EE 527 MICROFABRICATION

Lecture 6

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PURIFICATION OF SILICON

- Starting material: use Si as an example:

React SiO_2 with Carbon at very high temperatures (~1800°C) to reduce SiO_2,

$$SiO_2 + 2C \rightarrow Si + 2CO$$

This forms metallurgical grade Si (MGS): impurity level 1 ppm

This MGS is refined further,

$$Si + 3HCl \rightarrow SiHCl_3 + H_2$$

Produces impurity chloride vapors and condensed at different temperatures from $SiHCl_3$

Convert SiHCl3 to Si,

$$2SiHCl_3 + 2H_2 \rightarrow 2Si + 6HCl$$

This produces electronic grade Si (EGS): impurity level 1 ppb

CZOCHRALSKI (CZ) CRYSTAL GROWTH

- Growth of Single Crystal Ingot: use Si as an example:

Next to convert polycrystalline EGS to single crystal Si ingots or boules by the process commonly called *Czochralski*,

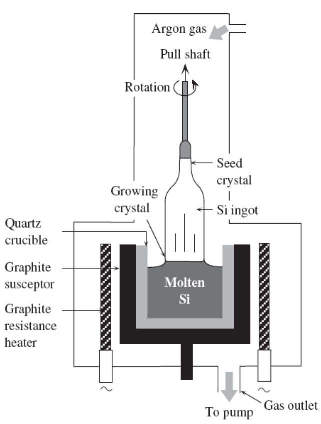
Starting from a seed crystal which can provide a template for growth,

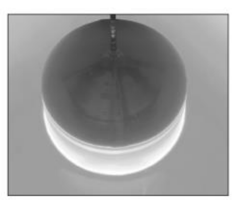
We melt the EGS in a quartz-lined graphite crucible by resistively heating to 1412°C (melting point of Si)

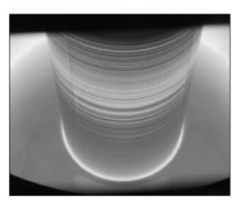
CZOCHRALSKI (CZ) CRYSTAL GROWTH

- Growth of Single Crystal Ingot: use Si as an example:

A seed crystal is lowered into the molten Si and raised slowly,







The crystal is rotated slowly as it grows!

CZOCHRALSKI (CZ) CRYSTAL GROWTH

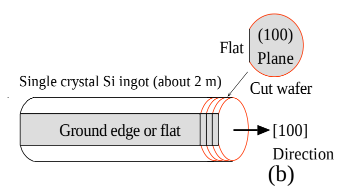
- Growth of Single Crystal Ingot: use Si as an example:

The shape of the ingot is determined by a combination of the tendency of the cross section to assume a polygonal shape due to crystal structure and the influence of surface tension, which encourage a circular cross section.

SINGLE-CRYSTAL CZOCHRALSKI GROWTH

- Wafers: use Si as an example:

Single-crystal ingots are mechanical grinding to perfect cylinder shape with precisely controlled diameters. Then diced to slices of wafers.



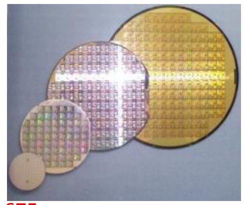
The crystallographic orientation of the silicon ingot is marked by grounding a flat. The ingot can be as long as 2 m. Wafers are cut using a rotating annular diamond saw. Typical wafer thickness is 0.6-0.7mm

http://en.wikipedia.org/wiki/

CZOCHRALSKI (CZ) CRYSTAL GROWTH

- Wafers: use Si as an example:

  Single-crystal ingots are mechanical grinding to perfect cylinder shape with precisely controlled diameters. Then diced to slices of wafers. The size of wafers as following,



2 inch (50.8 mm). Thickness 275 µm.
3 inch (76.2 mm). Thickness 375 µm.
4 inch (100 mm). Thickness 525 µm.
5 inch (127 mm) or 125 mm (4.9 inch). Thickness 625 µm.
150 mm (5.9 inch, usually referred to as "6 inch"). Thickness 675 µm.
200 mm (7.9 inch, usually referred to as "8 inch"). Thickness 725 µm.
300 mm (11.8 inch, usually referred to as "12 inch" or "Pizza size" wafer). Thickness 775 µm.
450 mm ("18 inch"). Thickness 925 µm (expected).[12]

http://en.wikipedia.org/wiki/

DOPANT INCORPORATION

- As pulling advances, the melt volume decreases, doping concentration in the melt increases since the segregation coefficient is defined as

$$k_0 = \frac{\text{concentration}_{\text{solid}}}{\text{concentration}_{\text{liquid}}} < 1$$

- And the dopant concentration in the ingot increases along its length:

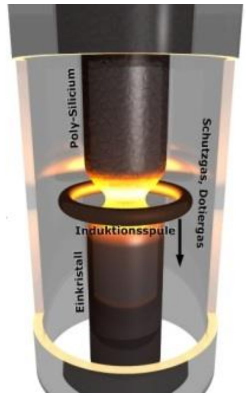
$$C_s = k_0 C_0 (1 - X)^{k_0 - 1}$$

Where C_0 is the initial dopant concentration in the melt, X is the fraction solidified.

- Oxygen from the air and crucible would affect ingot resistivity as well.
- Magnetic Czochralski (MCZ) growth enables better control of oxygen levels in the crystal.

FLOAT ZONE CRYSTAL GROWTH

- Float zone (FZ) crystal growth provides high-resistivity silicon.
- A polysilicon ingot is placed on top of a single crystal seed.
- The polycrystalline ingot is melted and then solidified. The solidifying silicon copies the single crystal structure of the seed.
- The highest FZ silicon resistivities are on the order of 20,000 ohm-cm, compared to 1000 ohm-cm for CZ.



http://meroli.web.cern.ch/meroli/Lecture_silicon_floatzone_czochralski.html