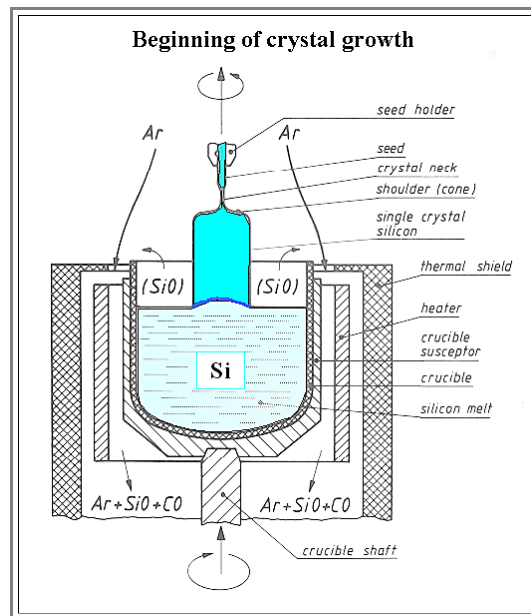


# Czochralski Crystal Growth Process

## Illustration

You start growing a "*Czochralski crystal*" by filling a suitable crucible with the material - here hyperpure correctly doped Si pieces obtained by crushing the poly-Si from the [Siemens process](#). Take care to keep impurities out - do it in a clean room - and use hyperpure silica for your crucible.

- Make sure that the inside of the machine is very clean too and that the gas flow - the gas you introduce but also the SiO coming from the molten Si because parts of the crucible dissolve - does not interfere with the growing crystal.
- Dissolve the Si in the crucible and keep its temperature close to the melting point. Since you cannot avoid temperature gradients in the crucible, there will be some *convection* in the liquid Si. You may want to suppress this by big magnetic fields.
- Insert your *seed crystal*, adjust the temperature to "just right", and start withdrawing the seed crystal. For homogeneity, *rotate* the seed crystal and the crucible. Rotation directions and speeds and their development during growth, are closely guarded secrets!
- First pull *rather fast* - the diameter of the growing crystal will decrease to a few mm. This is the "**Dash process**" ensuring that the crystal will be dislocation free even though the seed crystal may contain dislocations.
- Now decrease the growth rate - the crystal diameter will increase - until you have the desired diameter and commence to grow the commercial part of your crystal at a few mm/second.

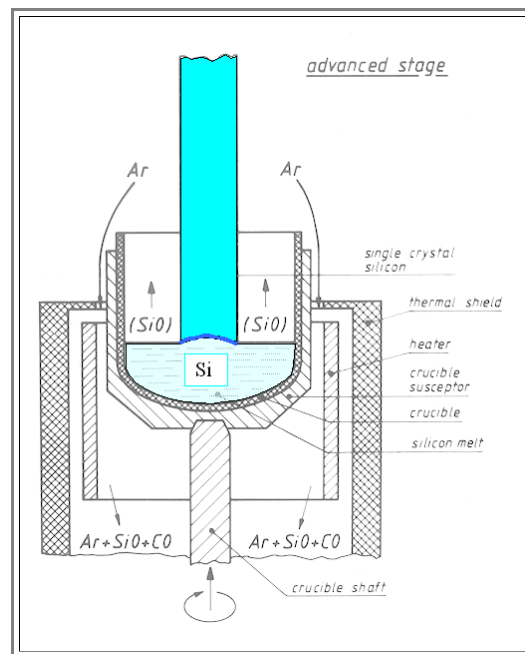


As your crystal grows, the impurity concentration (including the dopants if you do not watch out) will increase in the melt (due to [segregation](#)) and therefore also the percentage incorporated into the crystal. The temperature profile of the whole system will also change - you are now deeper down in the crucible and the crystal cools off a little more slowly. All these factors influence the homogeneity of the crystal.

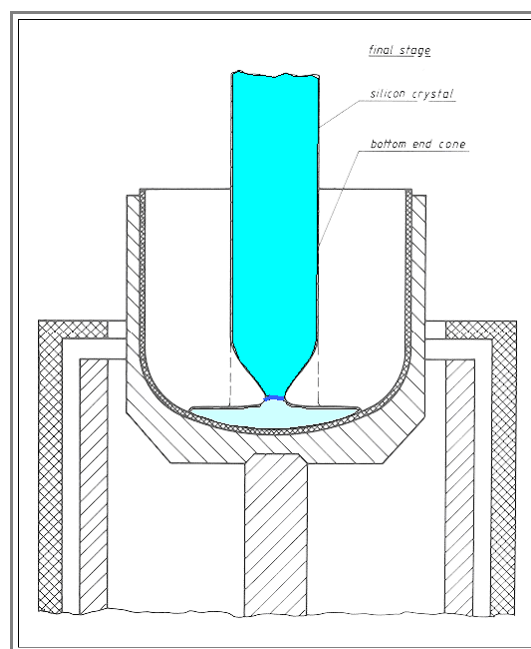
- The radial and lateral doping level is influenced - it will not stay constant without some special measures
- The concentration of impurities, especially interstitial oxygen, may change. In general, the concentration increases from "head" to "tail".
- Crystal lattice defects still present (essentially agglomerates of the point defects present in thermal equilibrium at high temperatures) may change in size and distribution.

You do not want this - you want a crystal where all these factors are constant - everywhere!

- So you must do something - change the rotation speeds, the temperature, the growth speed - whatever.
- This is where crystal growing becomes an art - and you will not find much literature about this. This is the tricky and secret part: Changing all important parameters continuously so that the crystal is homogeneous!



- Now the crystal is nearly finished. You do not want to use up all the **Si**, because the "last drop" contains all the impurities not yet incorporated because of their small segregation coefficients.
- But you cannot simply pull out the crystal after the desired length has been reached. The thermal shock of the rapidly cooling end would introduce large temperature gradients in the crystal which in turn produce stress gradient - plastic deformation (easy in **Si** at high temperatures) will take place and this means dislocation are nucleated and driven into the crystal.
  - The dislocation will even run up into the formerly dislocation free part of the crystal, destroying your precious Silicon.
  - So you withdraw gradually by just increasing the pulling rate a little bit which will lead to a reduced diameter. The crystal then ends in an "end cone" similar to the "seed cone".



- The [finished product](#) can be seen in a different link.