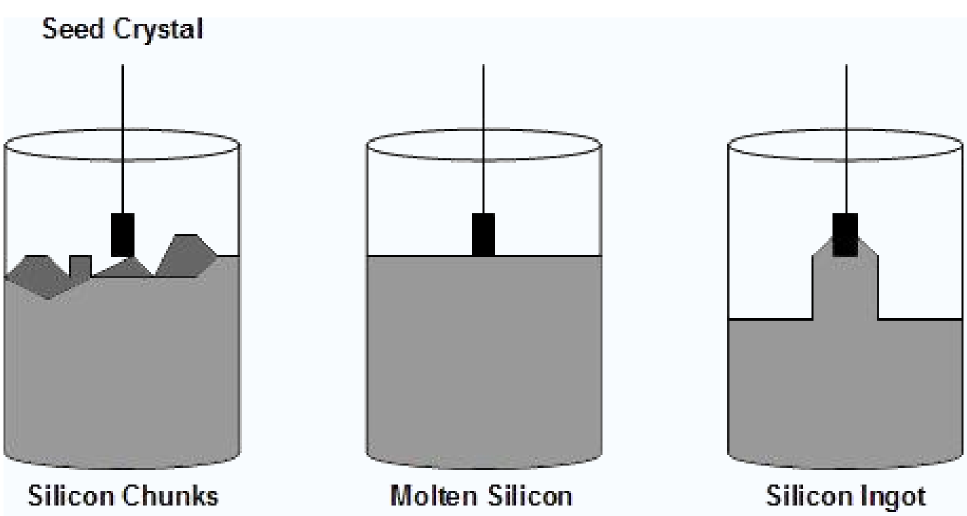
Czochralski Process

The **Czochralski process** is a method of crystal growth used to obtain single crystals of semiconductors (e.g), metals (e.g. palladium, platinum, silver, gold), salts and many oxide crystals (LaAlO3, YAG, .and GGG etc)

The most important application may be the growth of large cylindrical ingots, or boules, of single crystal silicon. High-purity, semiconductor-grade silicon (only a few parts per million of impurities) is melted down in a crucible , which is usually made of Quartz. Dopant impurity atoms such as boron or phosphorus can be added to the molten intrinsic silicon in precise amounts in order to dope the silicon, thus changing it into n-type or p-type extrinsic silicon. This influences the electrical conductivity of the silicon. A *seed crystal*, mounted on a rod, is dipped into the molten silicon. The seed crystal's rod is pulled upwards and rotated at the same time. By precisely controlling the temperature gradients, rate of pulling and speed of rotation, it is possible to extract a large, single-crystal, cylindrical ingot from the melt. This process is normally performed in an inert atmosphere, such as argon, and in an inert chamber, such as quartz.

Crucibles used in Czochralski method

Crucible after being used



Silicon wafer with mirror finish (NASA)

While the largest silicon ingots produced today are 400 mm in diameter and 1 to 2 metres in length, 200 mm and 300 mm diameter crystals are standard industrial processes. Thin silicon wafers are cut from these ingots (typically about 0.75 mm thick) and polished to a very high **flatness** to be used for creating integrated circuits. Other semiconductors, such as gallium arsenide, can also be grown by this method, although lower defect densities in this case can be obtained using variants of the Bridgeman technique.

When silicon is grown by the Czochralski method the melt is contained in a silica (quartz) crucible. During growth the walls of the crucible dissolve into the melt and Czochralski silicon therefore contains oxygen impurities with a typical concentration of $10^{18} cm^{-3}$. Perhaps surprisingly, oxygen impurities can have beneficial effects. Carefully chosen annealing conditions can allow the formation of oxygen precipitates. These have the effect of trapping unwanted transition metal impurities in a process known as gettering. Additionally, oxygen impurities can improve the mechanical strength of silicon wafers by immobilising any dislocations which may be introduced during device processing. It has experimentally been proved in the 1990s that the high oxygen concentration is also beneficial for radiation hardness of silicon particle detectors used in harsh radiation environment (eg. CERN's LHC/S-LHC projects)[1,2,3]. Therefore, radiation detectors made of Czochralski- and Magnetic Czochralski-silicon are considered to be promising candidates for many future high-energy physics experiments [5,6].

Occurrence of unwanted instabilities in the melt can be avoided by investigating and visualizing the temperature and velocity fields during the crystal growth process [4].

The process is named after Jan Czochralski, who discovered the method in 1916 while investigating the crystallization rates of metals.

[edit]

References

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