EG572EX: ELECTRONIC CIRCUITS I

CHAPTER 1

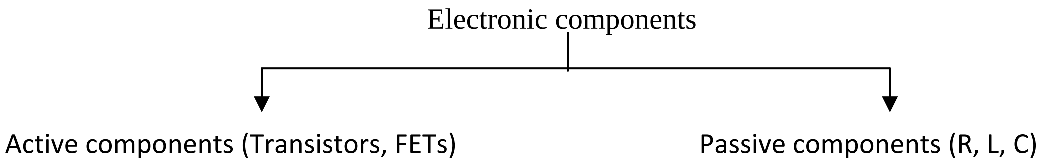
IC TECHNOLOGY AND DEVICE MODELS

Prepared By: Ajay Kumar Kadel, Kathmandu Engineering College

Integrated circuit:

The integrated circuit is a miniature, low cost electronic circuit consisting of active and passive components that are irreparably joined together on a single crystal chip of silicon. Most of the components used in ICs aren't similar to conventional components in appearance although they perform similar electrical functions.

In this chapter we describe the basic processes used in the fabrication of integrated circuits.



Active components:

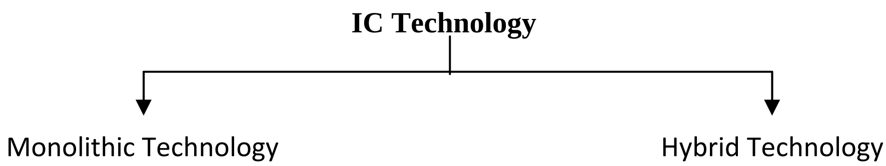
If a circuit element has the capability of enhancing the energy level of a signal passing through it, its called an active component. Eg: Vacuum tubes, transistors, op-amps. In other words active components are capable of producing gains.

Passive components:

Passive components are not capable of producing gains. Eg: Diodes, R, L, C

Advantages of IC:

1. Miniaturization and hence increased equipment density.
2. Cost reduction due to batch processing.
3. Increased system reliability due to elimination of soldered joints.
4. Improved functional performance as it is possible to fabricate even complex circuits for better characteristics.
5. Increased operating speeds due to the absence of parasitic capacitance effect.
6. Reduction in power consumption due to smaller size.
7. Small weight



Monolithic Technology:

In monolithic integrated circuits, all circuit components both active and passive elements and their interconnections are manufactured into or on top of a single chip of silicon. The monolithic circuit is ideal for applications where identical circuits are required in very large quantities and hence provides lowest per unit cost and highest order of reliability.

Hybrid Technology:

In hybrid circuits, separate component parts are attached to a ceramic substrate and interconnected by means of either metallization pattern or wire bonds. This technology is more adaptable to small quantity custom circuits. For example High power audio amplifier Ics

SSI=3 to 30 gates/chip

MSI=3 to 300 gates/chip

LSI=300 to 3000 gates/chip

VLSI=more than 3000 gates/chip

Monolithic IC technology and planar process:

A monolithic circuit is simply a circuit fabricated from a single stone or a single crystal. In Greek monos means single and lithos means stone. The fabrication process in a monolithic IC technology takes place through a single plane. The technology is referred to as a planar process.

BASIC structure of an IC:

The basic structure of an IC consists of four layers of different materials.

1) The bottom most layer, tyically 200 µm thick is a P-type silicon and serves as the body or substrate upon which the complete IC is built.
2) The second layer is of N-type Silicon material which is grown as a single crystal extension of the substrate using epitaxial deposition technique. All active and passive components are fabricated within this layer using selective diffusion of P-type and N-type impurities. This layer is typically 20µm thick.
3) The third layer is a very thin SiO_2 layer for preventing diffusion of impurities. This layer is typically 0.02-2 µm.
4) The fourth layer is an aluminum layer used for obtaining interconnection between components. This layer is typically 1 µm.

Basic Planar Process:

1. **Wafer preparation**: During this stage very high purity silicon is grown as a single crystal wafer, sliced, polished, doped and cleaned.

2. **Oxidation**: Silicon is oxidized to form SiO_2. SiO_2 has the property of preventing the diffusion of almost all impurities through it. It serves two important purposes.

- SiO_2 is extremely hard protective coating and is unaffected by almost all reagents except hydrofluoric acid. Thus, it stands against any contamination.
- By selective etching of SiO_2, diffusion of impurities through carefully defined window in the SiO_2 can be accomplished to fabricate various components.

3. **Diffusion**: It is a process of introducing impurity atoms (dopants) into silicon to change its doping. Boron (p-type) and phosphorus (n-type) are the two commonly used dopants. The monolithic technique requires the selective removal of the silicon dioxide (SiO_2) to form openings through which impurities may be diffused, if required. The photolithographic process is used for this purpose. The photolithographic process is illustrated in fig.1. During the process the wafer is coated with a thin layer of photosensitive material, commonly known as photo resist (such as kodak photoresist KPR). A large black and white layout of the desired pattern of openings or windows is made and then reduced photographically. This negative or stencil, of the required dimensions is placed as a mask over the photoresist as shown in fig.1. This wafer surface with mask is then exposed to ultraviolet light. Due to UV light, the photoresist below the transparent portions of the mask becomes polymerised. The mask is now removed, and the wafer is developed by a chemical process.

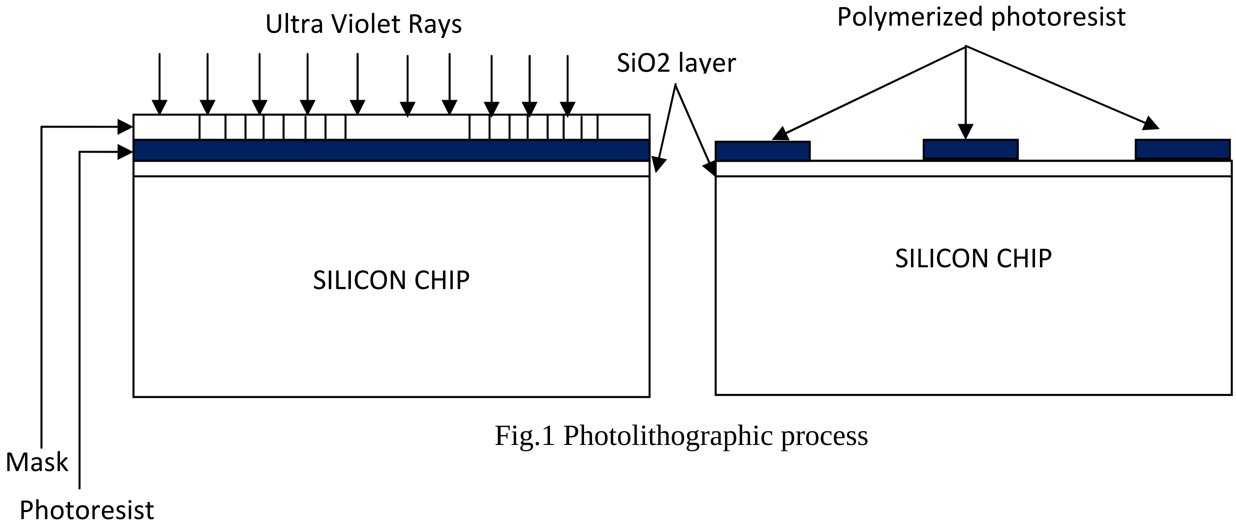


Fig.1 Photolithographic process

4. **Ion Implantation**: Ion implantation is the other technique which is superior to diffusion to introduce impurities into a silicon wafer. This technique has two important advantages.
    - It's preferred at low temperatures. Therefore, previously diffused regions have a lesser tendency for lateral spreading.
    - In diffusion process, temperature has to be controlled over a large area inside the oven, whereas in ion implantation technique, accelerating potential and the beam current are electrically controlled from outside.

5. **Chemical Vapor Deposition:** It's a process by which gases or vapors are chemically reacted leading to the formation of a solid on a substrate. It can deposit the SiO_2 layer at a faster rate and at lower temperatures.

6. **Metallization:** Metallization is employed to interconnect various components of the IC to form the desired circuit. Al is usually used for metallization as it offers several advantages.
    - It's a relatively good conductor.

- It’s easy to deposit aluminum films
- It makes good mechanical bonds with silicon
- It forms low resistance contact with p-type silicon and heavily doped n-type silicon

7. **Packaging:** Each of the wafers processed contains several hundred chips, each being a complete circuit. So these chips must be separated and individually packaged with the necessary connection legs.

Limitations of ICs:

- If any component in an IC fails, the whole IC has to be replaced by the new one. i.e. individual component can’t be removed or replaced.
- Limited power ratings as it’s not possible to manufacture high power (say greater than 10 W) ICs
- It’s not possible to fabricate inductors and transformers on the semi conductor chip surface.
- Its quite delicate so rough handling needs to be avoided.

REFERENCES AND FURTHER READING

1. Jyoti Tandukar *Course Manual of Electronic Circuits I*, IOE
2. Adel S. Sedra, Kenneth C. Smith *Microelectronic Circuits*, Harcourt Brace College Publishers