frequency which results in short circuit of the device, high current flows, & in the device fault, making less current flow in load.

Post Implantation Annealing Summary -

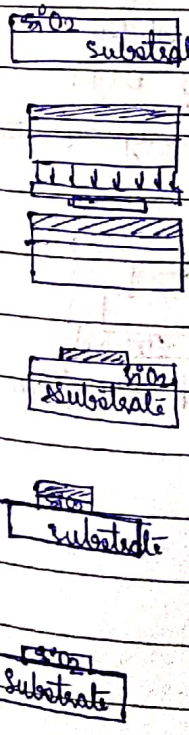
- After implantation, we need an annealing step.
  (1) Restore Si crystallinity
  (2) Place dopants into Si substitutional sites for electrical activation.

The lithographic process -

Design ⇒ Mask ⇒ Wafer.

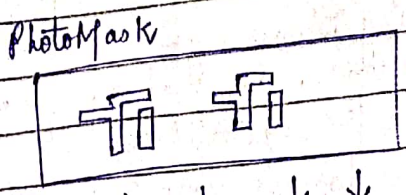
Photolithographic process -

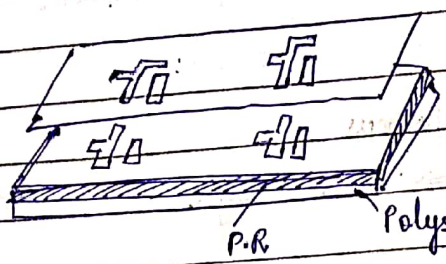
(a) Substrate covered with silicon dioxide Barrier layer
(b) Thin photoresist applied to wafer surface
(c) Mask in close proximity to surface
(d) Substrate following resist exposure and development
(e) Substrate after etching of oxide layer
(f) Oxide barrier on surface after resist Removal
(g) View of substrate with Silicon dioxide pattern on the surface



* Photomasks - CAD layout

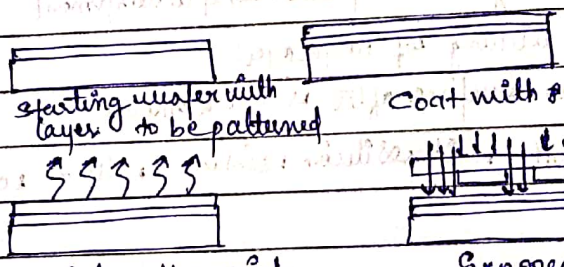
Page :
Date : / /

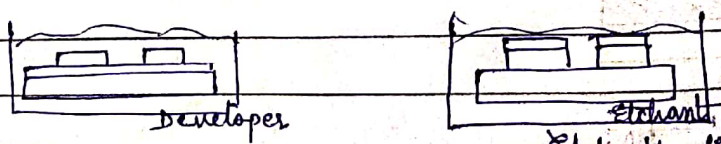




further, we remove PR, mask transferred onto substrate.

Lithographic Process. (Disadvantage - Diffraction)





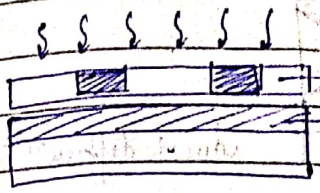
(5) Immerse exposed wafer in developer

Etch the film

Essential steps
- Dehydration Bake
- Adhesion promoter application
- Resist application
- Softbake
- Exposure
- Post exp. Bake
- Develop cycle
- Hardbake → resist stabilisation.

Page :
Date : / /

Contact Printing

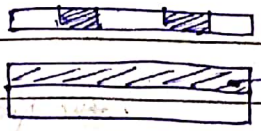


Both are very close to each other

Resolⁿ. R < 0.5 μm

mask plate is easily damaged or accumulates defects

Proximity Printing

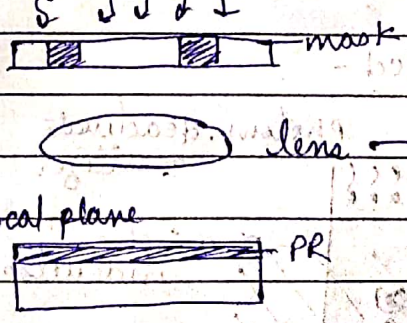


$R \propto \sqrt{\lambda g}$ (g = gap, λ = wavelength of light)

~ 1 μm for visible photons

much smaller for X-Ray lithography

Projecⁿ Printing



lens → through this focus light so that we can have many types of magnification

But expensive

~ 0.2 μm Resolⁿ (deep UV photons)

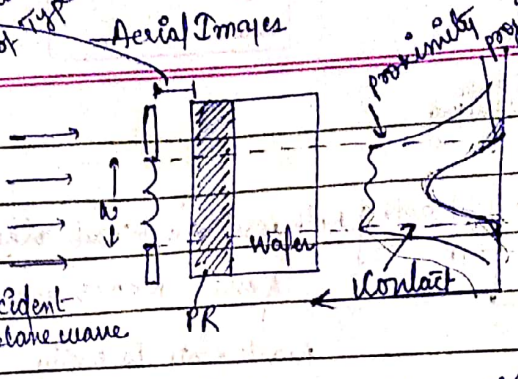
trade off : optics complicated and expensive

Ex - Magnificatⁿ ex : 10x stepper
4x
1x

Page :
Date : / /

Separat^{n} Depends of Type of system

Aerial Images



due to diffrac^{n}, it may distort our pattern

Resists for Lithography.

Exposure Sources
- Light
- Electron Beam
- Xray sensitive

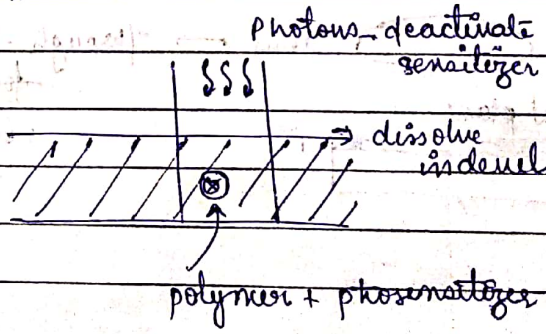
Resists
+ve &
-ve

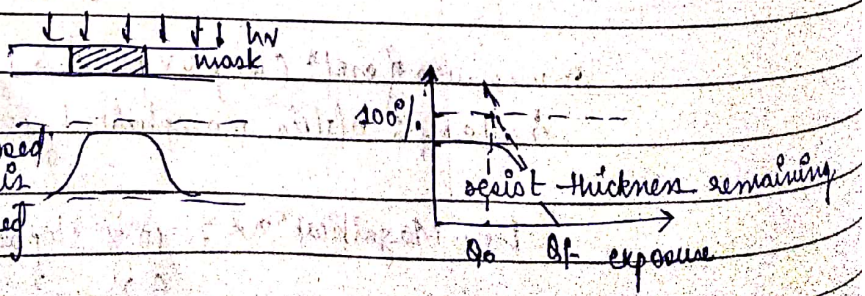
Two Resist Types

-ve Resist
- Composit^{n}
  - Polymer (MW ~ 65000)
  - Volatile solvents
- Light breaks N-N in light sensitive additive
- Sensitive, hard, swelling during Develop

+ve Resist
- Comp^{n}
  - Polymer (~5000)
  - photoactive Diss^{n} inhibitor. (20%)
  - Volatile solvents
- Inhibitor loses N_2
  ⇒ Alkali soluble Acid
- Develops by "etching"
- No swelling

Positive PR Mech -

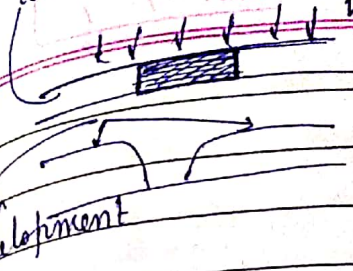


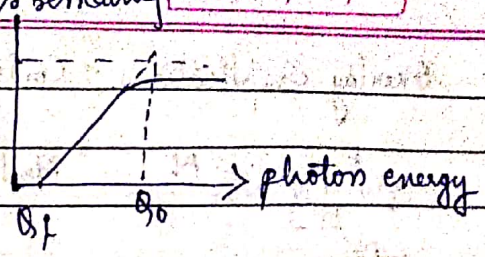


Resist contrast

$$\frac{1}{\log_{10}(D_f/D_o)}$$

due to incidence of light ∴ there is crosslinking which prevents from dissolution.



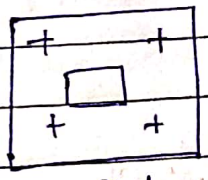


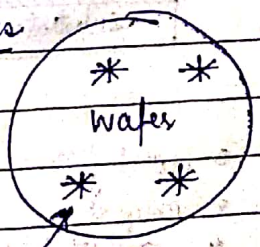
$h\nu \Rightarrow$ cross linking $\Rightarrow$ insoluble in developer soln

+ve PR
- higher Resoln
x - requires aqueous-based solvents
x - less sensitive

-ve PR
- more sensitive $\Rightarrow$ higher exposure throughout
- less expensive
x - lower Resoln
x - requires organic-based solvents
- relatively tolerant of developing conditions
- Better chemical Resistance $\Rightarrow$ better Mask Material.

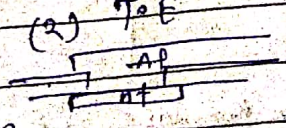
Overlay Errors



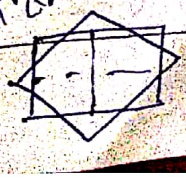


Alignment marks are not properly placed; (cross cross match nhi kiya) toh error.

Rotational/Translational Errors.

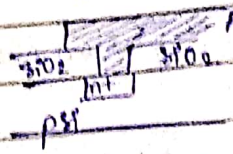


(3) R.E.

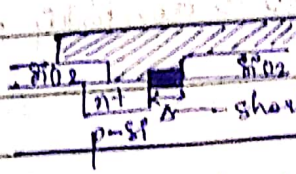


Page :
Date : / /

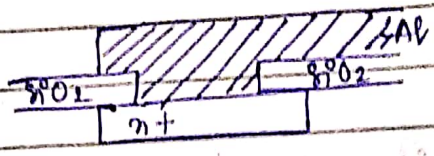
Overlay Implications : Contacts



Alignment errors



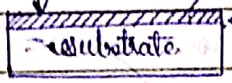
So/n : Design n+ region larger than contact hole.



Thin-film deposition –

Physical Methods – Evaporation & sputtering

Chemical vapour deposition (CVD)
Atomic Layer Deposition (ALD)

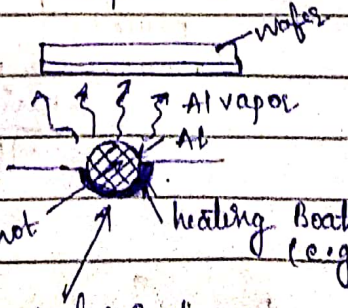


App^n –

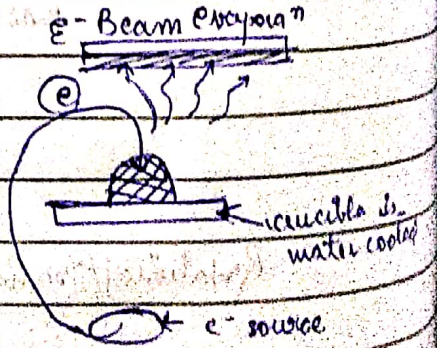
- Metalizn
- poly Si
- dielectric layers, surface passivatn

Evaporat^n :–

Thermal Evaporat^n



e- Beam Evaporat^n

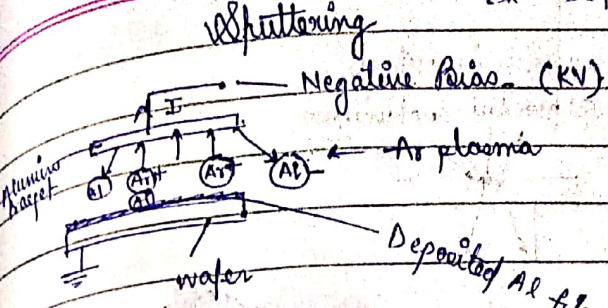


Gas Pressure $\leq 10^{-5}$ Torr.

Page :
Date : / /

Ex — DC plasma

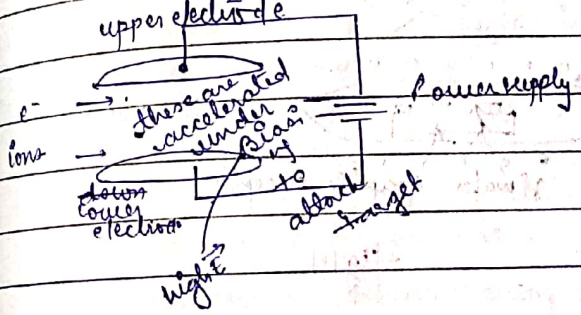
Sputtering



Gas pressure ≈ 1-10 m Torr.

Deposit^{n} Rate = constant · I · S — sputtering yield
↓
ion current

Plasma — is a low pressure gas where a high energy field is used to ionize ionizat^{n} creating a large no. of ions & free e^{-}



Basic prop of plasma

(1) Bulk of plasma contains — conc of ions & e^{-}

(2) Plasma used in IC processing — weak plasma; containing mostly neutral atoms/molecules.
degree of ionizat^{n} ≈ 10^{-3} to 10^{-6}

(3) Electric potential developed is not over the plasma instead at the ends ≈ constant inside bulk of plasma.

→ Requirements for desirable traits for depos^{n} ←
(qualities of deposited films)

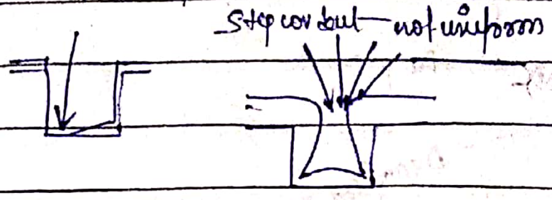
Good step coverage (conformal coverage)
Good filling of spaces
planarized films.

Uniform thickness of wafer & wafer to wafer.
Desired composit^{n}
low contaminates;
good electrical and mechanical properties.

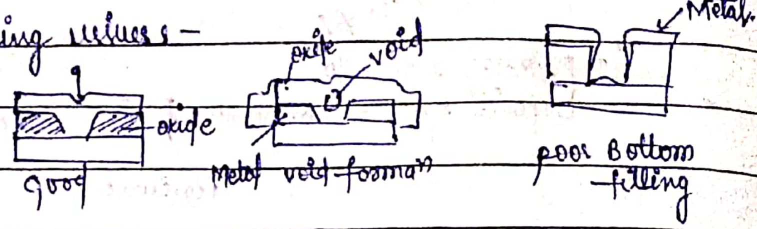
(Depositn ho per yeh problem nahi connections me problem)

Step coverage issues :-

Step coverage concerns in contacts



Filling issues :-



Two main types of deposition methods - -

CVD
PVD

a) CVD —

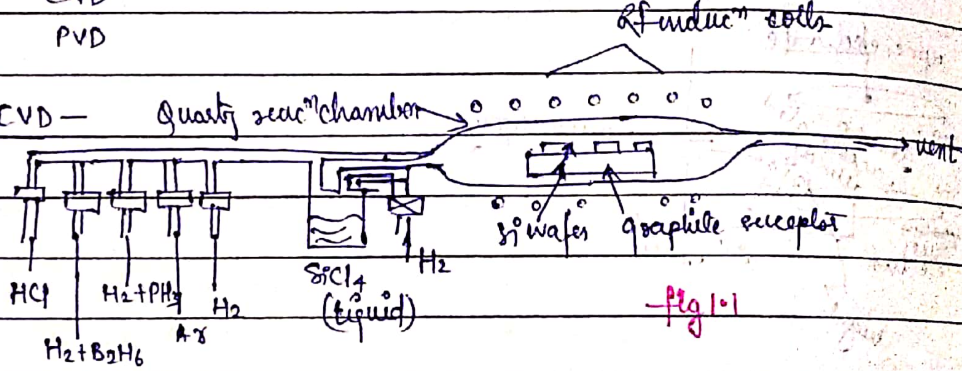


fig 1.1

b)

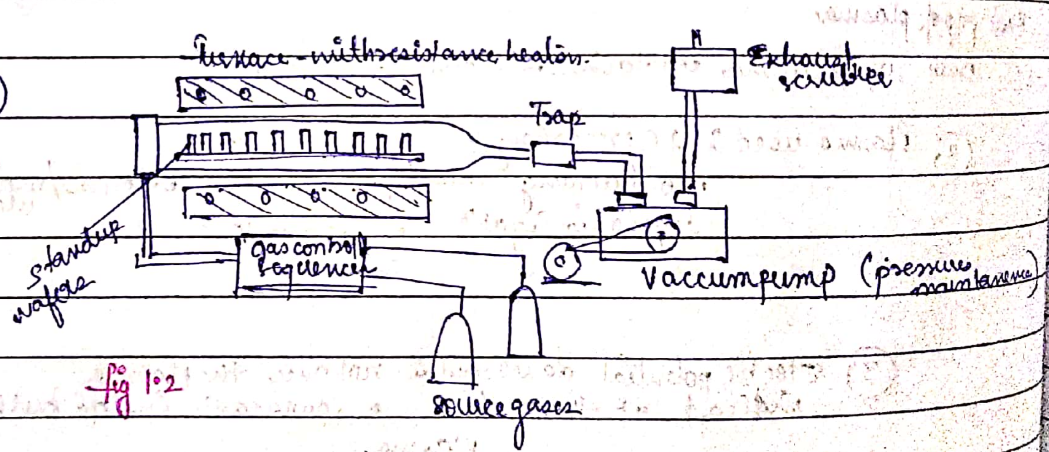


fig 1.2

Example — Depositn of epitaxial (single crystal) silicon in cold walled, atm pressure

$$SiCl_4(g) + 2H_2(g) \rightleftharpoons Si(s) + 4HCl(g)$$ — epitaxial

$$SiH_4(g) \rightleftharpoons Si(s) + 2H_2(g)$$

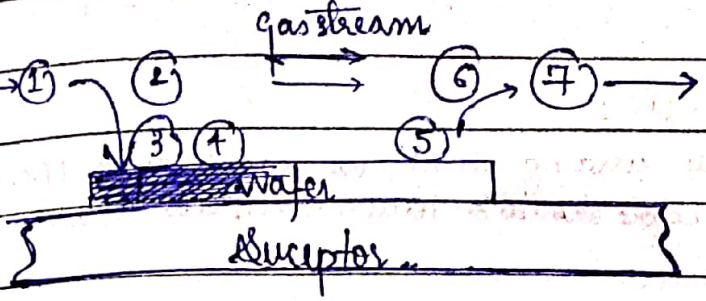
Page :
Date : / /

Present a system to deposition epitaxy?

Deposition of Amorphous silicon dioxide in hot walled, low pressure system

$$SiH_4(g) + O_2(g) \longleftrightarrow SiO_2(s) + 2H_2(g) \quad (3)$$

Mechanism -



1) Transport of Reactants - to the deposition region
2) Transport of Reactants from the main gas stream
(2) through the Boundary layer to the wafer surface.

3) Adsorp^n of Reactants on the wafer surface
4) Surface reactions, including: ~~CVD~~ chemical deposit^n reac^n, surface migrat^n to attachment sites - (kinks & ledges); site incorporat^n ; & other surface reactions (emission & re-deposition for example).

5 Desorption of by-products.
6 Transport of by-products ~~away from the deposition~~ through the
(4) Boundary layer.
7. Transport of By-products away from the deposition Region.

Page :
Date : / /

Atm pressure issues :

- how pressure Chemical Vapor Deposition LPCVD

If Temperature ↑, a horizontal configuration must be used (flow will be turbulent)

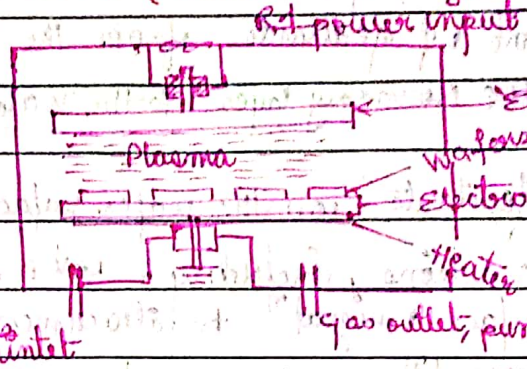
If Temperature ↓, the deposition rate goes down & throughput is again low

Therefore we go for LPCVD,

Fig 1.2 By having this arrangement; we can reduce the pressure inside the tube (pressure should be lower than atmospheric pressure)

PECVD (Plasma Enhanced CVD)

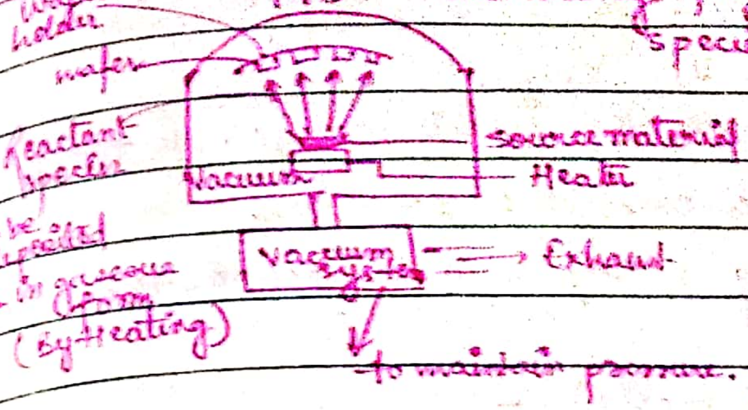
plasma's advantage in CVD is it provides non-thermal energy



(agar mujhko lower temp per CVD karna hai)

- Non-thermal energy to enhance processes at lower temperatures
- plasma consists of e^-, ionised molecules, neutral molecules, neutral and ionised fragments of broken-up molecules, excited molecules and free radicals.
- free radicals are electrically neutral species that have incomplete bonding and are extremely reactive. (e.g. SiO, SiH_3, F)
- The net result from the fragn, the free radicals, & the ion bombardment is that the surface process and deposit occur at much lower temp than in non-plasma system.

PVD — uses mainly physical processes to produce reactant species in the gas phase & to deposit films.



high pressure not used why? Because atoms then come closer, becomes dense, then it hampers movement of these species, we need to provide more energy to make them move. Hence, we require lower pressure.

PVD-

- In evaporation source material is heated in high vacuum chamber. ($P < 10^{-5}$ torr).
- Mostly LOS depoⁿ since pressure is low. (if not low, then atoms present would deviate the species).
- Depositⁿ rate is determined by emitted flux and by geometry of the target.

kitne area me kitna material deposit

- The evaporatⁿ source can be considered either a point source or as a small area surface source. — more applicable to most evaporatⁿ systems.

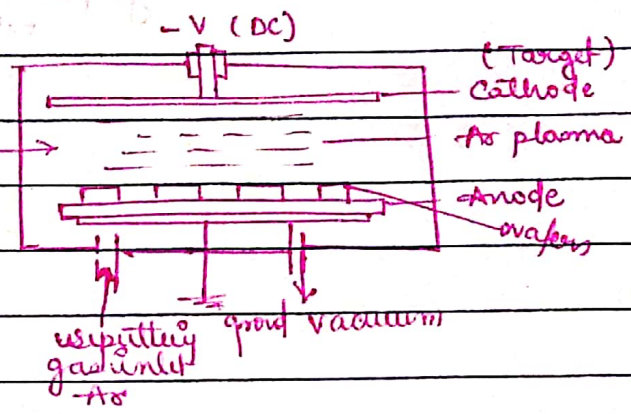
Page :
Date : / /

Sputter Deposit^n – (not all material can be evaporated)

— Uses plasma to sputter the target
dislodging atoms which then deposit on wafer to form film
— Higher pressures than evapora^n – 1 – 100 m torr.
— Better at depositing alloys and compounds than evapora^n

DC sputter Deposition –

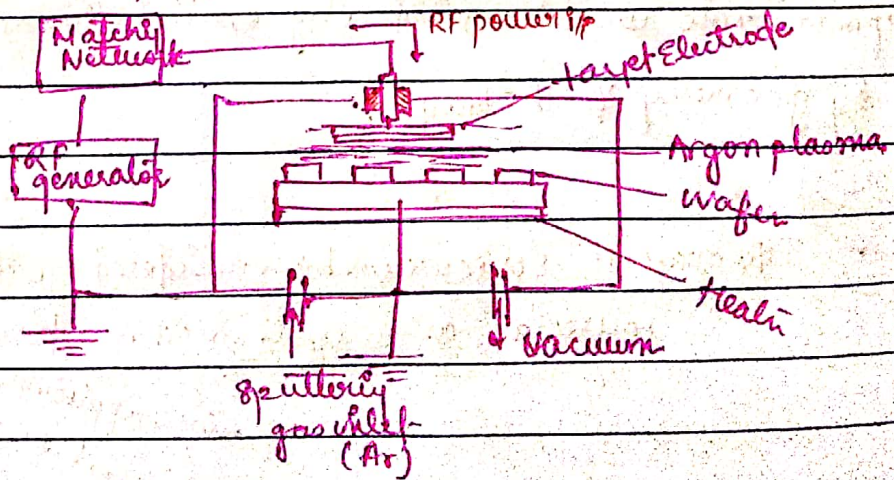
(conductive material deposit karnaho toh)



under very high E; it becomes Ar plasma & it would hit the cathode, & the target atoms get knocked out, fall onto Si wafer

(AC) RF Sputter Deposition –

(Dielectric, insulator ko deposit karna ho toh) — For DC sputtering, target electrode is conductive
To sputter dielectric Materials – use RF power source



Page :
Date : / /

Advantages of Sputtering over Evaporation –

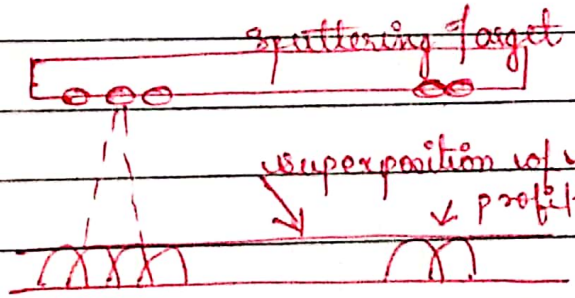
– for multi-component thin films, sputtering gives better composition control using compound targets.

– Evaporation depends on vapor pressure of various vapor components and is difficult to control.

in sputt – pressure is not so crucial parameter
But " evap" " " " "

sputtering me pressure ↑ than evap".

Sputtering Rate Better material thickness uniformity – superposition of multiple point sources.



	Equipment	Typical Reaction.
(Crystalline silicon) Epitaxial	APCVD, LPCVD	$SiH_4 \rightarrow Si + 2H_2$ $SiCl_4 + 2H_2 \rightarrow Si + 4HCl$
polysilicon	LPCVD	Same as epitaxial Si
Si_2N_4	LPCVD / PECVD	$3SiH_4 + NH_4 \rightarrow Si_3N_4 + 12H_2$
SiO_2	LPCVD, PECVD, HDPCVD	$SiH_4 + O_2 \rightarrow SiO_2 + 2H_2$ $Si(OC_2H_5)_4 + (+O_2) \rightarrow SiO_2 + Byproducts.$

Al – Magnetron sputter deposition