TN 423: VLSI CIRCUITS

Lecture 2

INTRODUCTION TO SILICON

Outline

1. Introduction to Silicon
2. Silicon Wafer preparations
3. IC Fabrication Processes

Silicon

- Silicon is the 8th most common element in the universe by mass, 14^{th} in the Periodic Table, but very rarely occurs as the pure free element in nature.
- It is most widely distributed in dusts, sands, planetoids, and planets as various forms of silicon dioxide (silica) or silicates.
- Over 90% of the Earth's crust is composed of silicate minerals, making silicon the 2nd most abundant element in the Earth's crust
- Because of wide use of silicon in integrated circuits, it is a great deal of modern technology depends on it.

Silicon…

- Silicon rocks

Silicon…

- Most silicon is used commercially without being separated, and indeed often with little processing of compounds from nature.
- These include
  - ✓ Cement and mortar production
  - ✓ silica sand and gravel to make concrete.
  - ✓ Building materials ceramics such as porcelain, and glasses.
  - ✓ More modern silicon compounds such as silicon carbide form abrasives and high-strength ceramics.

Silicon Preparations

- Si is available in nature in the form of sand, i.e. silica and silicates
- The Si used should be a crystal of very high purity
- Si is chemically treated to form a high purity polycrystalline s/c from which single crystals are formed
- Crystals are shaped to determine the diameter of the material and then sawed into wafers
- Wafers are polished to provide smooth and clean surface on which devices will be made and then be interconnected to form a monolithic IC

Silicon Preparations…

- Silicon is prepared in two stages
  - ✓ Preparation of Metallurgical Grade Silicon (MGS)
  - ✓ Preparation of Electronic Grade Silicon (EGS)

Silicon Preparations…

Preparation of Metallurgical Grade Silicon (MGS)

- Sandstone through metamorphism forms Quartz
- Carbon arc furnace is used to reduce Quartzite to Si wafer
- Si (l) is solidified to obtain Metallurgical Grade Silicon (MGS)
- MGS is 98% pure (impurities: Fe, Al and C)

Silicon Preparations…

- *Preparation of Electronic Grade Silicon (EGS)*
- Powdered MG-Si is reacted with anhydrous HCl at 300 °C in a fluidized bed reactor to form $SiHCl_3$

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

- During this reaction impurities such as Fe, Al, and B react to form their halides (e.g. $FeCl_3$, $AlCl_3$, and BCl3).
- The $SiHCl_3$ has a low boiling point of 31.8 °C and distillation is used to purify the $SiHCl_3$ from the impurity halides.
- Finally, the pure $SiHCl_3$ is reacted with hydrogen at 1100°C for ~200 – 300 hours to produce a very pure form of silicon.
- $SiHCl_3 + H_2 \rightarrow Si + 3\ HCl$

Why $SiHCl_3$

- Can be easily formed by the reaction of anhydrous hydrogen chloride with MGS at low temperature (200 – 400 °C)
- It is liquid at room temperature so that purification can be accomplished using standard distillation technique
- It is easily handled and if dry can be stored in carbon steel tanks
- Its liquid is easily vaporized and, when mixed with hydrogen it can be transported in steel lines without corrosion

Why $SiHCl_3$

- It react at lower temperature (1000 – 1200 °C), and at faster rate than $SiCl_4$
- Its deposition can take place on heated silicon, thus eliminating contact with any foreign surfaces that may contaminate the resulting silicon

Silicon Preparations…

- The reaction takes place inside large vacuum chambers and the silicon is deposited onto thin polysilicon rods (small grain size silicon) to produce high-purity polysilicon rods of diameter 150-200mm.
- The resulting rods of semiconductor grade silicon are broken up to form the feedstock for the crystallisation process.
- The production of semiconductor grade silicon requires a lot of energy.
- EGS is used in fabrication of ICs

Silicon Preparations…

Metamorphism

Furnace, Solidification

Purification

Sandstone → Quartz → MGS → EGS

Silicon Preparations…

Crystal Growth

ΩEGS has very small impurity levels

ΩEGS is polycrystalline material

ΩUsed in the preparation of single crystal silicon

ΩPolycrystalline silicon rods (EGS) are converted to even purer and defect free single crystals

ΩTwo techniques are used in the growth

i. Czochralski (CZ) technique

ii. Float Zone (FZ) technique

Silicon Wafer Preparations

Crystal Shaping

- Si crystal obtained from CZ and FZ processes is called an ingot
- Ingot is hard and brittle
- To give a shape to ingots to form wafers, it is treated with a series of mechanical processes
- Diamond is used in cutting and shaping Si
- After cutting and polishing, the Si wafers are packed
- The packed wafers are ready to be used in the fabrication of ICs

HOMEWORK

- Read about
  - ✓ CZ and FZ processes and how ingots are formed
  - ✓ Watch the videos on Silicon production