CHEMISTRY OF ELECTRONIC MATERIALS
SUB. CODE: SCY1102
UNIT- 3
THIN FILM TECHNIQUES

Introduction : Lithogrphy. Thin-Film deposition: Chemical Vapour Deposition – Physical Vapour Deposition, Pulsed Laser and Atomic Layer Deposition. Epitaxy: Vapour Phase Epitaxy- Liquid Phase Epitaxy – Molecular Beam Epitaxy. Evaporation: Thermal Evaporation and e-beam evaporation. Sputtering Techniques: Direct Current (DC) Sputtering and Radio Frequency (RF) sputtering. Preparation of Si/Ge semiconductors –Czochralski crystal growth technique: Doping of semiconductors by ion implantation.

Lithography

For decades, micro- and nanolithography technology has been contributed to the manufacturing of integrated circuits (ICs), microelectromechanical system (MEMS) devices and microchips. In Greek lithos, meaning "stone" and Graphy means “writing”.

Lithography Definition:

It is the process of printing from a plane surface on which image to be printed is ink-receptive and the blank area ink-repellent.

(Or)

It is the process of producing patterns on semiconductors crystals for use as integrated circuits.

Lithography techniques are divided into two types by the use of masks or templates:

(1) Masked lithography: Masked lithography makes use of masks or molds to transfer patterns over a large area simultaneously.

Ex: Photolithography, Soft lithography and nano-imprint lithography.

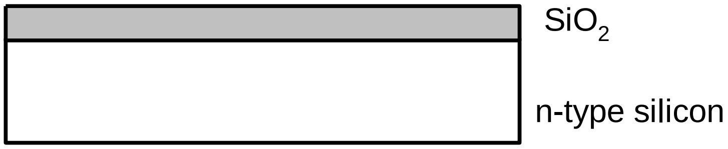
(2) Maskless lithography: Which fabricates arbitrary patterns by a serial writing by without using masks.

Ex: Electron beam lithography, focused ion beam lithography and scanning probe lithography

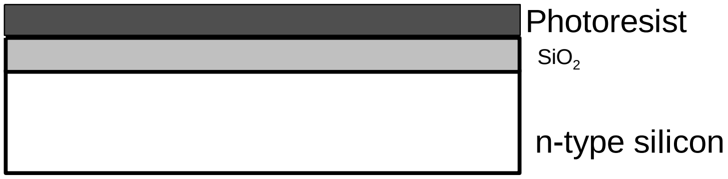
PHOTOLITHOGRAPHY:

It is an optical technique for transferring patterns from a glass photomask onto a semiconductor substrate.

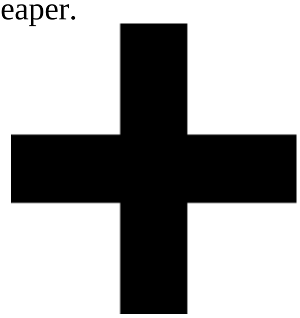
1. Surface Preparation: Clean and dry wafer surface was needed for Photolithographic process. The grease, oil or wax stains will be removed by ultrasonic bath. The spin dry (wafer) by N_2 blow results the clean surface.



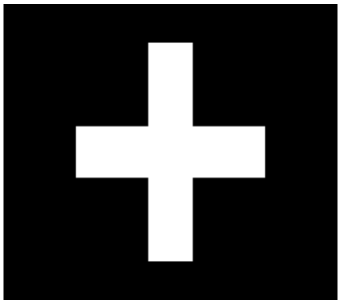
2. Photoresist - Apply:
   Photoresist is a light-sensitive liquid (hydrocarbon) compound. A thin layer of photoresist was applied on the prepared surface.



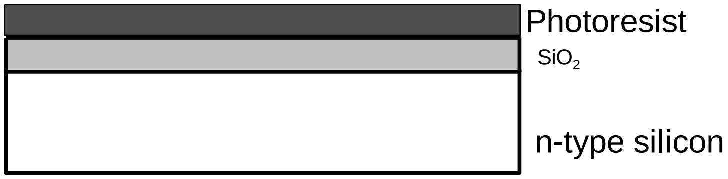
a) Positive Photoresist: On exposure to UV light breaks the chemical bonds in the material, so that the exposed region dissolves in developer, unexposed region remains. Pattern on resist same as pattern on mask. Positive resist more common, have better resolution, cheaper.



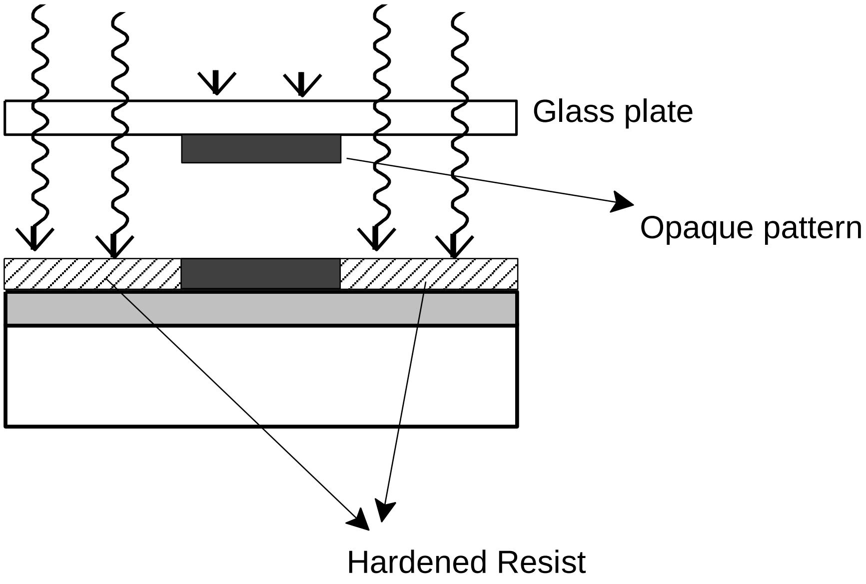
b) Negative Tone: On exposure to UV light strengthens the chemical bonds in the material, so that the exposed region stays but the unexposed region dissolves in developer.



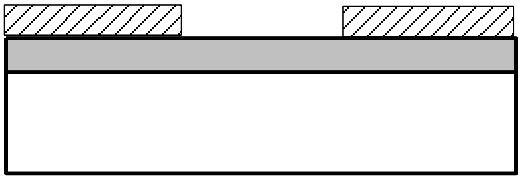
3. Softbake: Partial evaporation of photoresist solvents leads to the strong adhesion between SiO_2 and Photoresist.



4. Exposure: Precise alignment of mask on glass plate to wafer and exposure to U.V. light.

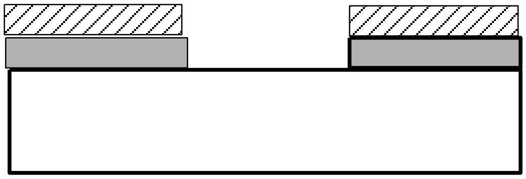


5. Development:
   Wafer is rinsed in developing solution, to remove unexposed areas of photo resist. This results in bare and photo resist coated areas of oxide.



6. Etching:

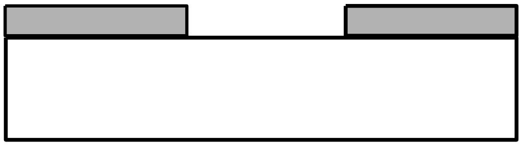
   Etching is traditional process of using strong acid to remove or cut into the unprotected parts of substrate surface to create a design. In present case, the wafer is placed in an etchant (eg HF or NH_4F) , this attacks oxide and not on the photo resist.



7. Photo resist removal:

   Positive photoresists could be removed by acetone, trichloroethylene, phenol-based strippers. Negative photoresists could be removed by Methyl ethyl ketone, Methyl isobutyl ketone.

   In the present case photo resist is stripped off with a Strong acid (H_2SO_4), this attacks only the photo resist, not on Si or SiO_2.



Applications:

1. Commercial microelectromechanical system (MEMS) devices and photolithographic stamps
2. Electronic gadgets to health care and medical devices: Microneedles for transdermal drug delivery, artificial retina microchip, and microfluidic devices
3. MEMS accelerometers employed in automobiles and consumer electronic devices :
   MEMS accelerometers are employed for crash-airbag deployment in automobiles and for motion detection in consumer electronic devices such as game controllers (e.g., Nintendo Wii), iPhone and other smartphones.
4. Digital micromirror devices (DMD) for display applications in projectors and televisions
5. MEMS pressure sensors for detecting pressures in car tires and blood vessels.

THIN FILM DEPOSITION:

Deposition: Transfer atoms from a target to a vapor (or plasma) to a substrate.

Thinfilm: A thin film is a layer of material ranging from fractions of a nanometer to several micrometers in thickness.

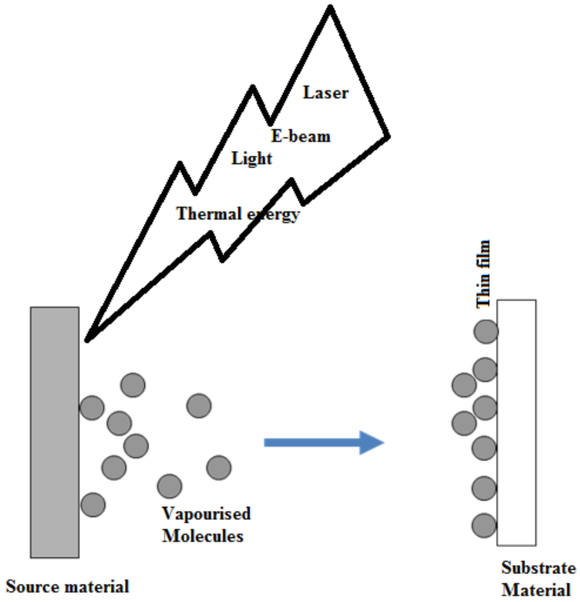
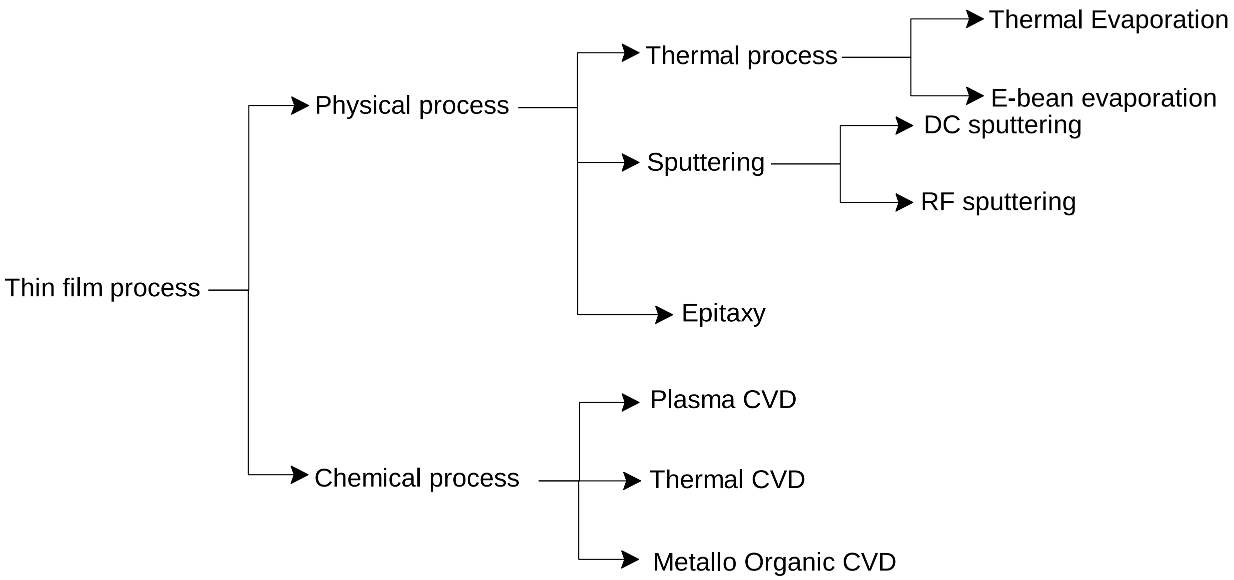


Fig.1 Schematic representation of Thin film deposition

CLASSIFICATION OF THIN FILM DEPOSITION PROCESS:



CHEMICAL VAPOUR DEPOSITION

Chemical vapour deposition (CVD) method involves a transport of reactant gases towards the substrate kept at some temperature, where reactants crack into different products, which diffuse on the surface and undergo certain chemical reactions at appropriate site, nucleate and grow to form desired films, coatings, wires and tubes.

Precursors

The common precursors used in CVD reactions are

- i) Metalhydrides – SiH_4, GeH_4
- ii) Metalhalides-$TiCl_4$, $TaCl_5$, WF_6
- iii) Metal organics- $AlMe_3$, $AlBu_3$, $Fe(CO)_5$, $Ni(CO)_4$

Types of CVD Reactions:

(i) Thermal Decomposition (Pyrolysis)

$$SiH_4\,(g) + O_2 \xrightarrow{450\ ^\circ C} SiO_2(s) + 2H_2$$

(ii) CNT synthesis Thermal CVD: Fe, Co and Ni impregnated zeolite or SiO2 was used as substrate to grow the CNT.

$$CH_4\,(g) + H_2 \xrightarrow{900\ ^\circ C} CNT + 3\,H_2$$

(iii) Reduction:

$$WF_6\,(g) + 3H_2 \xrightarrow{350\ ^\circ C} W\,(s) + 6HF\,(g)$$

(iv) Oxidation:

$$SiH_4\,(g) + O_2 \xrightarrow{450\ ^\circ C} SiO_2(s) + 2H_2$$

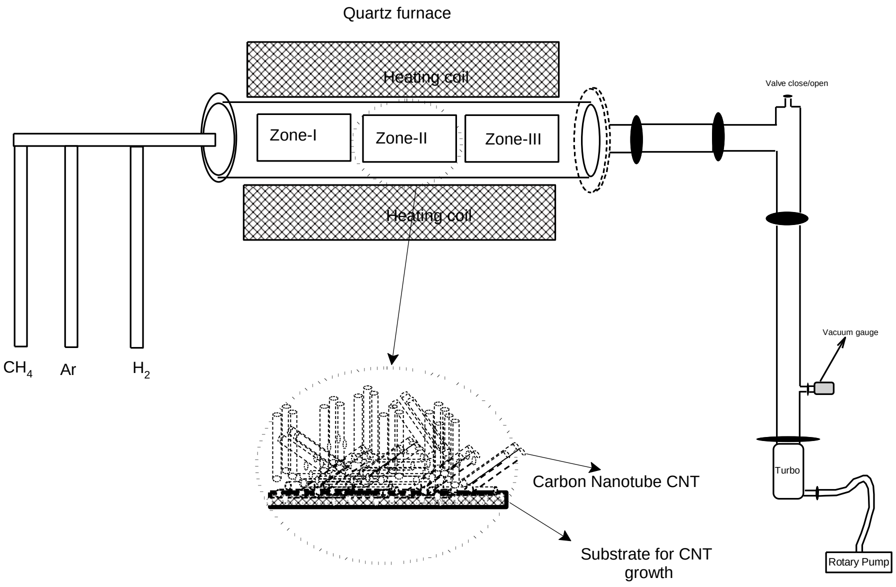


Fig.2 Schematic diagram of Thermal CVD designed for CNT Synthesis

TYPES OF CVD

In CVD, the temperature of 300-1200°C is usually used. The heat input can be in the form of thermal, light, plasma and so on. This give rise to number of CVD techniques.

S.No.	Name of the CVD	Source of thermal energy
1	Thermal activated CVD	IR radiation, RF heating
2	Photo assisted CVD	Arc Lamps, CO2 laser, Nd:YAG laser, Argon ion laser
3	Plasma assisted CVD	RF diode, Microwave
4	Metallo-organic CVD	It uses organometallic as precursors

MECHANISM

Whatever may be the type of CVD, the system follows a five step mechanism.

(i) Transport of precursors into reactors
(ii) Absorption and diffusion of precursors on the surbstrate
(iii) Chemical reaction or decomposition at the substrate
(iv) Thin film Deposition
(v) Removal of unreacted precursors and by-products

ADVANTAGES

(i) Versatile- CVD can deposit any element or compound
(ii) High purity of 99.99%-99.999% can be obtained.
(iii) CVD produces a high dense films
(iv) Economical in production since many products can be coated at time

APPLICATIONS

(i) CVD can be used for the synthesis of nanotubes and nanowires
(ii) CVD can be used for hard coatings and metal films which are used in microelectronics
(iii) CVD can also be used for preparing semiconducting devices, dielectrics, energy conversion devices etc.

ATOMIC LAYER DEPOSITION

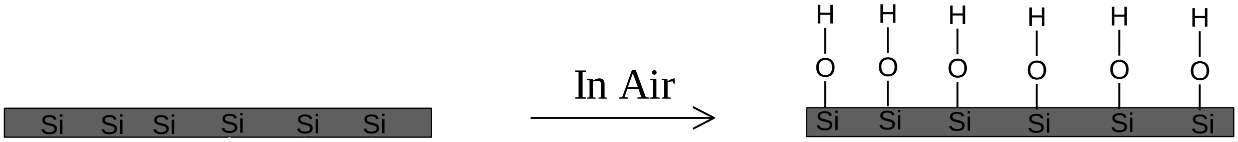
ALD is a method of applying thin films to various substrates with atomic scale precision. In ALD method the precursor gases or vapors are alternately pulsed on to the substrate surface They will chemisorb or surface reaction takes place at the surface. The Surface reactions on ALD are complementary and self-limiting.

Precursor Gas requirements for ALD:

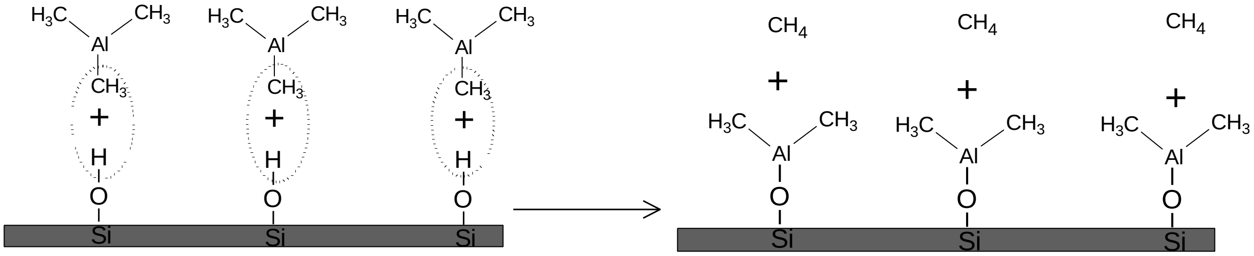
1. Must be volatile and thermally stable
2. Preferably liquids and gases
3. Should Chemisorb onto the surface or rapidly react with surface and react aggressively with each other
4. Short saturation time, good deposition rate, no gas phase reactions
5. Should not self-decompose and should not etch, dissolute into film or substrate

Mechanism:

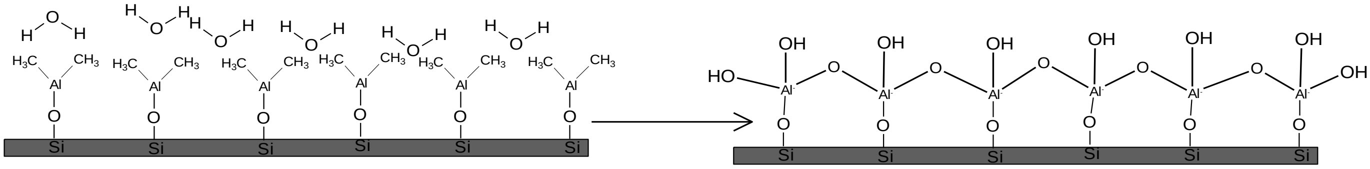
Step-I: In air H_2O vapor is adsorbed on most surfaces, forming a hydroxyl group.



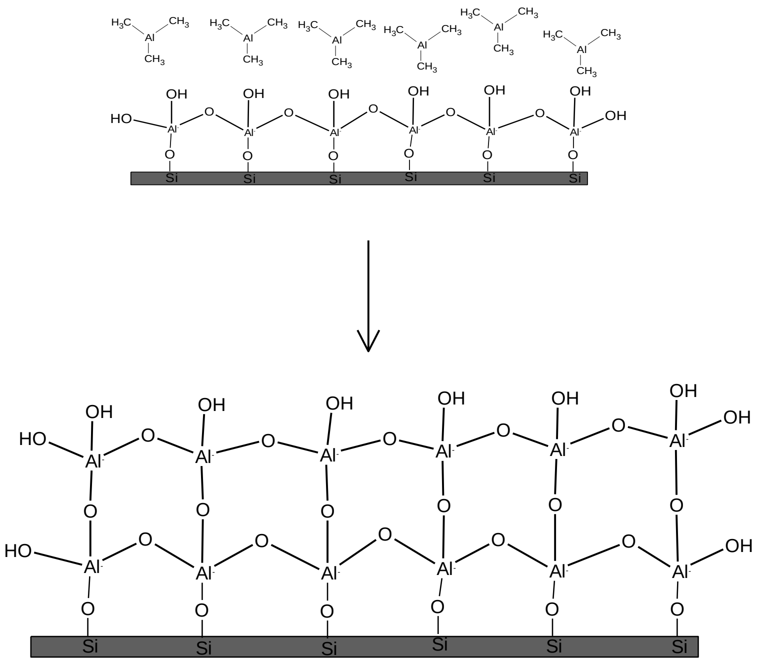
Step-II: Release of sequential precursor gases (TMA-Trimethyl aluminium) pulses to deposit a monolayer of gas on the Si surface until the surface is passivated and producing methane as the reaction product.



Step-III: The second precursor of H_2O vapour is introduced into the chamber. The H_2O reacts with the dangling methyl groups on the new surface forming Aluminum-oxygen (Al-O) bridges and hydroxyl surface groups,



Step-IV: Again TMA and water vapour was purged simultaneously results one more monolayer was fomed.



Recently, it turned out that ALD method also produces outstanding dielectric layers and attracted semiconductor industries for making High-K dielectric materials.

ALD Applications:

1. High-k gate oxides
2. Storage capacitor dielectrics
3. Pinhole-free passivation layers for OLEDs and polymers
4. Passivation of crystal silicon solar cells
5. High aspect ratio diffusion barriers for Cu interconnects
6. Adhesion layers
7. Organic semiconductors
8. Highly conformal coatings for microfluidic and MEMS applications
9. Other nanotechnology and nano-electronic applications
10. Coating of nanoporous structures
11. Fuel cells, e.g. single metal coating for catalyst layers
12. Bio MEMS

THE DIFFERENCES BETWEEN CVD AND ALD:

	CVD	ALD
Growth mode	Continuous	Step wise – layer by layer
Growth rate	Variable	Growth per step is accurately defined
Thickness control	Rate x Time	Dialed in with a selected number of steps
Growth initiation	Nucleation, grain growth	Continuous film
Precursor	Less reactive and must decompose at temperature	Highly reactive and can decompose at temperature

PHYSICAL VAPOR DEPOSITION

Physical Vapor Deposition (PVD) is a collective set of processes used to deposit thin layers of material, typically in the range of few nanometers to several micrometers. PVD processes are environmentally friendly vacuum deposition techniques consisting of three fundamental steps.

1) Vaporization of the material from a solid source assisted by high temperature vacuum or gaseous plasma.
2) Transportation of the vapor in vacuum or partial vacuum to the substrate surface.
3) Condensation onto the substrate to generate thin films.

EVAPORATION

The source material used in this process are generally refractory metals such as W, Ta, Mo etc. In evaporation technique, both substrate and source materials (to be deposited) are placed inside the vacuum chamber (10^{-6} to 10^{-7} torr). The vacuum is required to allow the molecules to evaporate and to move freely in the chamber.

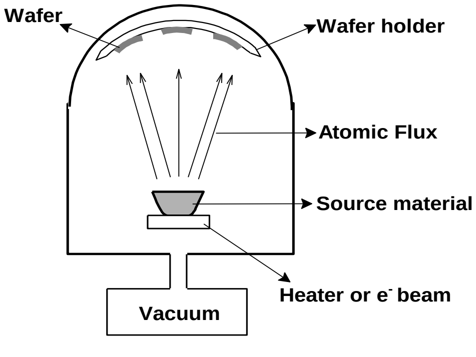


Fig.3 Schematic diagram of evaporation equipment

Thermal Evaporation:

The thermal evaporation process comprises evaporating source materials in a vacuum chamber below $1x10^{-6}$ torr ($1.3x10^{-4}$ Pa) and condensing the evaporated particles on a substrate.

The thermal evaporation process is conventionally called vacuum deposition. Two types of thermal evaporation processes are available.

Resistive heating:

In thermal evaporation the materials to be evaporated is put on conductive (graphite or tungsten) crucibles which are intensely heated by filament. It is most commonly used for the deposition of thin films. The source materials are evaporated by a resistively heated filament or boat, generally made of refractory metals such as W, Mo or Ta, with or without ceramic coatings.

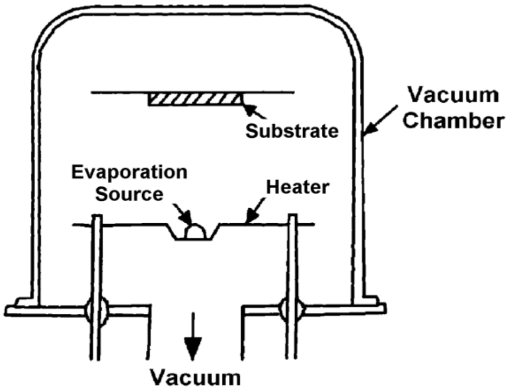


Fig.4 Resistive heating

Limitations:

Contamination Problem with Thermal Evaporation Container material also evaporates, which contaminates the deposited film.

E-beam evaporation:

Al electron gun (e-gun) is used to produce electron beam of 10 keV. This beam is directed at the source material in order to develop sufficient vapour so as to produce deposits on wafer or substrates. In the e-beam evaporation the necessary vapours for the production of the

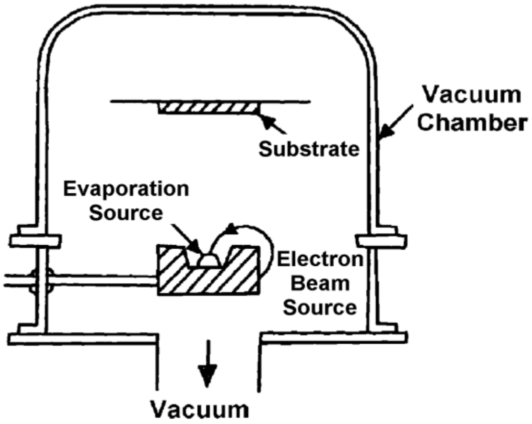


Fig.5 E-beam evaporation

coating are obtained by focussing an energetic electron beam on the crucible containing the material, and heating it until reaching its evaporation. Crucibles of quartz, graphite, alumina, beryllia, boron-nitride or zirconia are used with indirect heating. The refractory metals are evaporated by electron-beam deposition since simple resistive heating cannot evaporate high melting point materials.

The thin film thickness will be depending on mass, density of the source ions and the distance between source and target

$$f = \frac{m}{4d\pi h^2}$$

f = film thickness
m = mass of the source ions
d = density of the source ions
h = The distance between source and target

SPUTTERING:

When a solid surface is bombarded with energetic particles such as accelerated ions, surface atoms of the solid are scattered backward due to collisions between the surface atoms and the energetic particles. This phenomenon is called sputtering. The source materials used in this process are generally an alloy, ceramic or a compound. In sputtering technique, a high energy atom in ionized form (usually Ar+) is used to hit the surface atoms of the targeted source (Cathode) material. Then the knocked out atoms in vapour form are deposited on the surface of the (Anode) substrates to produce an uniform coating.

DC sputtering:

This composed of a pair of planar electrodes. One of the electrodes is a cold cathode and the other is the anode. The front surface of the cathode is covered with target materials to be

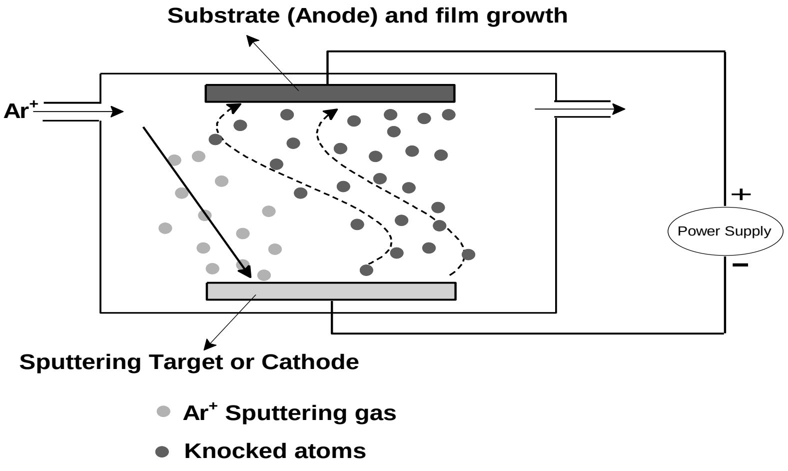


Fig.6 Schematic diagram for DC sputtering

deposited. The substrates are placed on the anode. The sputtering chamber is filled with sputtering gas, typically argon gas at 5 Pa ($4x10^{-2}$ torr). The glow discharge is maintained under the application of DC voltage between the electrodes. The Ar^+ ions generated in the glow discharge are accelerated at the cathode fall (Sheath) and sputter the target, resulting in the deposition of the thin films on the substrates. In the DC sputtering system, the target is composed of metal since the glow discharge (current flow) is maintained between the metallic electrodes.

RF Sputtering:

An rf diode and a dc diode are visually the same thing. The only real difference is that, for diodes, the power supply is operated at high frequency. The most common frequency is 13.56 MHz, although experiments have run the gamut from 60 Hz to 80 MHz or more. Most manufacturing systems use 13.56 MHz. The rf diode operates in a slightly different way than the dc diode: for a small part of the rf cycle, the cathode and anode are electrically reversed and shielded by guard rings. This eliminates charge buildup on an insulating surface by providing an equal number of ions, then electrons, then ions, and so on. This allows insulators to be sputtered or metals to be sputtered in reactive environments. By simple substitution of an insulator for the metal target in the dc sputtering discharge system, the sputtering discharge cannot be sustained because of the immediate buildup of a surface charge of positive ions on the front side of the insulator.

The sputtering procedure is commenced by evacuating the chamber to pressures lower than 10^{-6} Torr. Ar, being a noble gas which does not react with either the target or substrate, is then introduced into the chamber at a specified pressure. This is followed by allowing O_2 into the chamber at a set rate. The r.f. supply is then switched on and stabilised to the required power and induced d.c. bias levels; this bias is an indication of the sheath potential and is a good sign of the ion bombardment energy. During this time the substrate is shielded by the top shutter. Once pre-conditioning is complete, the top shutter is opened marking the beginning of the deposition process.

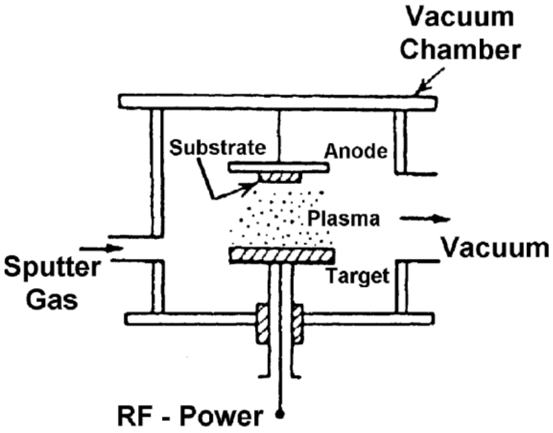


Fig.7 Schematic diagram for RF sputtering

The difference between RF and DC sputtering process

DC sputtering	RF sputtering
DC power is used	AC power is used
Applicable for Metals or Conductors	Applicable for both Conductor and Insulators
It is Cheap	It is expensive

The difference between Evaporation and Sputtering processes

Evaporation	Sputtering
Low energy atoms	Higher energy atoms
High vacuum path Few collisions Line of sight deposition Little gas in film	Low vacuum, plasma path Many collisions Less line of sight deposition Gas in film
Larger grain size	Smaller grain size
Fewer grain orientation	Many grain orientations
Poorer adhesion	Better adhesion

PULSED LASER DEPOSITION:

Pulsed Laser Deposition (PLD) is a thin film deposition technique that is used to deposit materials on substrates. A base system consists of a target, substrate carrier which is mounted in a vacuum chamber. An excimer laser is used to energize the surface of a target to produce a deposition plume. The plume is typically directed towards the substrate where a thin-film is deposited. Since each shot of the laser is directly related to the amount of material ablated, the deposition rate can be calibrated and controlled very precisely.

Advantages:

[1] Flexible and easy to implement
[2] Growth in any environment
[3] Exact transfer of complicated materials (YBCO)
[4] Variable growth rate
[5] Epitaxy at low temperature
[6] Resonant interactions possible (i.e., plasmons in metals, absorption peaks in dielectrics and semiconductors)
[7] Atoms arrive in bunches, allowing for much more controlled deposition
[8] Greater control of growth (e.g., by varying laser parameters)

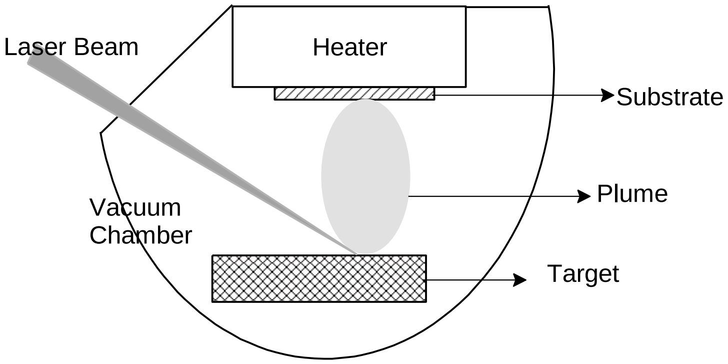


Fig.8 Schematic diagram of Pulsed Laser Deposition

Disadvantages:

- [1] Uneven coverage
- [2] High defect or particulate concentration
- [3] Not well suited for large-scale film growth
- [4] Mechanisms and dependence on parameters not well understood

EPITAXY:

The word Epitaxy is derived form the greek “epi” – upon and “taxis” – to arrange. Epitaxy means the regularly oriented growth of a crystal substance upon another.

Types of Epitaxy

Based on Substrate and Thin Film

1] Homo epitaxy

The film and the substrate are the same material. Ex: Si on Si growth.

2] Heteroepitaxy

Film and substrate are different materials. Ex: AlAs, GaAs on Si.

Requirements of Epitaxial growth:

- [1] Clean substrate surface needed
- [2] Defects of substrate surface results defects in epitaxial layer
- [3] Hydrogen passivation of surface with water/HF
- [4] High temperature is required heated substrate

Advantages of Epitaxial growth:

- [1] High purity
- [2] Low defect density
- [3] Abrupt interfaces
- [4] Controlled doping profiles
- [5] High repeatability and uniformity
- [6] Safe, efficient operation

Vapour Phase Epitaxy:

During vapour phase epitaxy, epitaxial layers are grown on silicon substrates by the controlled deposition of Si atoms from a chemical vapour containing Si. Silicon tetrachloride ($SiCl_4$), Dichlorosilane (SiH_2Cl_2),Trichlorosilane ($SiHCl_3$) and silane (SiH_4) are the sources used for vapour phase epitaxial growth. The silicon wafer on which epitaxial growth has to take place is kept on a graphite susceptor placed inside a quartz reaction chamber and hydrogen gas is passed through the quartz tube. The entire system is RF heated to a temperature above 1100^0C.

$$SiCl_4(g) + 2H_2(g) \longrightarrow Si(s) + 4HCl(g)$$

The above reaction which occurs on the silicon surface is surface catalysed and the Si atoms released can be deposited as an epitaxial layer. As the reaction is reversible the reaction can be driven to the left by adjusting the process parameters and provides etching of the silicon rather than deposition. This etching can be used for preparing an atomically clean surface on which epitaxy occurs. To grow epitaxial layer of silicon with desired doping,the dopant is introduced along with $SiCl_4$.Gaseous diborane(B_2H_6) is used as a P-type dopant and arsine(AsH_3) is used as the N-type dopant.

Advantages:

1) It can be Performed at low temperature
2) High purity epitaxial growth can be achieved.

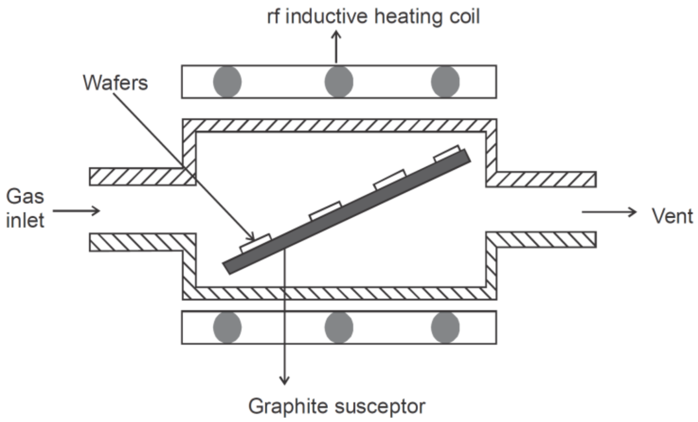


Fig.9 Schematic representation of Vapour Phase Epitaxy

Liquid Phase Epitaxy:

Liquid phase epitaxy is a method of grow semiconductor crystal layers from the melt on solid substrates. This happens at temperatures well below the melting point of the deposited semiconductor. The semiconductor is dissolved in the melt of another material. At conditions that close to the equilibrium between dissolution and deposition of the semiconductor crystal on the substrate is slowly and uniform. The equilibrium conditions depend very much on the

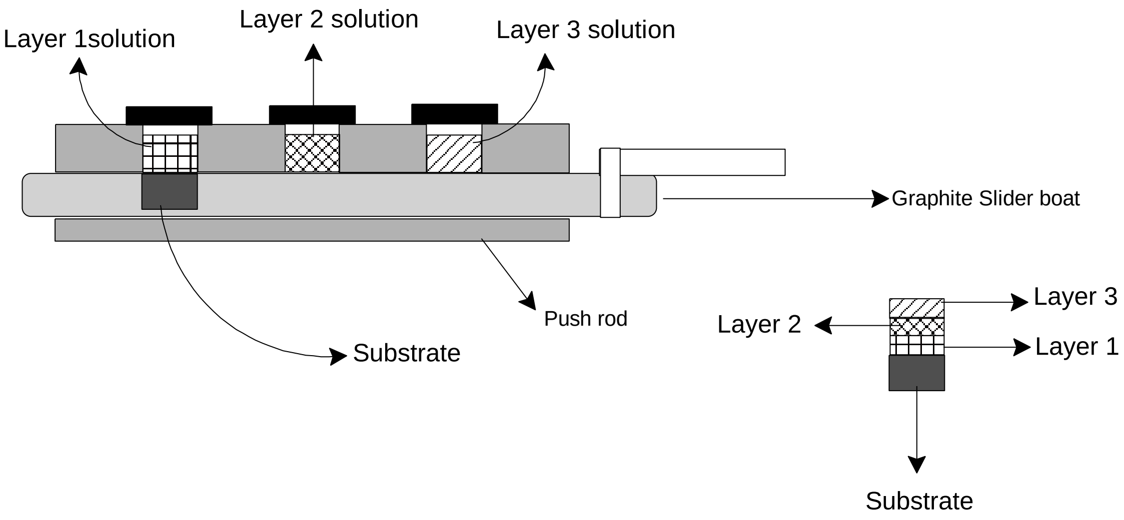


Fig.10 Schematic representation of Liquid phase epitaxy

temperature and on the concentration of the dissolved semiconductor in the melt. The growth of the layer from the liquid phase can be controlled by a forced cooling of the melt. Impurity introduction can be strongly reduced. Doping can be achieved by the addition of dopants.

A typical example for the liquid phase epitaxy method is the growth of ternery and quarternery III-V compounds on Galliumarsenid GaAs substrates. As a solvent quite often Gallium is used in this case. Another frequently used substrate is Indiumphosphide InP. However also other substrates like glass or ceramic can be applied for special applications. To facilitate nucleation, and to avoid tension in the grown layer the thermal expansion coefficient of substrate and grown layer should be similar.

The basic requirement is to bring the substrate and growth solution into contact while the epitaxial layer grows, and then to separate them cleanly at the end of the growth cycle. The method is mainly used for the growth of compound semiconductors. Very thin, uniform and high quality layers can be produced.

Advantages

- Less expensive and higher deposition rates wrt MBE
- Low defect concentration
- Excellent control of stoichiometry

Disadvantages

- Solubility considerations greatly restrict the number of materials for which this method is applicable
- Morphology (crystal orientation) control is difficult
- Surface quality often poor

Molecular Beam Epitaxy:

Molecular Beam Epitaxy (MBE) is an advanced ultra-high-vacuum facility (basic pressure 10^{-13} bar) to make compound semiconductor materials with great precision (< 0.01 nanometer). Because of the very low pressure, the mean free path is very long (can be hundreds of meters). Thus, the evaporated material travels in a straight line (a molecular beam) toward a hot substrate resulting in highly efficient raw materials. The epitaxial layers are deposited on the heated substrate from molecular beams impinging upon its surface, These beams are thermally generated in effusion cells containing the constituent elements such as Ga,As etc..All the effusion cells are located in an ultra high vacuum chamber. Each cell is provided with a shutter to control the composition or doping of the film. The duration in which each shutter opens and the temperature of the oven determines the flux of each element towards the substrate. The temperature of the cell is also accurately controlled to maintain the required intensity of the beams.

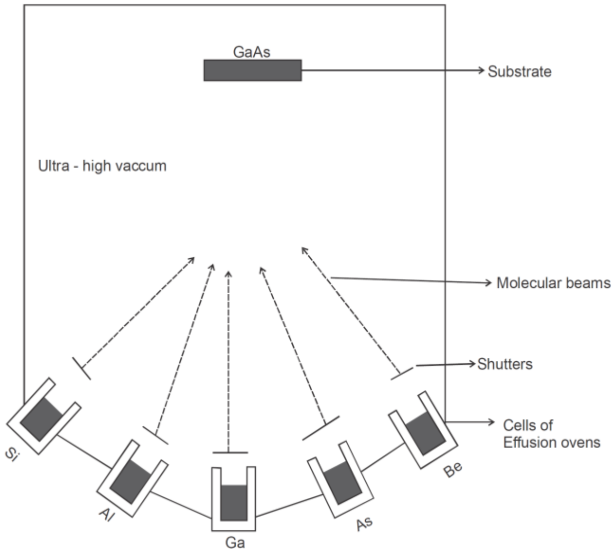


Fig.11 Schematic representation of MBE growth

There are several variables within MBE to improve the quality of growth, these are:

a) Flux rate: The number of atoms arriving at the substrate surface is known as Flux rate.
b) Substrate temperature (affects diffusive properties of impinging atoms)
c) Source temperature (speed of atomic arrival and flux rate)

Applications:

These materials are layered one on top of the other to form semiconductor devices such as transistors and lasers, which are devices being used in such applications as fiber-optics, cellular phones, satellites, radar systems, solar cells, and display devices.

Disadvantages:

a) It is highly expensive and complicated system
b) The thickness rises then strain energy is too high and defects are generated.
c) Higher temperatures result in more mobile surface atoms and the disadvantage is that interfaces become smoothed due to diffusion of atoms.
d) Lower temperatures generate more abrupt interfaces and introduces more point defects into the layer.

The Czochralski technique for Si crystal growth

A crystal growth technique proposed by Jan Czochralski, the so-called Czochralski method, has been widely applied for growing various types of single crystals such as silicon (Si), germanium (Ge) and oxide materials in industry. In fact, if this growth method had not been discovered, the current development of Si technology using large-scale dislocation-free crystals would not be possible.

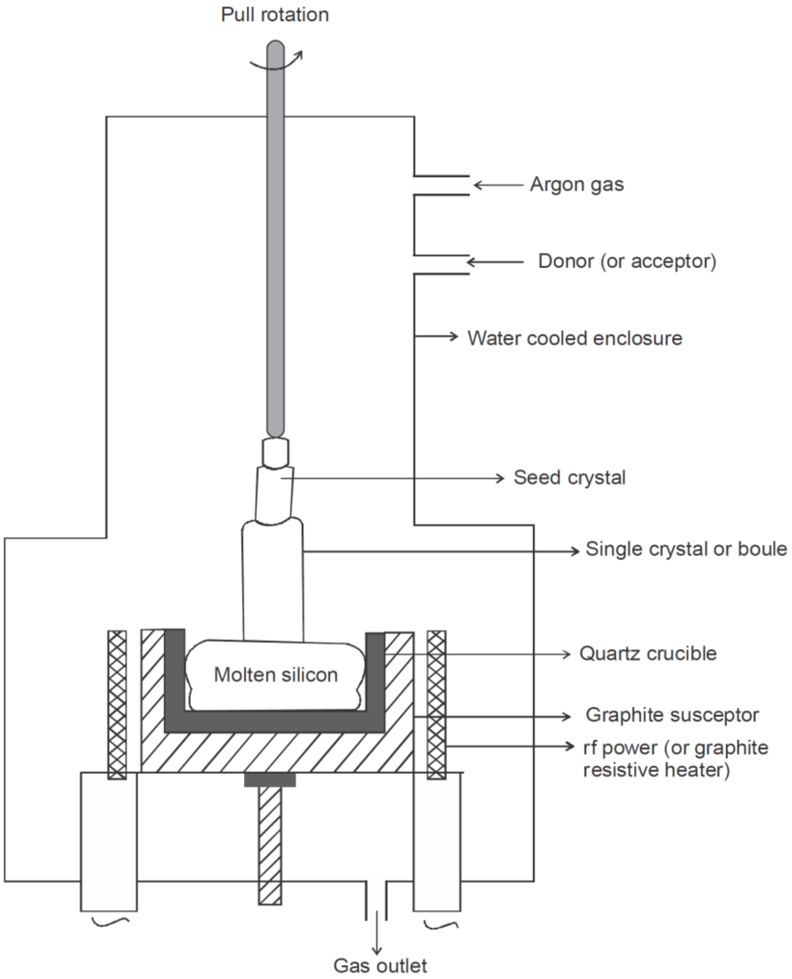


Fig.12 Schematic representation of Czochralski technique for Si crystal growth

In this method solid polycrystalline semiconducting material silicon is taken in a fused quartz crucible (wall contains Pt/Ir/Graphite) placed in an evacuated chamber. The furnace chamber is filled with an inert argon gas and heated to around 1500 ^{0}C just above the melting point of silicon which is 1412 ^{0}C. When the silicon is fully melted, a small seed crystal mounted on the end of a rotating shaft is slowly lowered until it just dips below the surface of the molten silicon. The shaft rotates counterclockwise and the crucible rotates clockwise. The rotating rod is then drawn upwards very slowly, allowing a roughly cylindrical boule to be formed. The melt in contact with the seed crystal starts solidifying and produce the orientation identical to that of the seed crystal. After this the pull rate is fixed at about 1.5 to 5 cm/min and the rotation speed is maintained at 100rpm. The boule can be from one to two metres, depending on the amount of silicon in the crucible. Finally large single crystals of about 15cm diameter and 10 cm length is grown which is tested for its conductivity and is cut into wafers.

DOPING OF SEMICONDUCTOR BY ION IMPLANTATIONS

In the ion implantation method, charged dopants (ions) are accelerated in an electric field and irradiated onto the wafers. The penetration depth can be set very precisely by reducing or increasing the voltage needed to accelerate the ions. Since the process takes place at room temperature, previously added dopants cannot diffuse out. Regions that should not be doped, can be covered with a masking photoresist layer. This technique is now commonly employed for implanting As, P and B to a depth of 0.5,1 and μm at 1000KV in silicon.

Process

An ion implanter consists of the following components:

1) **Ion source:** The dopants in the gaseous state (e.g. boron trifluoride BF_3) are ionized.
2) **Accelerator:** The ions are accelerated with approximately 30 keV out of the ion source.
3) **Mass separator:** The charged particles are deflected by a magnetic field by 90^o C. Too light/heavy particles are deflected more/less than the desired ions and trapped with screens behind the separator.
4) **Lenses:** Lenses are distributed inside the entire system to focus the ion beam.
5) **Deflectors:** The ions are deflected with electrical fields to irradiate the desired location.
6) **Wafer station:** The wafers are placed on a large rotating wheels and held into the ion beam

Method

The ion source has a heated filament which breaks the dopant gas such as BF3 or ASH3 into charged ions (B^+ or As^+). The ions then pass through a mass separator to eliminate unwanted ionic species. The selected ions then enter the accelerator and gets accelerated to high energies by an electric field, deflected and gets implanted into the semiconductor substrate. The average depth of implantation can be controlled by adjusting the acceleration energy. The dopant dose concentration can be controlled by monitoring the ion current during implantation. Typical ion energies used are between 30-300KeV and typical ion doses vary from 10^{11} to 10^{16} ions/cm. The dose is usually expressed as the number of ions implanted into 1cm^2 area of the semiconductor surface.

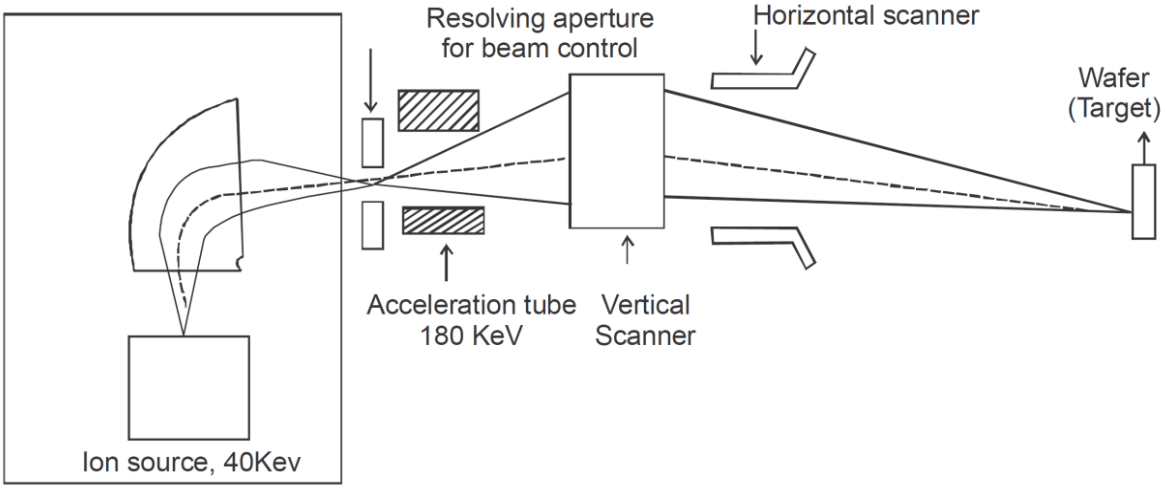


Fig.13 Schematic representation for Ion implantation

Advantages:

a. The reproducibility of ion implantation is very high.
b. Nearly every element can be implanted with highest purity.
c. Independent control of impurity depth and dose
d. Complex profiles can be achieved by multi-energy implants.

Disadvantages:

a) Very deep and very shallow profiles are difficult
b) Semiconductor lattice can be damaged due to ion collisions during ion implantation.
c) Hence a subsequent annealing treatment is needed to remove these damages. Not all the damage can be corrected by annealing.
d) Three-dimensional structures cannot be doped by ion implantation
e) Often uses extremely toxic gas sources such as arsine (AsH_3) and phosphine (PH_3).
f) Ion implanters are very expensive, the costs per wafer is relatively high.

Part-A Questions:

1] What is thin film?

Ans:

A thin film is a layer of material ranging from fractions of a nanometer to several micrometers in thickness.

2] What is PVD?

Ans: Physical Vapor Deposition is a collective set of processes used to deposit thin layers of material, typically in the range of few nanometers to several micrometers.

3] Difine – Sputtering?

Ans:

When a solid surface is bombarded with energetic particles such as accelerated ions, surface atoms of the solid are scattered backward due to collisions between the surface atoms and the energetic particles. This phenomenon is called sputtering.

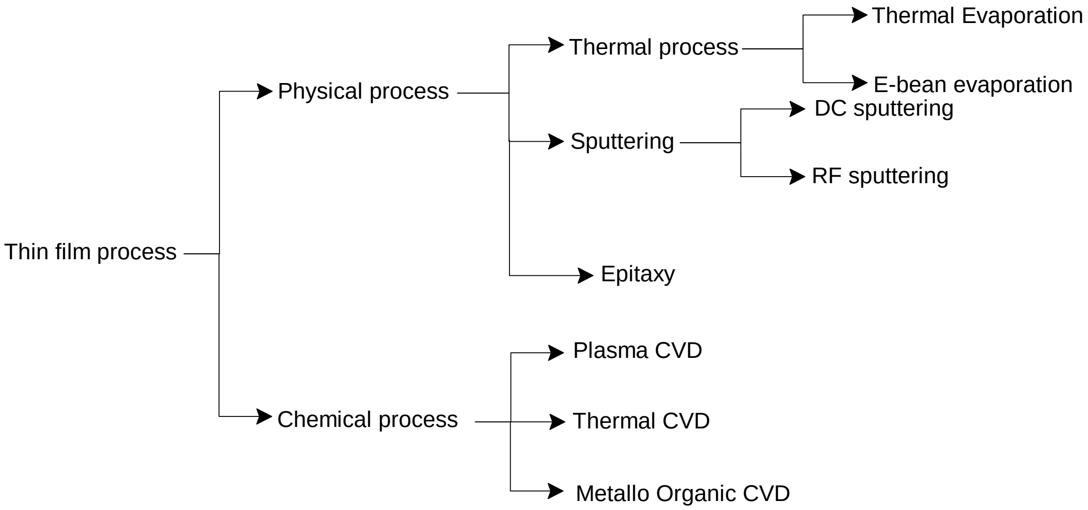
4] What is Photoresist?

Ans:

A photoresist is a light-sensitive material used in several industrial processes, such as photolithography and photoengraving, to form a patterned coating on a surface.

5] Classification of Thinfilm deposition techniques?

Ans:



6] The difference between evaporation and sputtering?

Ans:

Evaporation	Sputtering
Low energy atoms	Higher energy atoms
High vacuum path Few collisions Line of sight deposition Little gas in film	Low vacuum, plasma path Many collisions Less line of sight deposition Gas in film
Larger grain size	Smaller grain size
Fewer grain orientation	Many grain orientations
Poorer adhesion	Better adhesion

7] The difference between CVD and ALD.

Ans:

Parameter	CVD	ALD
Growth mode	Continuous	Step wise – layer by layer
Growth rate	Variable	Growth per step is accurately defined
Thickness control	Rate x Time	Dialed in with a selected number of steps
Growth initiation	Nucleation, grain growth	Continuous film
Precursor	Less reactive and must decompose at temperature	Highly reactive and can decompose at temperature

8] Write an advantages of Epitaxy method?

- High purity
- Low defect density
- Abrupt interfaces
- Controlled doping profiles
- High repeatability and uniformity
- Safe, efficient operation

9] What is etching?

Ans: Etching is traditional process of using strong acid to remove or cut into the unprotected parts of substrate surface to create a design.

10] Difine lithography?

It is the process of printing from a plane surface on which image to be printed is ink-receptive and the blank area ink-repellent.

(Or)

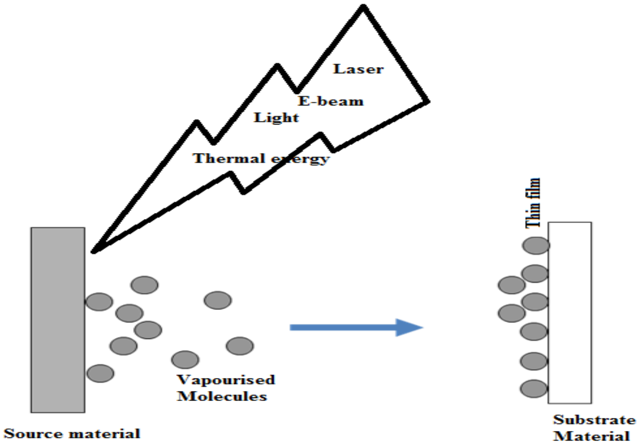
It is the process of producing patterns on semiconductors crystals for use as integrated circuits.

11] Write applications of Lithography?

- Commercial microelectromechanical system (MEMS) devices and photolithographic stamps
- Electronic gadgets to health care and medical devices: Microneedles for transdermal drug delivery, artificial retina microchip, and microfluidic devices
- MEMS accelerometers employed in automobiles and consumer electronic devices : MEMS accelerometers are employed for crash-airbag deployment in automobiles and for motion detection in consumer electronic devices such as game controllers (e.g., Nintendo Wii), iPhone and other smartphones.
- Digital micromirror devices (DMD) for display applications in projectors and televisions
- MEMS pressure sensors for detecting pressures in car tires and blood vessels.

12] Write an schematic representation of Thinfilm deposition?

Ans:



13] Types of CVD.

S.No.	Name of the CVD	Source of thermal energy
1	Thermal activated CVD	IR radiation, RF heating
2	Photo assisted CVD	Arc Lamps, CO2 laser, Nd:YAG laser, Argon ion laser
3	Plasma assisted CVD	RF diode, Microwave
4	Metallo-organic CVD	It uses organometallic as precursors

14] Types of epitaxies.

1] Vapour Phase Epitaxy 2] Liquid Phase Epitaxy 3] Molecular Beam Epitaxy

15] Write types of sputtering techniques.

1] DC Sputtering   2] RF Sputtering

16] Requirements for precursor in ALD.

Ans**:**

- Must be volatile and thermally stable
- Preferably liquids and gases
- Should Chemisorb onto the surface or rapidly react with surface and react aggressively with each other
- Short saturation time, good deposition rate, no gas phase reactions
- Should not self-decompose and should not etch, dissolute into film or substrate

17] Write the factors affecting thinfilm growth in evaporation technique?

Ans: The thin film thickness will be depending on mass, density of the source ions and the distance between source and target

$$f = \frac{m}{4d\pi h^2}$$

f = film thickness
m = mass of the source ions
d = density of the source ions
h = The distance between source and target

18] Difference between RF and DC sputtering.

Ans:

DC sputtering	RF sputtering
DC power is used	AC power is used
Applicable for Metals or Conductors	Applicable for both Conductor and Insulators
It is Cheap	It is expensive

Part-B Questions:

1] Explain the sequential steps involved in Photolithography.
2] Explain the mechanism of Atomic Layer Deposition
3] What is CVD. Explain the mechanism involved in Thermal CVD.
4] Write an essay on Czochralski technique for Si crystal growth with neat diagram
5] Write a short notes on Sputtering and Evaporation.
6] Write an essay on various Epitaxy methods.
7] Write an short note on Ion implantation method.