These mechanical operations are very similar to those applied to glasses.

Various thermal and mechanical properties are reported in Table 5.1.

For more details the reader is invited to consult the References [5–8].

Table 5.1 Thermal and mechanical properties of silicon

Property	Value
Atomic weight	28.085
Atomic density (atoms/cm^3)	5.0×10^{22}
Melting point (°C)	1410
Boiling point (°C)	2355
Density (g/cm^3 at 25°C)	2.329
Heat of fusion (kJ/g)	1.8
Heat of vaporisation at MP (kJ/g)	16
Volume of contraction on melting (%)	9.5