0D Quantum dots — 1-D Nanowires, Nanorods, Nanotubes — 2-D Nanostructured thin film — 3-D Nano particle powder

properties

→ Incresed surface to volume ratio
→ high percentage of atoms/molecules at the surfaces
→ Dominent surface forces
→ plasmonic resonence effects
→ confined energy states [quantum confienment]
→ Drastic physical chemical Biological changes
→ size shape composition
→ Lowered phase transition temp.
→ Incresed mechanical strength
→ different optical effects
→ Altered electric conductivity
→ change megnetic properties
→ Eeffective surface chemical reaction
→

ques daimeter = 100 nm volume = ? surface area = ?

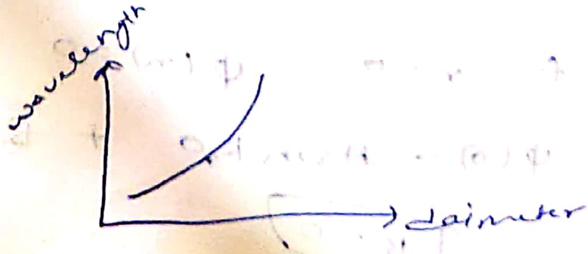
$V = \frac{4}{3}\pi r^3$ $SA = 4\pi r^2$

$V = \frac{4}{3} \times 3.14 \times$ (50) 125000×10^{-27} = 5.24×10^{-22} m^3

$SA = 3.14 \times 10^{-14}$ m^2 $\frac{SA}{V} = 6 \times 10^7$

Daimeter = 100 m
→ $\frac{SA}{V}$ = 0.06

$E = \frac{hc}{\lambda}$
→ for nanoparticle energy increase



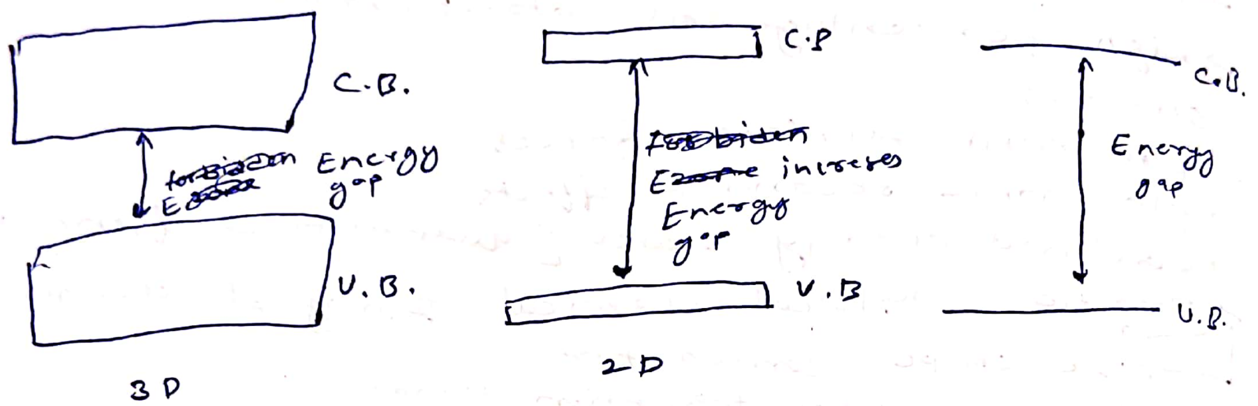
Energy levels and quantum confinement effects in nanostructure

3D → 0D

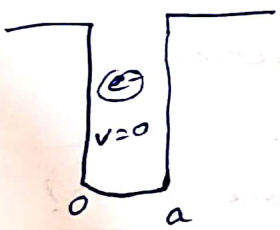
$D_f + D_c = 3$

Degree of freedom — Degree of confinement

	D_f	D_c
3D	3	0
2D	2	1
1D	1	2
0D	0	3



Energy levels and quantum confinement effect in nanostructure :→



$$\frac{\partial^2 \varphi}{\partial x^2} + \frac{2m}{\hbar^2}(E - V)\varphi(x) = 0$$

Inside the 1-D well ⇒ $V = 0$

$$\frac{\partial^2 \varphi}{\partial x^2} + \underbrace{\frac{2mE}{\hbar^2}}_{k^2}\varphi(x) = 0$$

$$k^2 = \frac{2mE}{\hbar^2}$$

$$k = \sqrt{\frac{2mE}{\hbar}}$$

$$E = \frac{k^2\hbar^2}{2m}$$

sol^n = $\varphi(x) = A \sin kx + B \cos kx$

If $x = 0$ $\varphi(x) = 0$

$\varphi(0) = A \sin k_x 0 + B \cos k_x 0$

$\boxed{B = 0}$

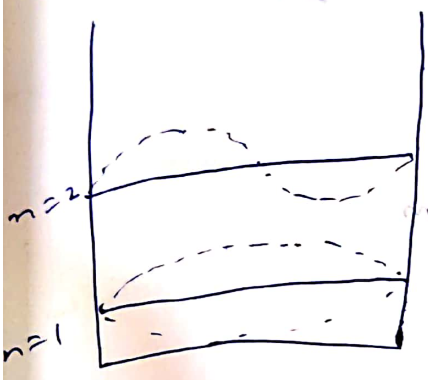
$\psi(x) = A \sin kx$

If $\psi(x=a) = 0$ for $x=a$

$\psi(a) = A \sin ka$

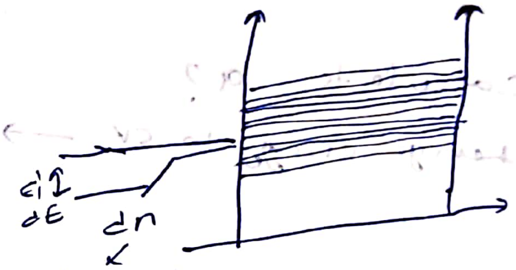
$0 = A \sin ka \Rightarrow A \neq 0 \Rightarrow ka = n\pi \Rightarrow k = \frac{n\pi}{a}$

$E = \frac{n^2 \pi^2 \hbar^2}{2ma^2}$ → Energy of a electron in 1-D well



$E_2 = \frac{4\pi^2 \hbar^2}{2ma^2}$

$E_1 = \frac{\pi^2 \hbar^2}{2ma^2}$



no of ~~stats~~ allowed energy state given the steady / Reference

$g(E) = \frac{dn}{dE}$

$dE = \frac{\cancel{2} n\, dn\, \pi^2 \hbar^2}{\cancel{2} m a^2}$

$\frac{dE}{dn} = \frac{n \pi^2 \hbar^2}{ma^2}$

$g(E) = \frac{dn}{dE} = \frac{ma^2}{n\pi^2 \hbar^2}$

$k^2 = \frac{n^2 \pi^2}{a^2}$

$E = \frac{n^2 \pi^2 \hbar^2}{2ma^2}$

$n^2 = \frac{2ma^2 E}{\pi^2 \hbar^2}$

$n = \frac{a}{\hbar\pi} \sqrt{2mE}$

$\frac{dn}{dE} = \frac{ma^2}{\pi^2 \hbar^2} \frac{\pi\hbar}{a\sqrt{2mE}}$

$g(E) = \frac{dn}{dE} = \frac{a}{\pi\hbar}\sqrt{\frac{m}{2E}}$

$g(E) \propto E^{-1/2}$

Ques. Kinetic Energy = 1eV Calculate wavelength
assume non relativistic case

sol $KE = \frac{\cancel{m}^2 v^2}{2m}$ $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

$$\lambda = \frac{6.64 \times 10^{-34}}{\sqrt{2 \times 9 \times 10^{-31} \times 1.6 \times 10^{-19}}}$$

$$\frac{6.64 \times 10^{-34}}{10^{-25} \times 5.3} = 1.24 \times 10^{-9} = 1.24 \text{ nm}$$

calculate a?

change energy to 5V $\longrightarrow$ $\lambda = 0.55$ nm

Scanned with OKEN Scanner

(#) Synthesis method

- Top Bottom approach
- Bottom-up approach
  - physical
  - chemical
  - Biological
  - Hybrid

physical
- mechanical
  - Ball milling
  - melting mixing
  - Lithography
- vapour
  - PVD physical vapour Deposition
  - Laser ablation
  - sputtering
  - Ion implantation

Chemical — collid, sol-gel,
SILAR → successive ionic layed absorption and
CBD, spray pyrolsis

Biological — micro organisms, Bacterial method, emulsion

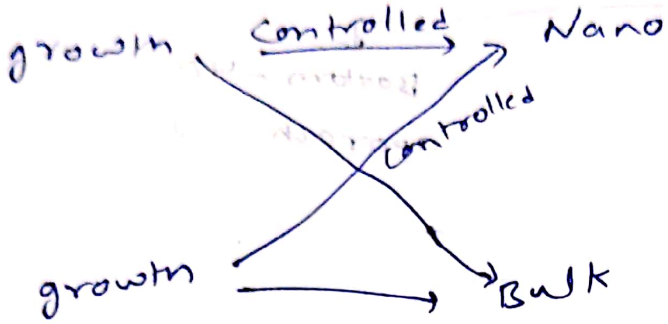
Hybrid → Electrod deposition

→ precursor, evoporation / liquid / gaseus
→ Nucleation
→ growth

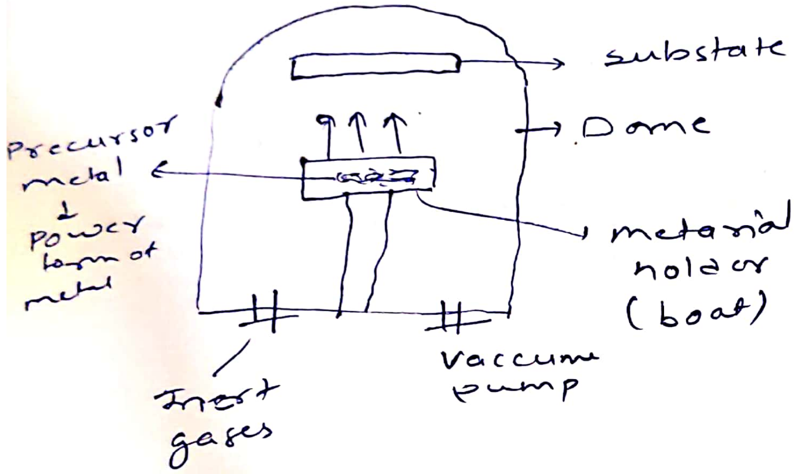
precursor $\xrightarrow{\text{evoporation}}$ gaseous form → Nucleation $\xrightarrow{\text{Intermediat}}$ gas-on solid interaction

precursor → Liquid Form → Nucleation $\xrightarrow{\text{Intermediate}}$ liquid solid Interaction $\xrightarrow{\text{realation}}$ growth

Scanned with OKEN Scanner



Thermal evaporation method:



→ get heated

> Resistive heating of holder
> Advantages very fine coting
> Disadvantages → metarial holder should have higher melting point

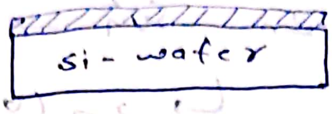
Lithography Process :→ Devicing Nanostructures

↳ transfering of geometrically patterns to develop nano structures

LGP

- Photolithography
  - 200 - 800 nm
  - visible, ultraviolete
- x-ray lithography
  - 50nm - 2,3 nm
- E-beam lithog

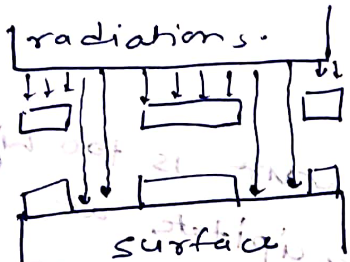
① coating the photoresist on si-wafer



→ photoresist
↓
photosensitive, polymeric material.

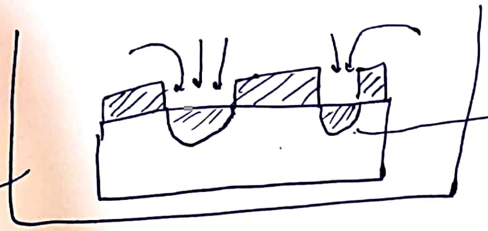
spin coter

② Exposure to radiations.



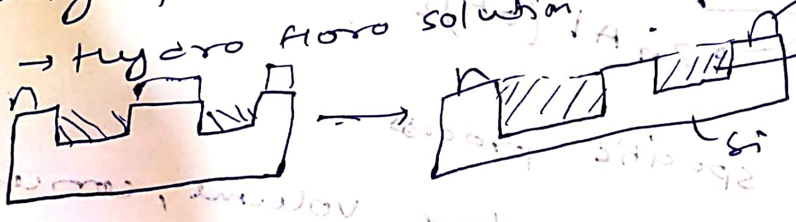
the nessasory pattern

③ use developer for developing



④ Etching process

HF → Hydro floro solution.

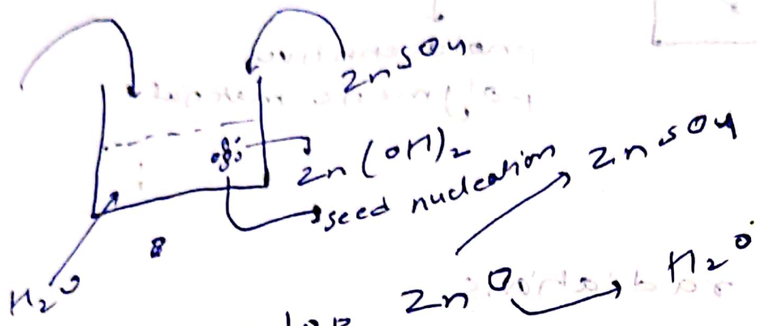


⑤ Dopinging (Ion implantation process)
swift heavy ion process : If energy is very high electron pass thru Si
Si ↳ not useful

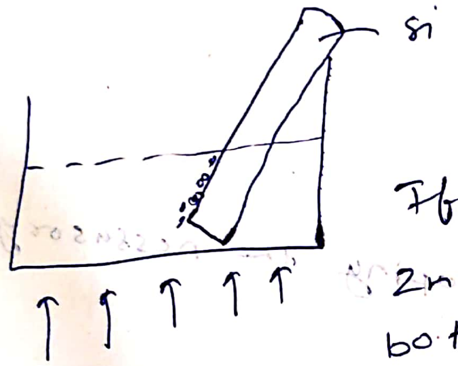
↳ By acelarator

Chemical Bath deposition
→ simplest doping process

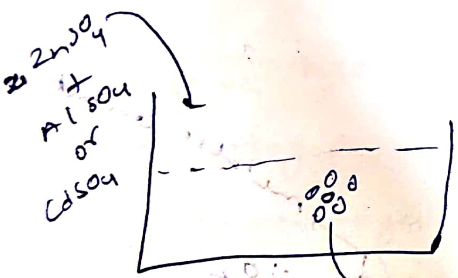
Zn^{2+} SO_4^{2-} → H^+ — OH^-
↳ $Zn(OH)_2 + H_2SO_4$



need to develop ZnO → H_2O



If temperature is too high
Zn will precipitate at
bottom because of H_2SO_4

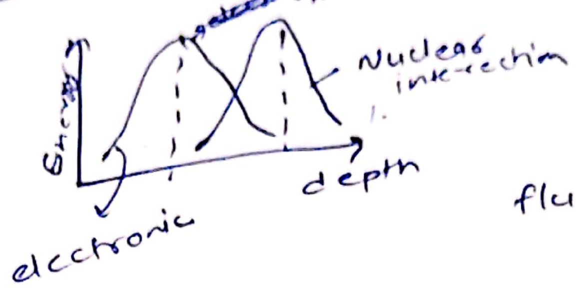


Not very specific process

<u>parameter</u>: pH, temperature, volume, concentration
, time

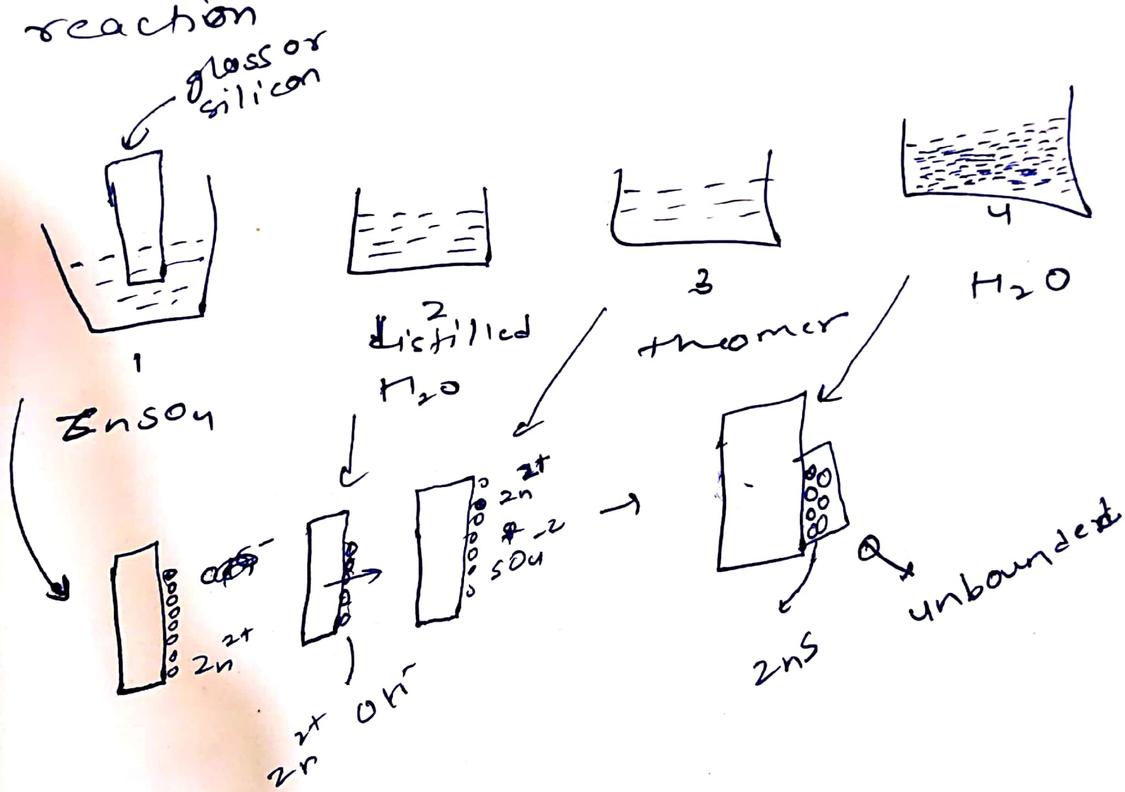
(#) Chemical and Biological synthesis of NS :-

Ion implantation :-

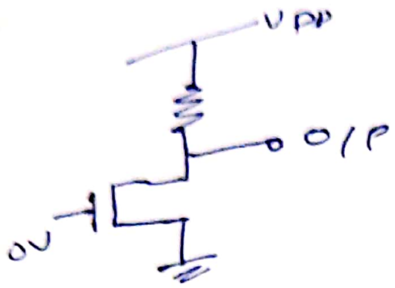


$$\text{fluience} = \frac{\text{no. of ion}}{cm^2}$$

(#) SILAR → successive ionic layer absorption and reaction

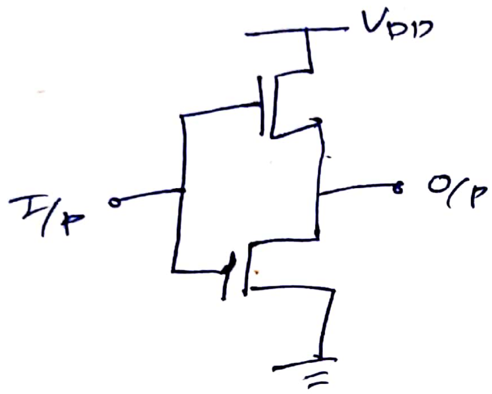


CMOS Complementry MOS



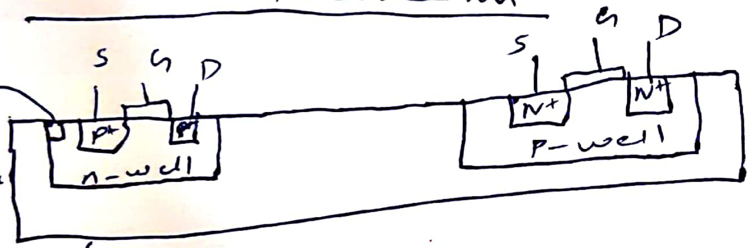
→ Resistive inverter

replace resistor so less space



⇒ CMOS

CMOS fabrication

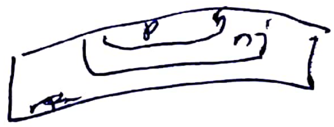


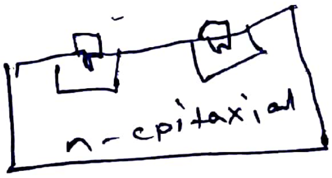
Eptaxy → intrinsic

→ diffusion resistor

→ Epitaxial resistor

→ Pinched resistor





Bi-CMOS (not in syllabus
BJT CMOS

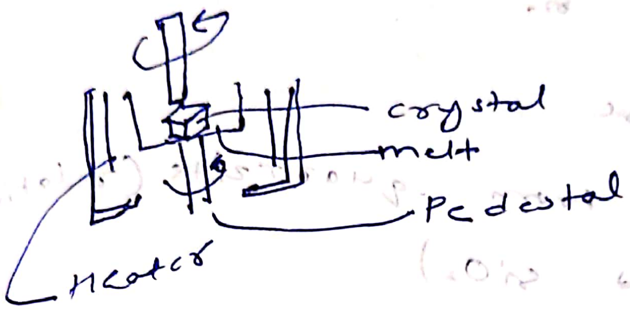
short channel effect

1) sub threshold current
2) Threshold voltage roll off
3) Drain Induced Barrier lowering (DIBL)
4) Punch Through
5) velocity saturation
6) hot electron effect

EGS to single crystal silicon

① Czochralski method.
② float zone method.
③ Bridgeman technique.

①



Diode fabrication

1) wafer preparation
2) oxidation
③ masking → photoresist pe mask
④ Lithography → Diffusion → metalisation
⑤ Etching

write the ste fabrication step of ~~most~~

N-mos

Lithography → photoresist
→ masking
→ U.V. exposure
→ Etching

Etching → SiO_2 is removel using ~~HF~~ HF (Hydro floric acid)

Epetexing → for Layer of SiO_2

Ti is used for metalication for high temp stability

Crystal growth and wafer preperation

Electronics Grade silicon

→ EGS is a polycrystalline material of high purity

→ it is a raw material for the preperation of single crystal Si.

→ It is 99.9% pure

→ EGS is obtained from quartzite (relatively pure form of sand SiO_2)

Quartzite → metallurgical Grade Si → EGS
MGS

① Quartizite → MGS
Electrode code fernece

It is performed in submerged electrode are furnace filled with quortize, cole, coke and wood chips

$$3C + 2SiO_2 = Si + SiO + CO\ (gas)$$
(solid) (Solid) (liquid) (gas)

② In next step MGS is treated with anhydrous HCl to form trichlorosilane ($SiHCl_3$)

$$Si\ (solid) + 3HCl\ (gas) = SiHCl_3 + H_2\ (gas)$$
↳ liquid at room temp

③ EGS is prepared from $SiHCl_3$ in a Chemical Vapour deposition process

$$2SiHCl_3\ (gas) + 2H_2 = 2Si\ (solid) + 6HCl\ (gas)$$

$C = 6$, $Si = 14$, $Ge = 32$, $Sn = 50$, $Pb = 82$

availability ⇒ Si is prefered ~~because~~ over ge

Si: work at ~~lower~~ 150 - 200°C temp

ge: work at 75 - 100°C temp

another reason Si forms ~~SiO2~~ oxide SiO_2 easily

(ii) environmental factor.

(iii) ~~elementaly stable~~ Si in elemental semiconductor is stable

Si : \$500 B

GaAs : \$15 B : High speed applications

SiC, GaN : \$5 B High power

LED : \$15 B

MEMS : \$15 B

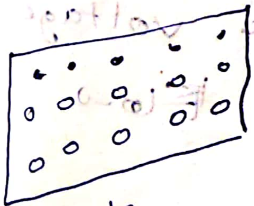
mobility (LV_2 E = ee)		Band-gap
Si (e/n)	$= 1500\ cm^2/V\text{-}s$	1.12 eV
SiC (e/n)	$\rightarrow 4000\ cm^2/V\text{-}s$	0.67 eV
GaAs (e/n)	$= 8500\ cm^2/V\text{-}s$	1.43 eV

⊕ crystal growth

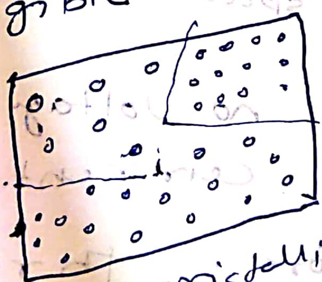
Amorphous sillicon - No crystall order

polycrystalline silicon - multiple crystal order

single crystall silicon - uniform crystal order Negligible defect



single crystal



poly cristalline

Amorphous

(#) Nanoscale device engineering

Circuit — Device

U-I Introduction to Nanoscience and nanotechnology

U-II IC fabrication & SPICE models

U-III Application of nanoscience & Nanotechnology

Ic fabrication
↓
Integrated circuits

Discrete circuits
↓
PCB → Printed circuit Board

→ SOI (small)
→ MSI (medium) (10-100)
→ LSI (Large) (1000-10^4) ↳ op-amp
→ VLSI (very large) (10^4-10^6)
→ ULSI (ultralarge)

Analogue
Digital
↓
on the basic of application

on the basis of fabrication
↓
monolythic
Hybrid

(#) IC Fabrication

why mosfET is better than BJT

(i) small size
(ii) Low power consomption
(iii) Easy fabrication
(iv) high input impedence

Drawback :- less speed

(#) Accumulation: no voltage or -ve voltage at gate so no current will flow

(#) Depletion: before threshold

(#) Inversion: After threshold