Crystal Growth-II

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Monocrystalline Si Wafer Manufacturing Process

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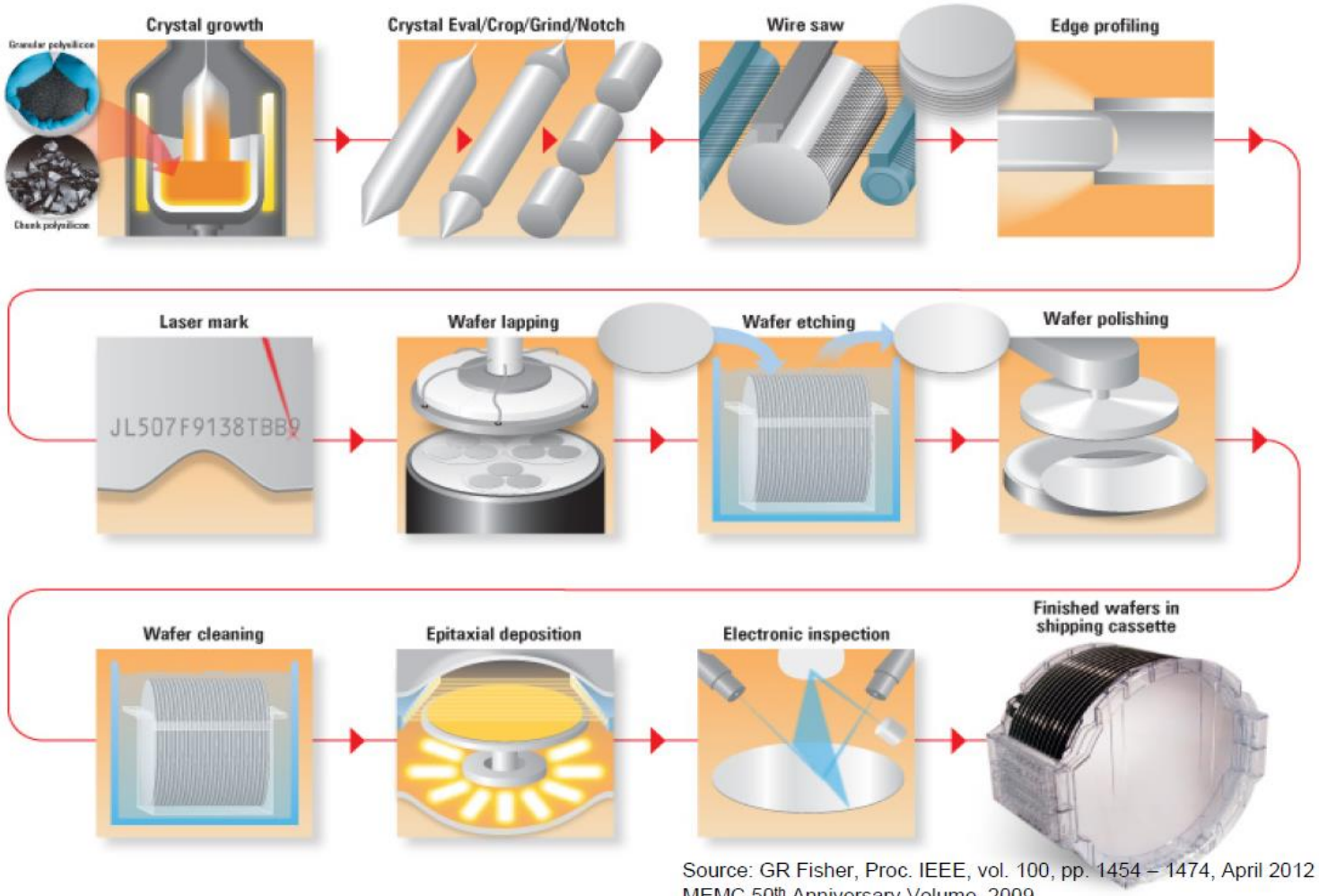
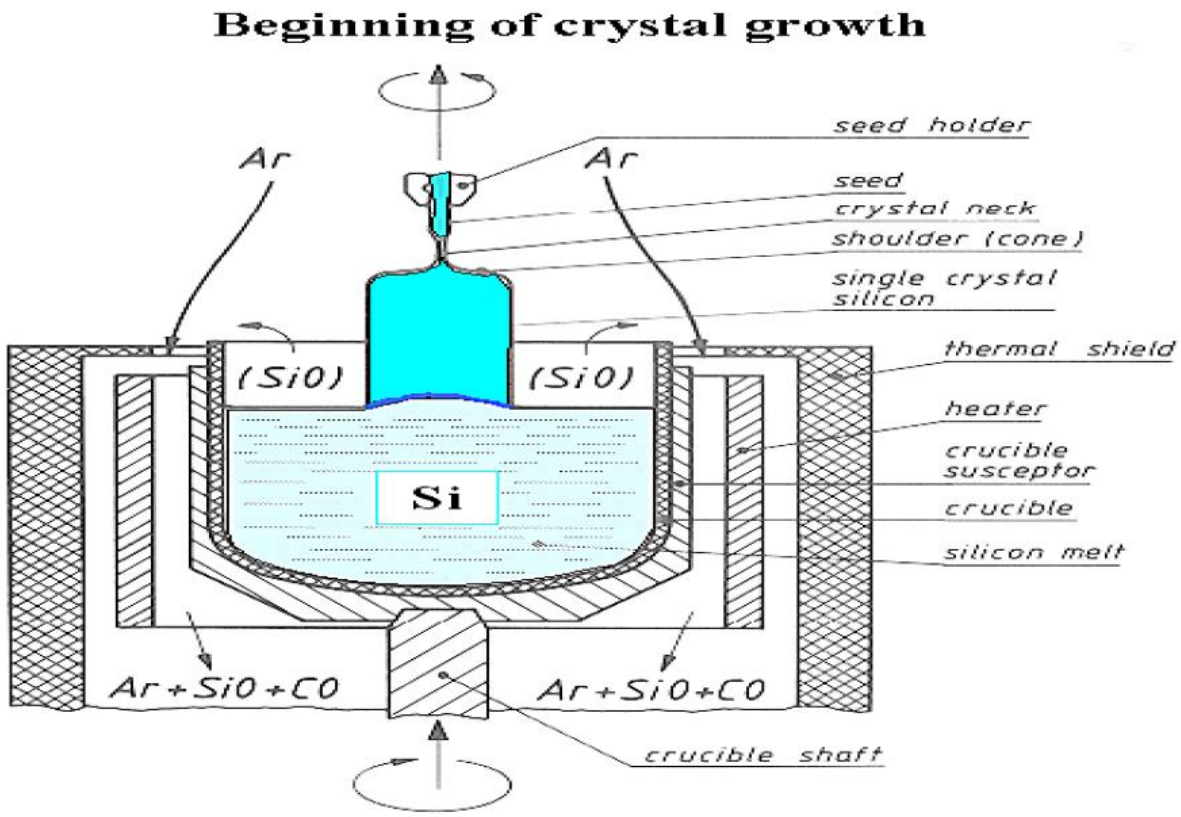


Source: GR Fisher, Proc. IEEE, vol. 100, pp. 1454 – 1474, April 2012
MEMC 50th Anniversary Volume, 2009

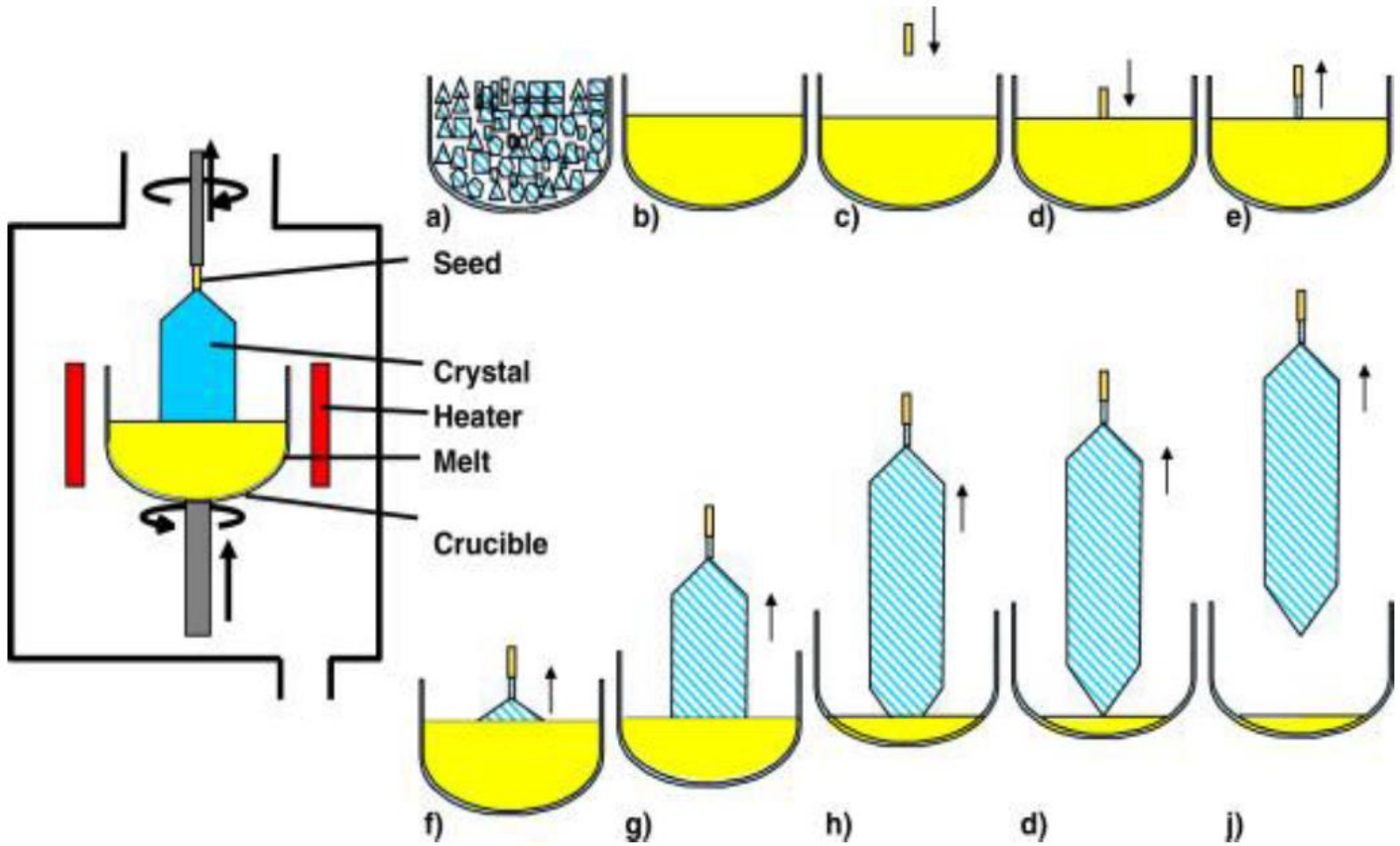
Czochralski method

- The Czochralski method or Czochralski process, is a method of crystal growth used to obtain single crystals of semiconductors (e.g. silicon, germanium and gallium arsenide), metals (e.g. palladium, platinum, silver, gold), salts and synthetic gemstones.
- It is also known as Pulling Technique
- This method is widely used for growing semi conducting material crystal. The shape of the crystal is free from the constraint due to the shape of the crucible.
- In this method the charge is melted and maintained at a temperature slightly above the melting point. The pulling rod is lowered to just touch the melt. Since the rod is at lower temperature of melt occurs at the point tip of the pulling rod. The crystal is pulled slowly.

Czochralski Crystal Growth Process



Czochralski Process



Advantages

- This method is used to grow large single crystals. Thus it is used extensively in the semiconductor industry.
- There is no direct contact between the crucible walls and the crystal which helps to produce unstressed single crystal.

Disadvantages

- In general this method is not suitable for incongruently melting compounds and of course the need for a seed crystal of the same composition limits is used as tool for exploratory synthetic research.

Czochralski Method for Silicon Crystal Growth

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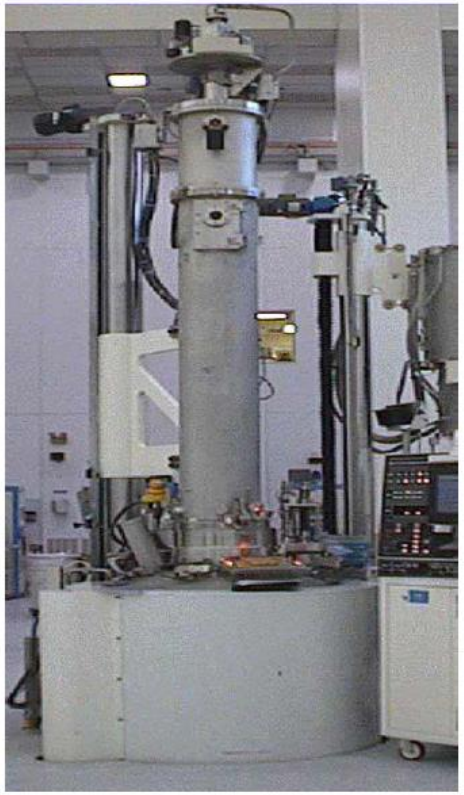

Crystal Puller

Product

Typical Factory Floor

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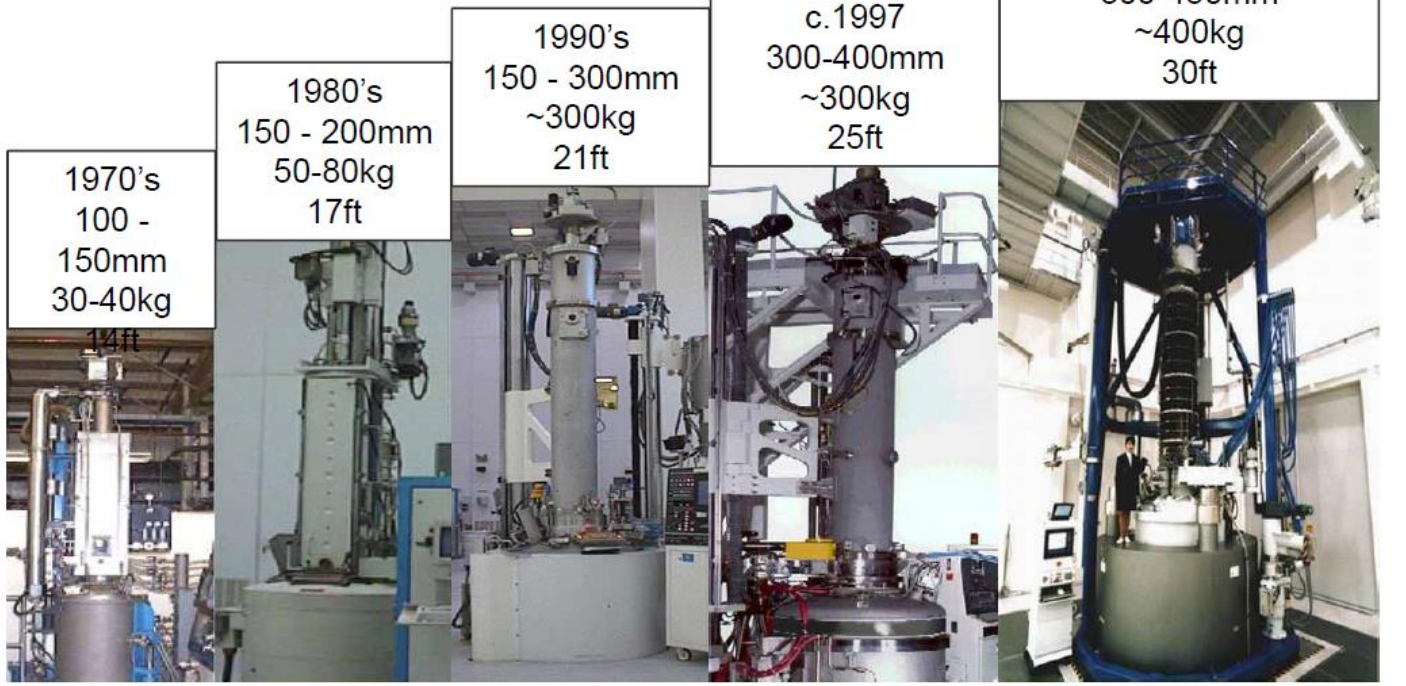
Early days of Czochralski(CZ) growth crystals were small and easy to handle. Current generation crystal are large, heavy and need specialized handling equipment.

Source: MEMC 50th Anniversary Volume, 2009

Crystal Puller Evolution



Examples of progress in Czochralski crystal pullers from 1970 through current diameter capability. Showing approximate period, crystal diameters, typical polysilicon charge weight and approximate height of the equipment above the working floor. Later models have services (water, argon, vacuum) below floor level. (Right hand photo shown is courtesy of Super Silicon Institute (SSI).)

Source: GR Fisher, Proc. IEEE, vol. 100, pp. 1454 – 1474, April 2012

Continuous Czochralski Crystal Growth

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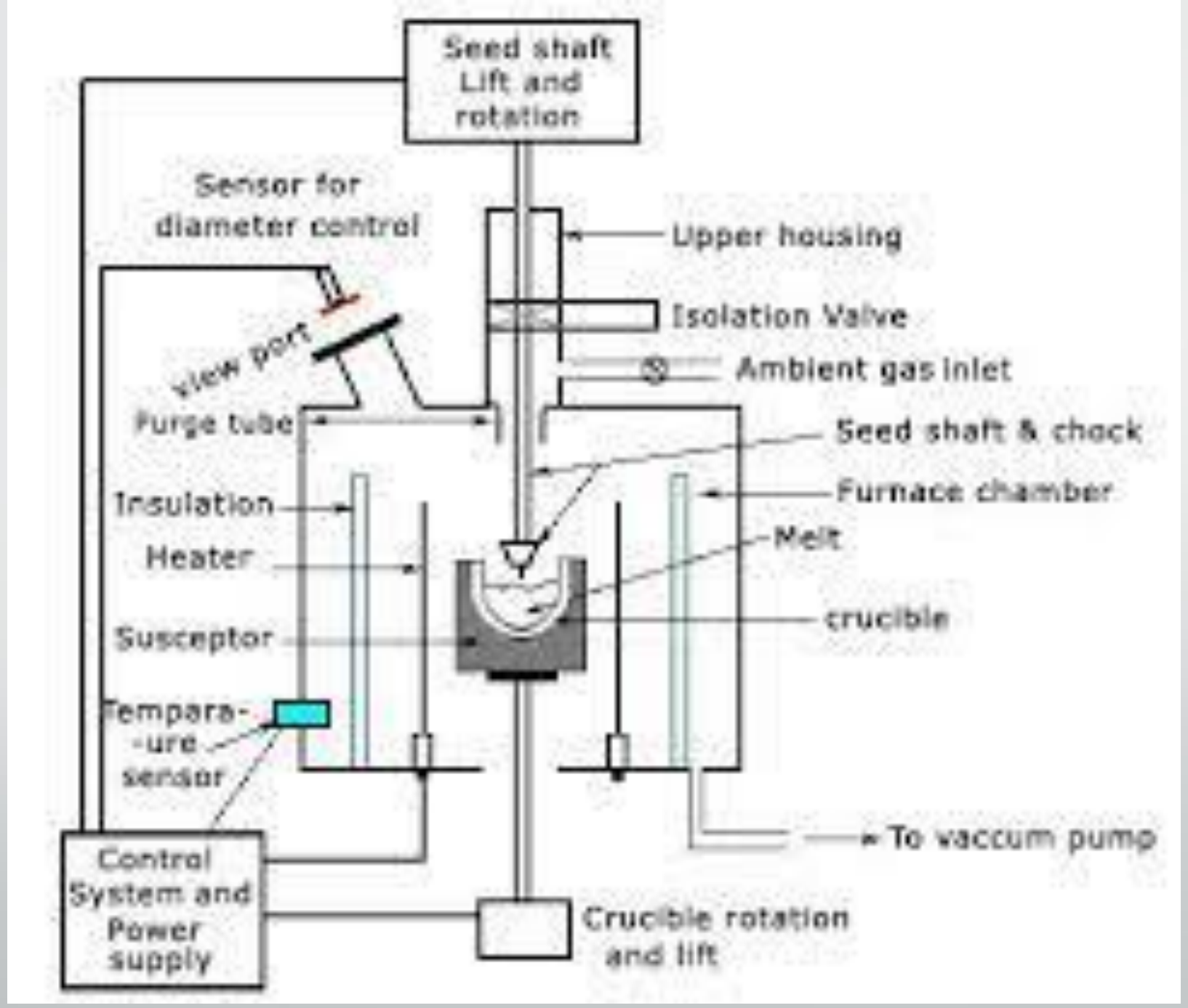
Crystal growing Practise

- A CZ crystal growth apparatus , also called a puller is shown in fig.
- The one pictured weighs 17,600 kg and is 6.5 kg of silicon, which can be transformed into a crystal of 100 mm diameter and 3.0 m length.
- The puller has four subsystem
  - **Furnance:**crucible,susceptor(crucible supporter) and rotation mechanism, heating element and power supply, and chamber.
  - **Crystal-pulling mechanism:** seed shaft or chain, rotation mechanism and seed chuck.
  - **Ambient control:**gas source, flow control, purge tube and exhaust and vaccum system.
  - **Control System**:Microprocessor, sensor and outputs.


Seed shaft
Lift and
rotation
Sensor for
diameter control
Upper housing
Isolation Valve
Ambient gas inlet
view port
Purge tube
Seed shaft & chock
Furnace chamber
Insulation
Heater
Melt
crucible
Susceptor
Tempara-
-ure
sensor
To vaccum pump
Control
System and
Power
supply
Crucible rotation
and lift

Crystal growing Practise

Furnance

- Since it contain melts, the crucible material should be chemically unreactive with silicon.This is a major consideration, because the electrical properties of silicon are sensitive to even ppb levels of impurities.
- Other desirable characteristics for crucible material are high M.P., thrmal stability and hardness.Additionally, the crucible should be inexpensive or reusable.
- Fused silica is in exclusive use today.It reacts with silicon releasing silicon and oxygen in melt.

Crystal growing Practise

- The susceptor is used to support the silica crucible.It also provides better thermal conditions. Graphite is used to make the susceptor as it high temperature properties.The graphite used should be highly pure to prevent contamination of the crystal from impurities.The susceptor is placed on the pedestral whose shaft is connected to motor that provide rotation.
- To melt the charge radio-frequency (RF) heating or resistance heating is used.RF heating for small melt and resistance heating for large melt.finally graphite heater is connected to DC supply.

Crystal Pulling Mechanism

- This mechanism should control the pull rate & crystal rotation so it should have minimum vibration and great precision.

Crystal growing Practise

- Seed holder crystal and pulling mechanism should maintain the proper orientation Perpendicular to melt surface.
- Lead screw are provided to withdraw and rotate the crystal.
- The crystal leave the furnance through the purge tube, where ambient gas is directed along the surface of the crystal to reduce its temp.From the purge tube, the crystal enter upper chamber, which is usually separated from the furnance by an isolation valve.s

Crystal growing Practise

Ambient Control

- This includes an inert gas source (of argon) a flow control and an exhaust system.
- The gas source must meet the purity requirement. Inert gas environment is required because the hot graphite part must be protected from oxygen to prevent erosion and gas around the process should not react with silicon.

Crystal growing Practise

Control System

- Control system includes control of process parameters like temperature , crystal diameter, pull rate, rotation speed etc.
- Programmed process step are provided through microprocessor based and infra-red sensor are used to judge any changes.