1 Wafer fabrication

1.1 Raw silicon

1.1.1 Production of raw silicon

Silicon as it is used in semiconductor manufacturing, is made up of quartz. Oxygen which reacts very fast with silicon even at room temperature, and which is present in quartz associated with silicon as silicon dioxide SiO_2, must be removed. This is done just above the melting point of silicon (1414 °C) in furnaces using carbon. At 1460 °C oxygen cleaves of the silicon and reacts with carbon C to carbon monoxide CO:

$$\mathrm{SiO_2 + 2\,CSi \longrightarrow 2\,CO}$$

Iron prevents the reaction of silicon and carbon to form silicon carbide. At these temperatures the carbon monoxide is in gaseous state and can be separated from the molten silicon easily. However, the raw silicon is still heavily polluted. There are up to 5 % impurities, such as for example iron, aluminum, phosphorus, and boron. These substances must be removed in additional processes.

1.1.2 Purification of the raw silicon

Using a trichlorosilane process many impurities are filtered out by distillation. The raw silicon and hydrogen chloride HCl react at about 300 °C to form gaseous hydrogen H_2 and trichlorosilane $SiHCl_3$:

$$\mathrm{Si + 3\,HCl \longrightarrow SiHCl_3 + H_2}$$

The contaminants which also react with the chlorine, need higher temperatures to transfer in the gaseous state. This allows separation of the trichlorosilane. Only carbon, phosphorus, and boron, which have similar condensation temperatures, can not be filtered out in this process.

The trichlorosilane process can be reversed, so that the purified silicon condeses in polycrystalline form. This is done at approximately 1100 °C by adding hydrogen inside a quartz chamber, in which thin silicon rods are placed:

$$SiHCl_3 + H_2 \longrightarrow Si + 3\,HCl$$
$$4\,SiHCl_3 \longrightarrow Si + 3\,SiCl_4 + 2\,H_2$$

The silicon reflects on the silicon rods which grow to bars with a diameter of more than 30 mm. This polysilicon could already be transformed into a single crystal using the Czochralski process, however, the degree of purity for semiconductor manufacturing is still not high enough.

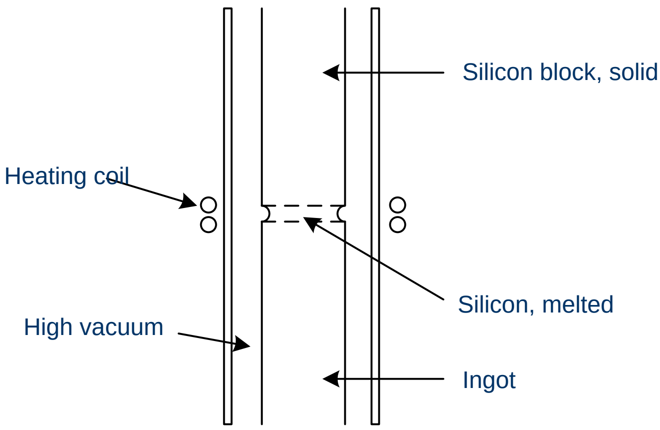

Fig. 1.1: Illustration of the zone cleaning process

1.1.3 Zone cleaning

To increase the purity once more a cleaning process is used. Thereby a high frequency coil is placed around the silicon rod to melt the silicon bars, and therefore the contaminations accumulate at the bottom due to higher solubility in the liquid phase; the surface tension of the silicon prevents the melt to flow out. By multiple repetition of this procedure, the content of impurities in silicon is further reduced and thus it can be used for fabrication of the single crystal. To prevent further contamination, all of the processes are made under a vacuum atmosphere.

At the end of these processes the silicon has a purity of more than 99,9999999 %, which means that there is less than 1 foreign atom per 1 billion silicon atoms.