

TN 423: VLSI CIRCUITS

Lecture 2

INTRODUCTION TO SILICON

Outline

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

Silicon

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

Silicon...

Ω Silicon rocks



VLSI CIRCUITS

UDOM

Silicon...

- Ω Most silicon is used commercially without being separated, and indeed often with little processing of compounds from nature.
- Ω 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

- Ω Si is available in nature in the form of sand, i.e. **silica and silicates**
- Ω The Si used should be a **crystal of very high purity**
- Ω Si is chemically treated to form a **high purity polycrystalline s/c** from which single crystals are formed
- Ω Crystals are **shaped** to determine the diameter of the material and then sawed into **wafers**
- Ω 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...

- Ω 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)

Ω Sandstone through metamorphism forms Quartz

Ω Carbon arc furnace is used to reduce Quartzite to Si wafer

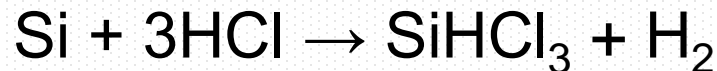
Ω Si (l) is solidified to obtain Metallurgical Grade Silicon (MGS)

Ω MGS is 98% pure (impurities: Fe, Al and C)

Silicon Preparations...

Ω *Preparation of Electronic Grade Silicon (EGS)*

- Ω Powdered MG-Si is reacted with anhydrous HCl at 300 °C in a fluidized bed reactor to form SiHCl₃



- Ω During this reaction impurities such as Fe, Al, and B react to form their halides (e.g. FeCl₃, AlCl₃, and BCl₃).
- Ω The SiHCl₃ has a low boiling point of 31.8 °C and distillation is used to purify the SiHCl₃ from the impurity halides.
- Ω Finally, the pure SiHCl₃ is reacted with hydrogen at 1100°C for ~200 – 300 hours to produce a very pure form of silicon.
- Ω $\text{SiHCl}_3 + \text{H}_2 \rightarrow \text{Si} + 3 \text{HCl}$

Why SiHCl_3

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

Why SiHCl_3

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

Silicon Preparations...

- Ω 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.
- Ω The resulting rods of semiconductor grade silicon are broken up to form the feedstock for the crystallisation process.
- Ω The production of semiconductor grade silicon requires a lot of energy.
- Ω EGS is used in fabrication of ICs

Silicon Preparations...

Metamorphism

Furnace,
Solidification

Purification

Sandstone

Quartz

MGS

EGS



Silicon Preparations...

Crystal Growth

Ω EGS has very small impurity levels

Ω EGS is polycrystalline material

Ω Used in the preparation of single crystal silicon

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

Ω Two techniques are used in the growth

- i. Czochralski (CZ) technique
- ii. Float Zone (FZ) technique

Silicon Wafer Preparations

Crystal Shaping

Ω Si crystal obtained from CZ and FZ processes is called an **ingot**

Ω Ingot is hard and brittle

Ω To give a shape to ingots to **form wafers**, it is treated with a series of **mechanical processes**

Ω Diamond is used in cutting and shaping Si

Ω After cutting and polishing, the Si wafers are packed

Ω The packed wafers are ready to be used in the fabrication of ICs

HOMEWORK

Ω Read about

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