MADE EASY

ELECTRONICS ENGINEERING

Advance Electronics

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- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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IC FABRICATION

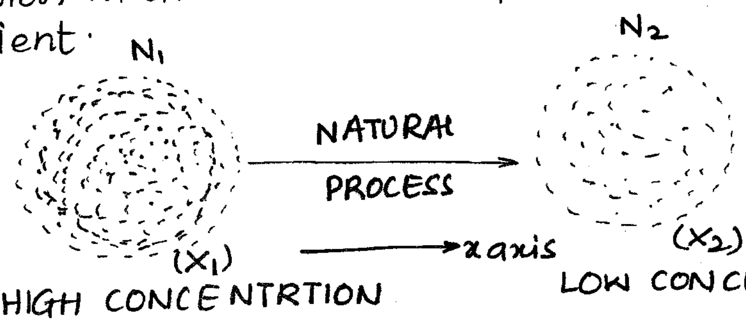
*NPTEL → Prof. Nandita Das gupta. (VLSI Fabrication).
* SK Gandhi
* oxidation, Ion Implantation diffusion → numericals.

* DOPING:

i) Diffusion.
ii) Ion Implantation.
iii) Epitaxy

i) DIFFUSION:

* Diffusion means movement of material under concentration gradient.



$N_1 > N_2$
$x_1 < x_2$

* As

$$\boxed{J = -D\frac{dn}{dx}}$$ ← FICKS 1st Law of Diffusion.

Hence -ve sign.
D = diffusion const.
J = Flux (always +ve). (we always say that flux is +ve).
$\frac{dn}{dx}$ = Concentration gradient

$$\boxed{\frac{dN}{dx} = \frac{N_2 - N_1}{x_2 - x_1}}$$ ← -ve quantity

* FICKS IInd LAW OF DIFFUSION:

* Ficks 2nd law of diffusion states that:

$$\boxed{\nabla \cdot J = -\frac{\partial \rho_v}{\partial t}}$$

$$\nabla = i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z}$$

* For one dimension we get:

$$\boxed{\frac{\partial J}{\partial x} = -\frac{\partial N}{\partial t}}$$

$$J = -D\frac{\partial N}{\partial x} \quad \text{---- (i)}$$

$$\frac{\partial J}{\partial x} = -\frac{\partial N}{\partial t} \quad \text{---- (ii)}$$

diff. eqn (i) w.r.t x we get:

$$\frac{\partial J}{\partial x} = -D\frac{\partial^2 N}{\partial x^2}$$

from eqn (ii) we get:

$$-\frac{\partial N}{\partial t} = -D\frac{\partial^2 N}{\partial x^2}$$

$$\boxed{D\frac{\partial^2 N}{\partial x^2} = \frac{\partial N}{\partial t}} \leftarrow \text{wave Equation}$$

N: concentration.
x: space.
t: time

* N is a funcn of Both space and time.

$$\boxed{N = f(x, t)}$$

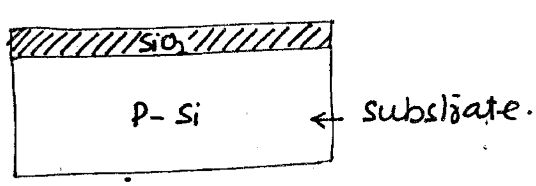
* TYPES OF DIFFUSION:

i) Predeposition / Infinite Source Diffusion.
ii) Drive in / limited source diffusion.

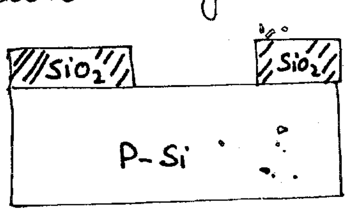
i) Predeposition / Infinite Source Diffusion:

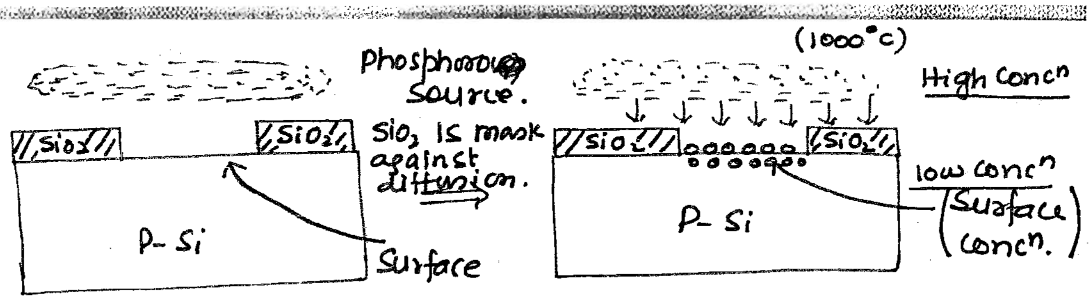
Diode Formation

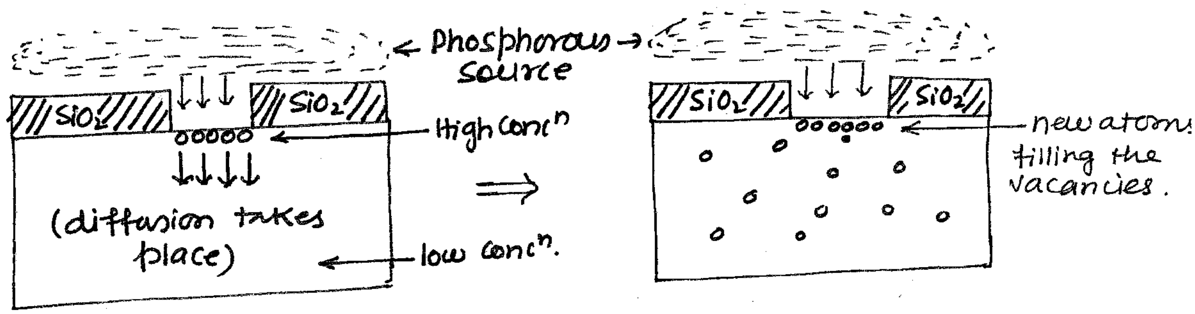
a) Take P substrate.

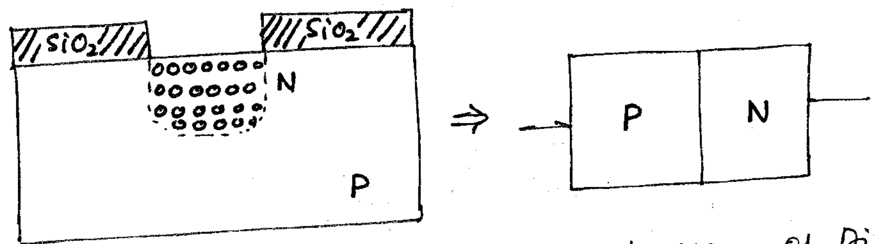


b) open a window using lithography + Etching



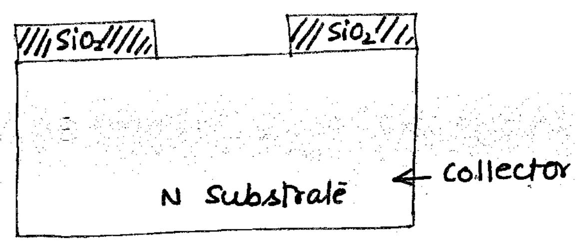
3) 

(4) 

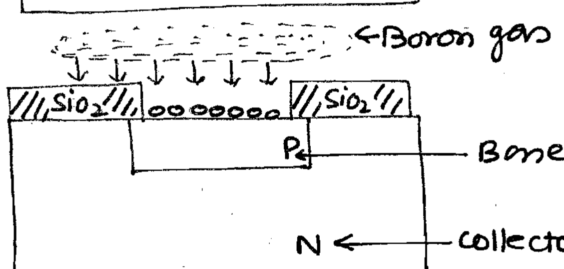
5) Finally, 

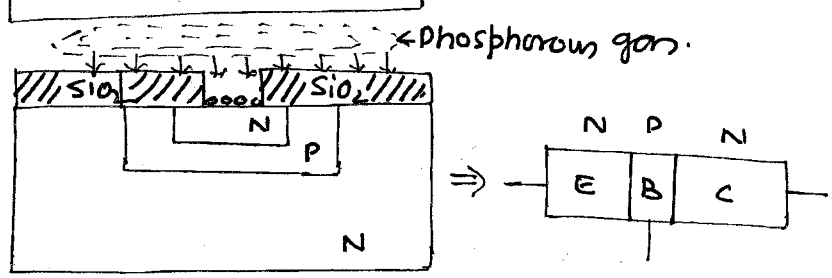
* Diffusion occurs at 1000°c and to stop the process of Diffusion decrease the temperature.

* BJT FORMATION (NPN).

1) Take N substrate 

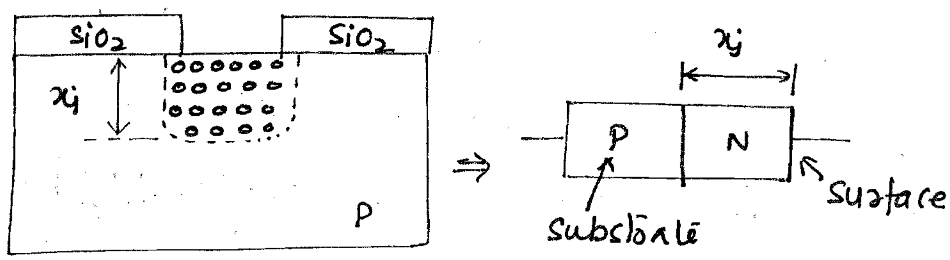
Note :.
* Contacts are also to be connected.

2) 

3) 

* Parameters of Diffusion:

- Junction Depth.
- Doping Profile.
- Surface concentration.

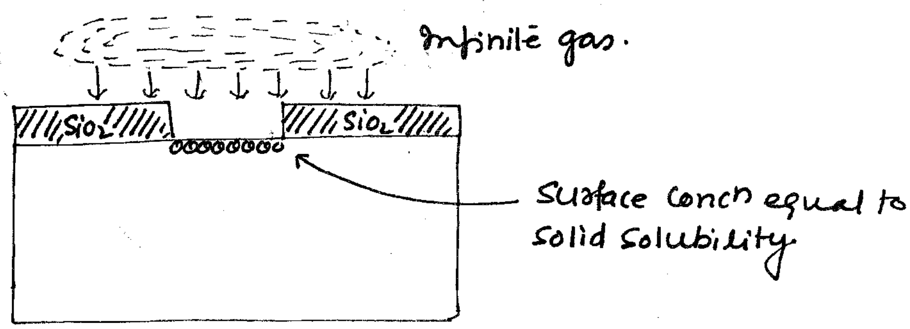


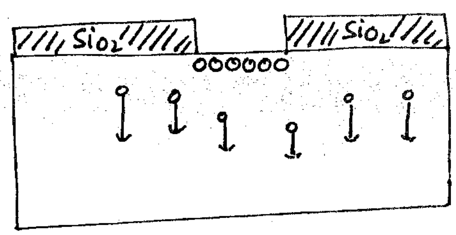
x_j: Junction Depth ie distance from surface where junction forms.

* Surface Concn in Predeposition:

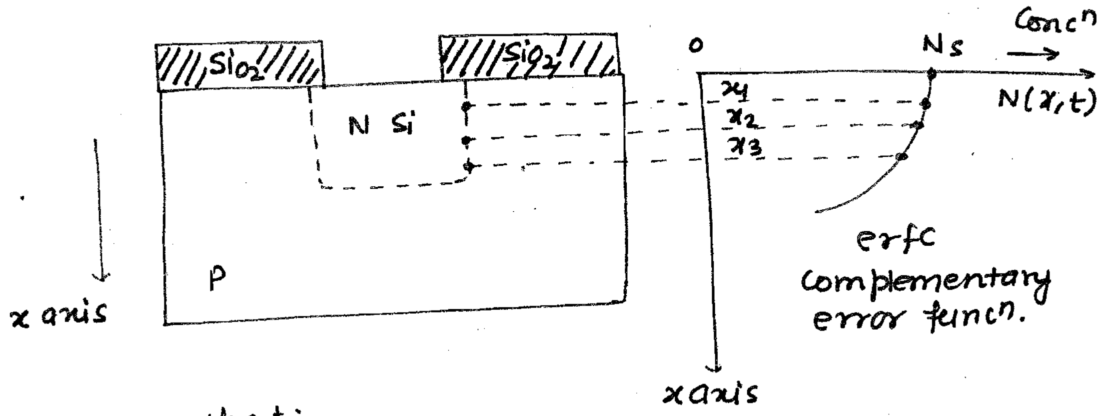
* Solubility is a funcn of Temp.

* surface concn is always constant ie the vacancies created at surface remain const.





* DOPING PROFILE:



We know that:

$$\boxed{D\frac{\partial^2 N}{\partial x^2} = \frac{\partial N}{\partial t}}$$ ← Partial differential equation.

$$\boxed{N(x,t)\Big|_{x=\infty} = 0}$$

$$\boxed{N(x,t)\Big|_{x=0} = N_s}$$ ← surface conc^n.

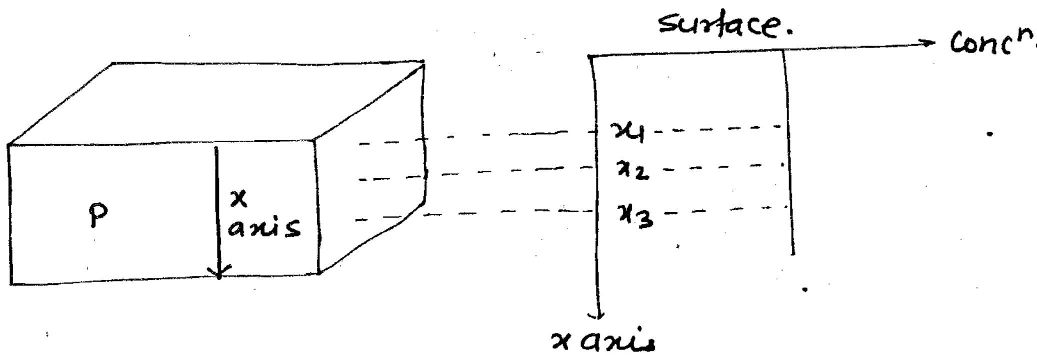
$$\boxed{N(x,t)\Big|_{t=0} = 0}$$ ← Boundary conditions

* Solution for the Partial differential equation is given as:

$$\boxed{N(x,t) = N_s\,\mathrm{erfc}\left(x/2\sqrt{Dt}\right).}$$ $\boxed{t: \text{time.}}$

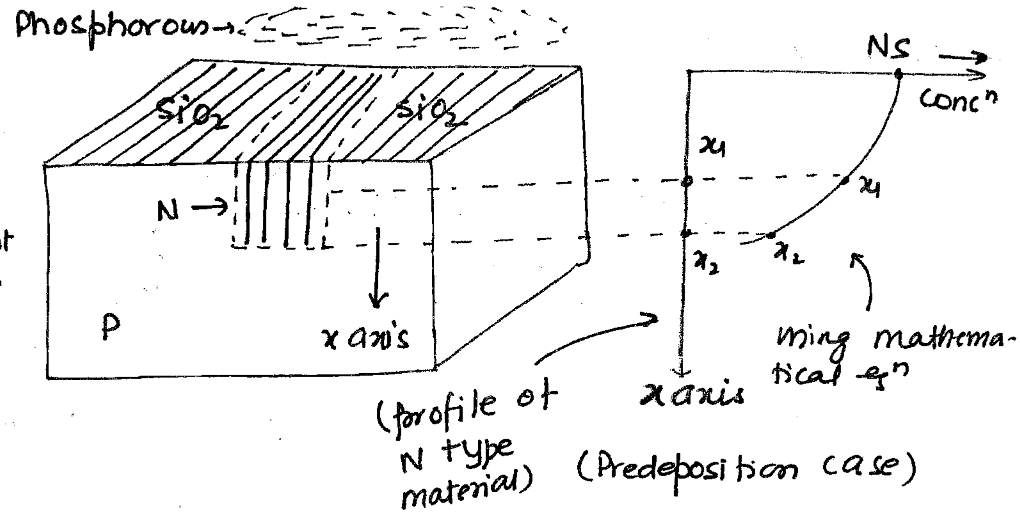
* EPITAXY is method of UNIFORM DOPING:

Note:



~~UNIF~~ UNIFORMLY DOPED SUBSTRATE.

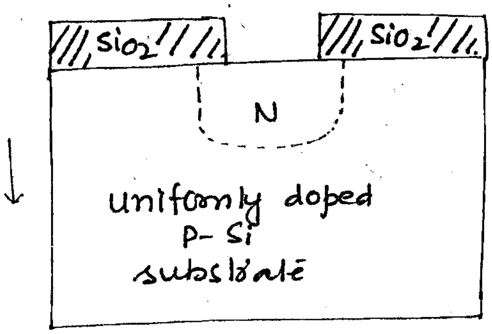
* at constant temp.
* N_s is constant at given temp.

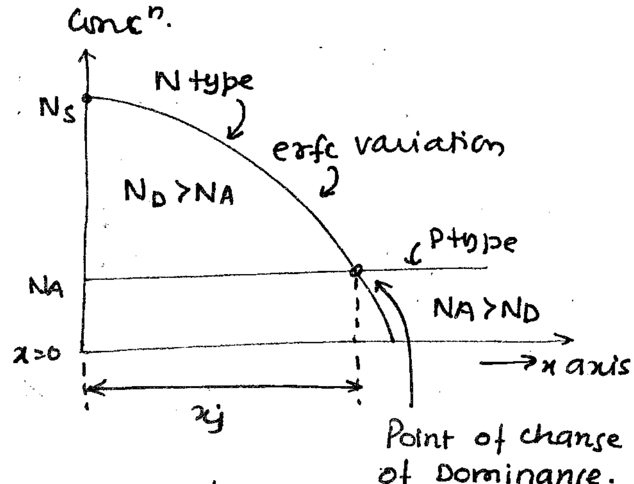


(Predeposition case)

*Junction Depth:

* Consider a uniformly doped P type substrate.
* Assume N type diffusion has been done





N_A: Acceptor conc^n
N_D: Donor conc^n.

* Junc^n forms when material changes from N type to P type and vice versa.
* At the junc^n ie $\boxed{x = x_j}$ ← Point of Intersection of curves.

$$\boxed{N_A = N(x, t)}$$

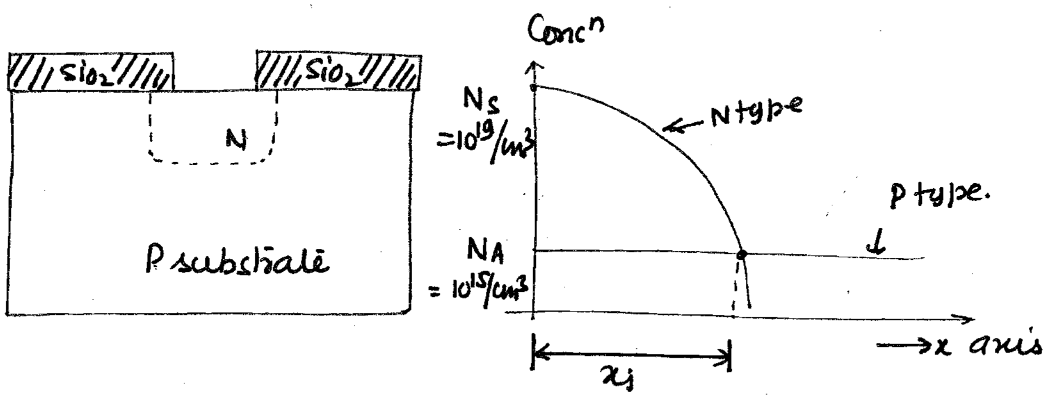
So, $\boxed{N_A = N_s \, \mathrm{erfc}\left(x/2\sqrt{Dt}\right) = N(x, t).}$

Q1) Phosphorous is diffused into uniformly doped P type substrate with background concⁿ of $10^{15}/cm^3$ at $T = 1100°c$. The diffusion constant at this temp is 10^{-12} cm^2/sec; solid solubility of Phosphorous and Silicon is $10^{19}/cm^3$ at $1100°c$. Assume predeposition time of 1 hour. Find the Juncⁿ Depth?

erfc of 2.75 = 10^{-4}

$$\text{erfc}(2.75) = 10^{-4}.$$

Soln:.



* At the Junction:.

$$N_A = N(x,t) = N_S \,\text{erfc}\left(x_j/2\sqrt{Dt}\right)$$

$$10^{15} = 10^{19}\,\text{erfc}\left(x_j/2\sqrt{Dt}\right)$$

$$10^{-4} = \text{erfc}\left(x_j/2\sqrt{Dt}\right).$$

So, $$2.75 = \frac{x_j}{2\sqrt{Dt}}$$

or $$x_j = 2.75 \times 2 \times \sqrt{10^{-12}\,cm^2/sec \times 3600\,sec}$$

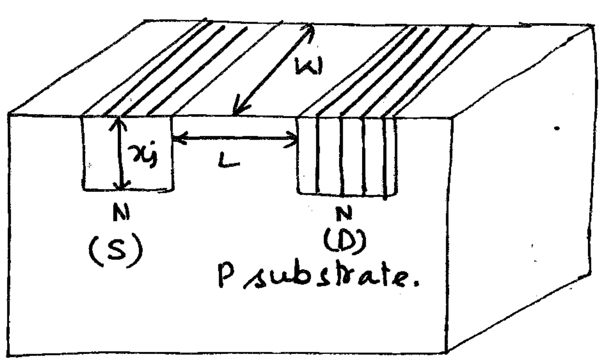
$$\boxed{x_j = 3.3\,\mu m}$$

Note:.

L: channel length.

W: channel width

x_j: Juncⁿ depth.



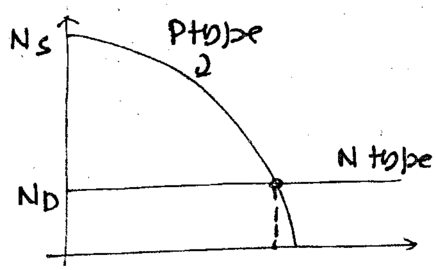
(N MOS)

Note:.

* Juncⁿ depth is decided during Diffusion process
* W/L Ratio decided during Lithography process. (lithography)
* x_j is important parameter in MOSFET fabrication.

Q2) Boron is diffused into an n type sc with back ground concn of $10^{14}/cm^3$. The predeposition is carried out for 2 hrs. Assume diffusion const of 5×10^{-13}; solid solubility of $10^{20}/cm^3$. Find the junc^n depth.

$$erfc(3.45) = 10^{-6}.$$



Soln:

$$N_s \, erfc(x_j/2\sqrt{Dt}) = N_D$$

$$10^{14} = 10^{20} \, erfc(x_j/2\sqrt{Dt})$$

$$10^{-6} = erfc(x_j/2\sqrt{Dt})$$

So, $$\boxed{\frac{x_j}{2\sqrt{Dt}} = 3.45}$$ ← in Prelims. ***

$$x_j = 2 \times 3.45 \times \sqrt{5 \times 10^{-13} \times 2 \times 3600}$$

$$x_j = 60 \times 10^{-6} \times 2 \times 3.45$$

$$\boxed{\begin{aligned} x_j &= 414 \times 10^{-6}\ cm. \\ &= 4.14\ \mu m. \end{aligned}}$$

Note (Prelims):

$$erfc(3.45) = 10^{-6} \Rightarrow erfc^{-1}(10^{-6}) = 3.45$$
$$erfc(2.75) = 10^{-4} \Rightarrow erfc^{-1}(10^{-4}) = 2.75$$
} Constant Value.

Now,

$$N_A = N_s erfc(x_j/2\sqrt{Dt})$$

$$\left(\frac{N_A}{N_s}\right) = erfc(x_j/2\sqrt{Dt})$$

$$erfc^{-1}(N_A/N_s) = constant = \frac{x_j}{2\sqrt{Dt}} = K.$$

So, $$x_j = 2\sqrt{Dt} \times K.$$

$$\boxed{x_j \propto \sqrt{t}}$$