LECTURE 150 – BASIC IC PROCESSES
(READING: Text-Sec. 2.2)

INTRODUCTION

Objective

The objective of this presentation is:

1.) Introduce the fabrication of integrated circuits

2.) Describe the basic fabrication process steps by which an integrated circuit is made

Outline

- Integrated circuit fabrication
- Basic processing steps

INTEGRATED CIRCUIT FABRICATION

Classification of Silicon Technology

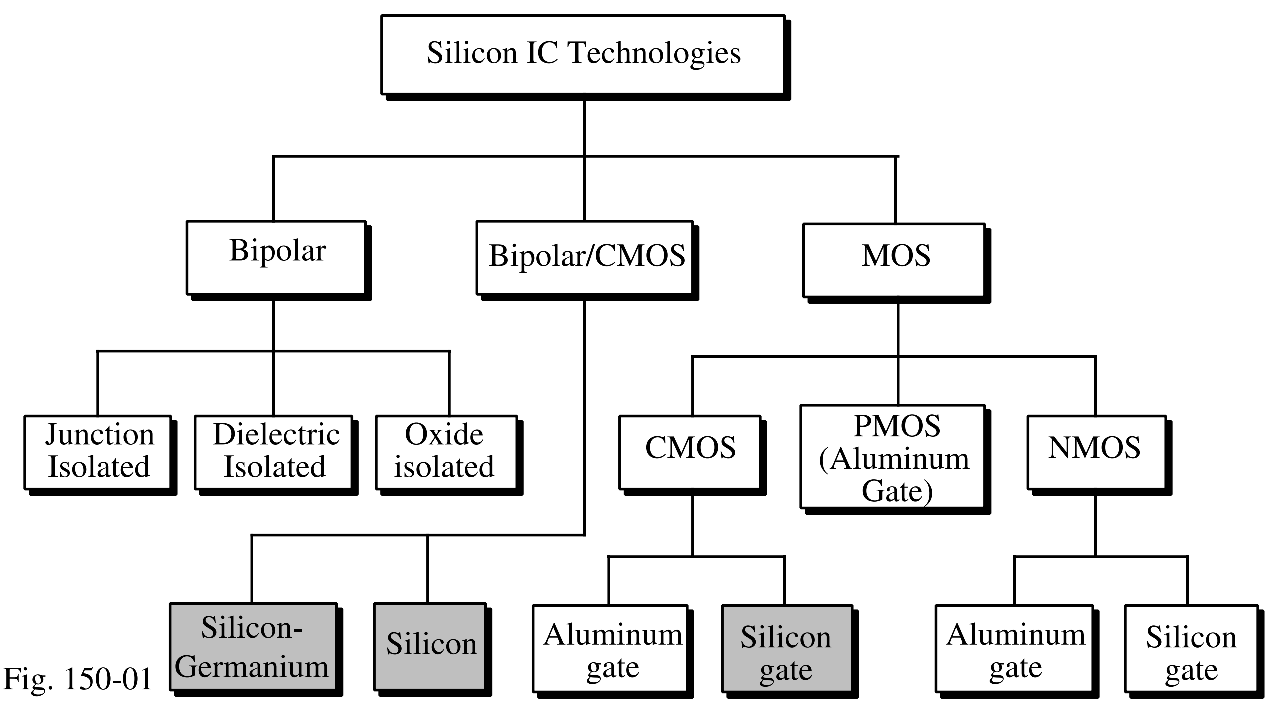


Fig. 150-01

Comparison of Bipolar and CMOS Technologies

Comparison of BJT and MOSFET technology from an analog viewpoint:

Feature	BJT	MOSFET
Cutoff Frequency(f_T)	100 GHz	50 GHz (0.25μm)
Noise (thermal about the same)	Less 1/f	More 1/f
DC Range of Operation	9 decades of exponential current versus v_{BE}	2-3 decades of square law behavior
Small Signal Output Resistance	Slightly larger	Smaller for short channel
Switch Implementation	Poor	Good
Capacitor Implementation	Voltage dependent	Reasonably good

Which is best?

- Almost every comparison favors the BJT, *however* a similar comparison made from a digital viewpoint would come up on the side of CMOS.
- Therefore, since large-volume technology will be driven by digital demands, CMOS is an obvious result as the technology of availability.

Other factors:

- The potential for technology improvement for CMOS is greater than for BJT
- Performance generally increases with decreasing channel length

BiCMOS may be the best compromise for the mixed signal system on a chip.

BASIC FABRICATION PROCESSES

Basic steps

- Oxide growth
- Thermal diffusion
- Ion implantation
- Deposition
- Etching
- Epitaxy

Photolithography

Photolithography is the means by which the above steps are applied to selected areas of the silicon wafer.

Silicon wafer

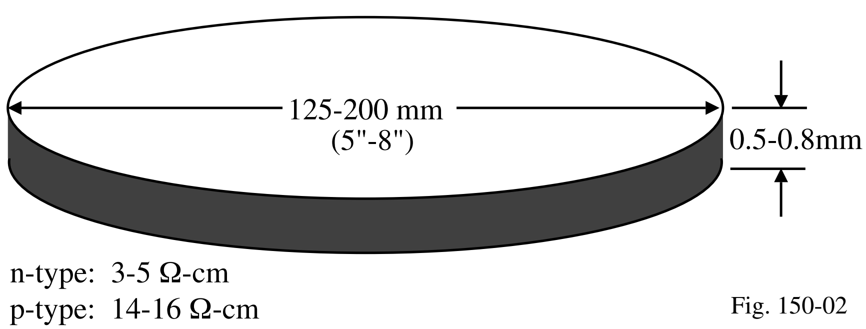


Fig. 150-02

Oxidation

Description:

Oxidation is the process by which a layer of silicon dioxide is grown on the surface of a silicon wafer.

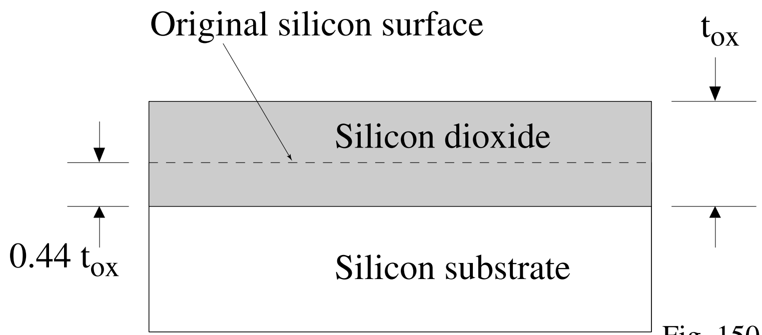


Fig. 150-03

Uses:

- Protect the underlying material from contamination
- Provide isolation between two layers.

Very thin oxides (100Å to 1000Å) are grown using dry oxidation techniques. Thicker oxides (>1000Å) are grown using wet oxidation techniques.

Diffusion

Diffusion is the movement of impurity atoms at the surface of the silicon into the bulk of the silicon.

Always in the direction from higher concentration to lower concentration.

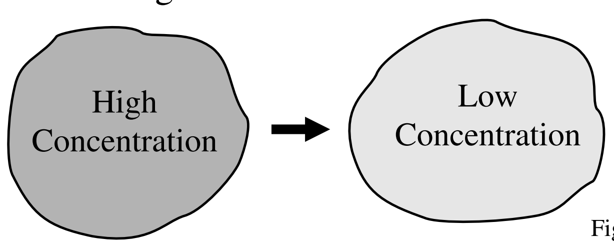
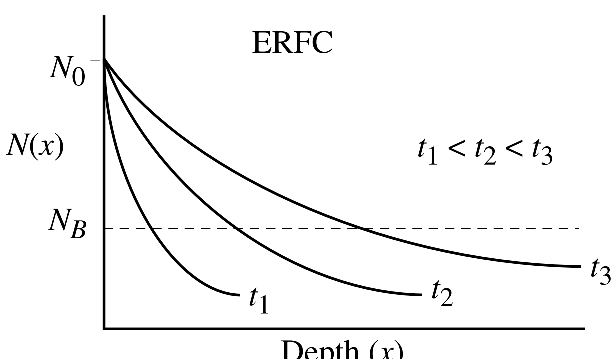
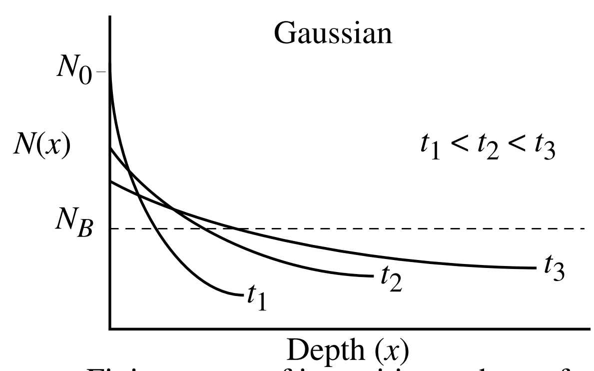


Fig. 150-04

Diffusion is typically done at high temperatures: 800 to 1400°C



Infinite source of impurities at the surface.



Finite source of impurities at the surface.

Fig. 150-05

Ion Implantation

Ion implantation is the process by which impurity ions are accelerated to a high velocity and physically lodged into the target material.

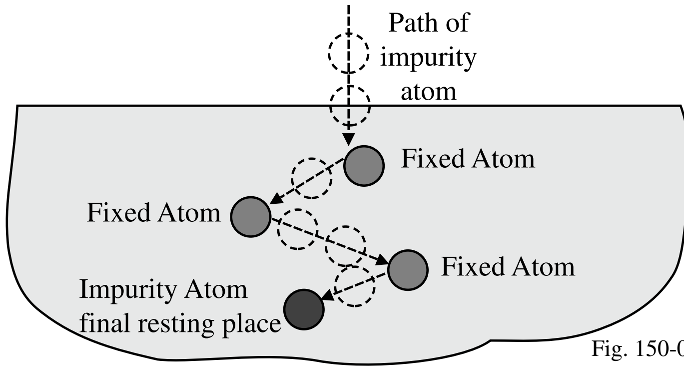


Fig. 150-06

- Anneal is required to activate the impurity atoms and repair the physical damage to the crystal lattice. This step is done at 500 to 800°C.
- Ion implantation is a lower temperature process compared to diffusion.
- Can implant through surface layers, thus it is useful for field-threshold adjustment.
- Can achieve unique doping profile such as buried concentration peak.

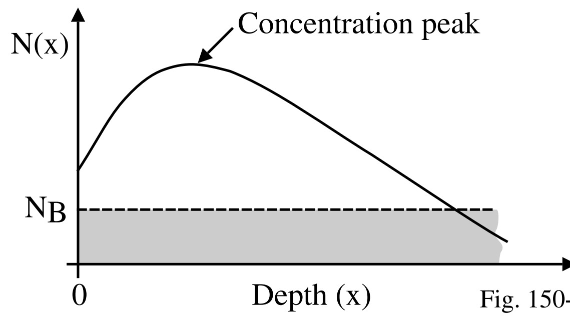


Fig. 150-07

Deposition

Deposition is the means by which various materials are deposited on the silicon wafer.

Examples:

- Silicon nitride (Si_3N_4)
- Silicon dioxide (SiO_2)
- Aluminum
- Polysilicon

There are various ways to deposit a material on a substrate:

- Chemical-vapor deposition (CVD)
- Low-pressure chemical-vapor deposition (LPCVD)
- Plasma-assisted chemical-vapor deposition (PECVD)
- Sputter deposition

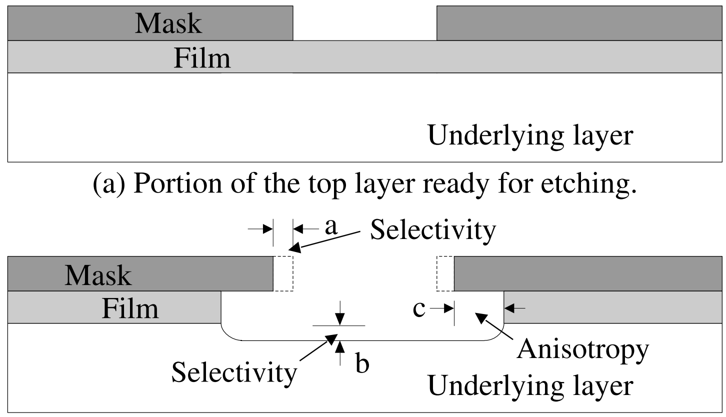
Material that is being deposited using these techniques covers the entire wafer.

Etching

Etching is the process of selectively removing a layer of material.

When etching is performed, the etchant may remove portions or all of:

- The desired material
- The underlying layer
- The masking layer



(a) Portion of the top layer ready for etching.

(b) Horizontal etching and etching of underlying layer.

Fig. 150-08

Important considerations:

- *Anisotropy* of the etch is defined as,

  A = 1-(lateral etch rate/vertical etch rate)

- *Selectivity* of the etch (film to mask and film to substrate) is defined as,

$$S_{film\text{-}mask} = \frac{\text{film etch rate}}{\text{mask etch rate}}$$

$A = 1$ and $S_{film\text{-}mask} = \infty$ are desired.

There are basically two types of etches:

- Wet etch which uses chemicals
- Dry etch which uses chemically active ionized gases.

Epitaxy

Epitaxial growth consists of the formation of a layer of single-crystal silicon on the surface of the silicon material so that the crystal structure of the silicon is continuous across the interfaces.

- It is done externally to the material as opposed to diffusion which is internal
- The epitaxial layer (epi) can be doped differently, even oppositely, of the material on which it grown
- It accomplished at high temperatures using a chemical reaction at the surface
- The epi layer can be any thickness, typically 1-20 microns

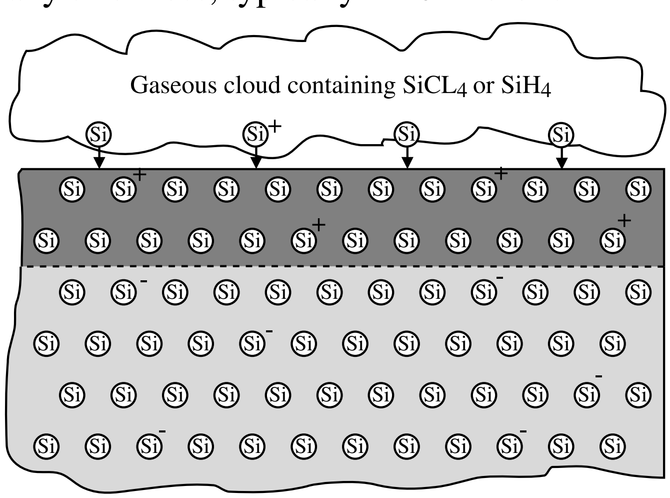


Fig. 150-09

Photolithography

Components

- Photoresist material
- Mask
- Material to be patterned (e.g., oxide)

Positive photoresist

Areas exposed to UV light are soluble in the developer

Negative photoresist

Areas not exposed to UV light are soluble in the developer

Steps

1. Apply photoresist
2. Soft bake (drives off solvents in the photoresist)
3. Expose the photoresist to UV light through a mask
4. Develop (remove unwanted photoresist using solvents)
5. Hard bake (≈ 100°C)
6. Remove photoresist (solvents)

Illustration of Photolithography - Exposure

The process of exposing selective areas to light through a photo-mask is called *printing*.

Types of printing include:

- Contact printing
- Proximity printing
- Projection printing

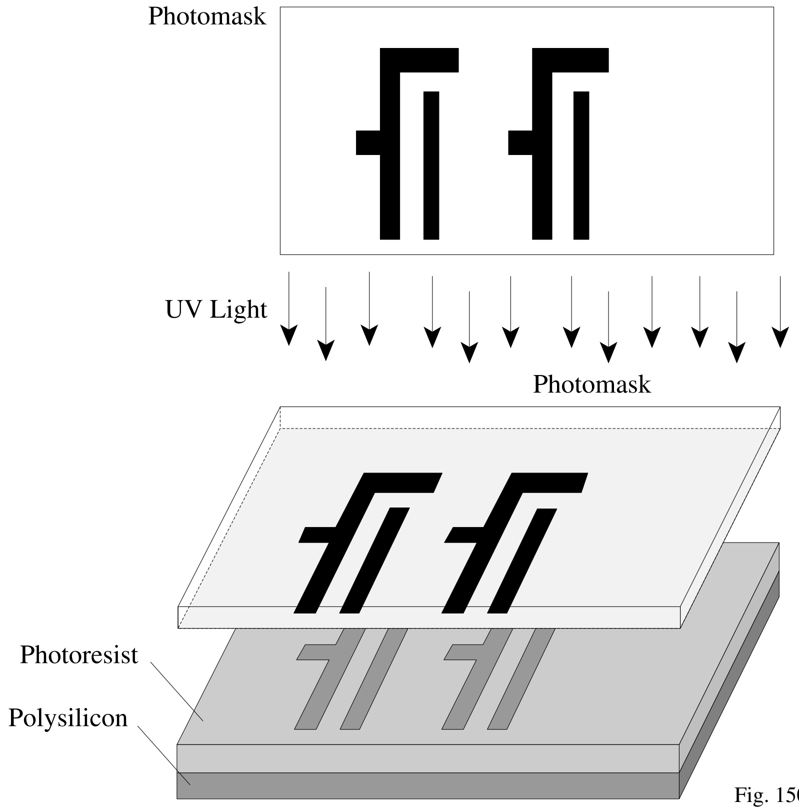


Fig. 150-10

Illustration of Photolithography - Positive Photoresist

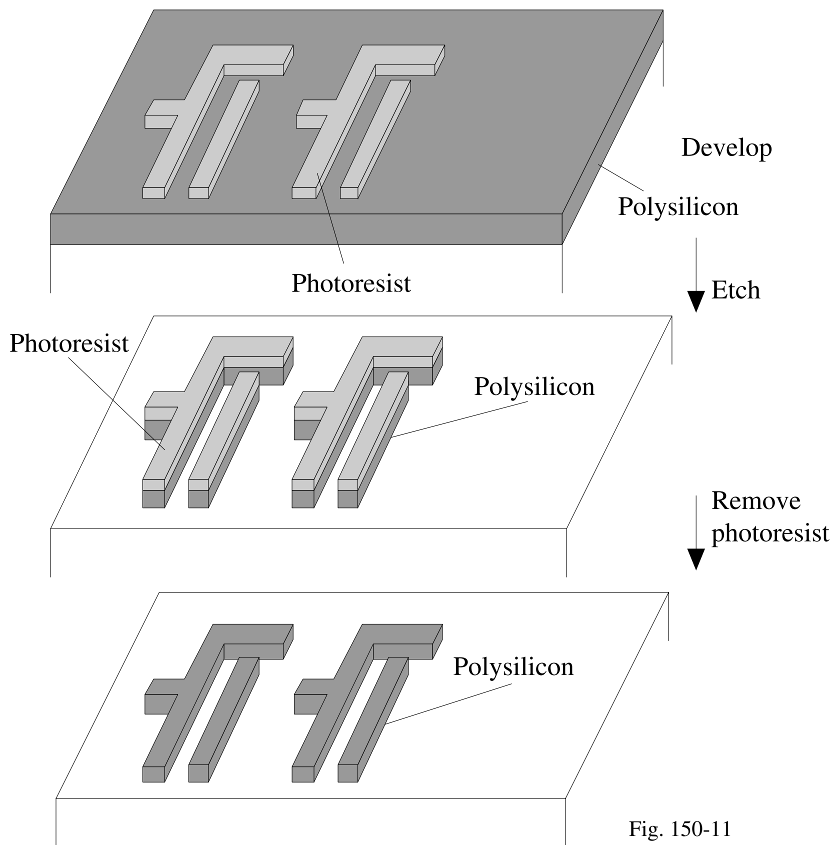


Fig. 150-11

Illustration of Photolithography - Negative Photoresist

(Not used much any more)

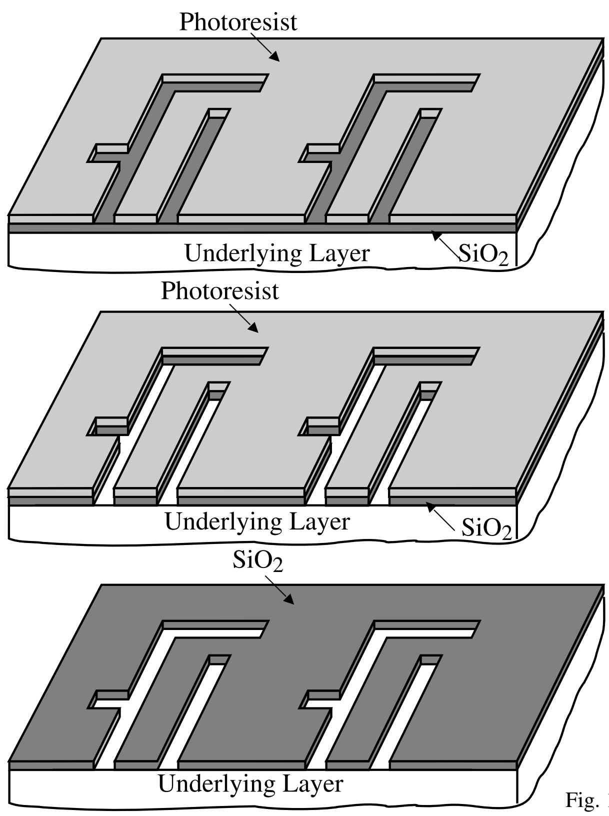


Fig. 150-12

SUMMARY

Fabrication is the means by which the circuit components, both active and passive, are built as an integrated circuit.

Basic process steps include:

- Oxide growth
- Thermal diffusion
- Ion implantation
- Deposition
- Etching
- Epitaxy

These steps are restricted to a physical area by the use of photolithography.

The use of photolithography to apply a process to a certain area is called a masking step.

The complexity of a process can be measured in the terms of the number of masking steps or masks required to implement the process.

