MADE EASY

Electronics Engineering

Toppers Handwritten Notes

Advance Electronics

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Integrated ckt

circuit: connection of Active and passive elements
Active Elements: BJT, MOSFET, JFET, etc
Passive Elements: R, L, C, etc.

Integrated circuit: connection of Active and Passive components on the top of the substrate. (Semiconductor or Insulator)

Integrated ckt	Discrete ckt
(1) small size	(1) More size
(2) small power consumption	(2) large power consumption.
(3) low cost (∵ IC fabrication is a batch process).	(3) High cost
(4) More durable	(4) less durable

Disadvantage:

IC's cannot be repaired but can only be replace.

Classification of ICs

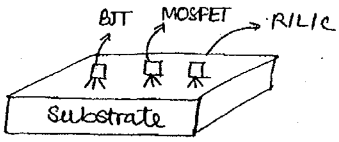
- Monolithic IC's
- Thin/Thick film IC's
- Hybrid IC's

- on the basis of level of integration
  (1) SSI
  (2) MSI
  (3) LSI
  (4) VLSI
  (5) ULSI

- Analog/Digital IC's

- Bipolar ICs
- CMOS ICs
- BiCMOS ICs

Monolithic Ic's



Mono ⟶ Single
Lithos ⟶ Stone

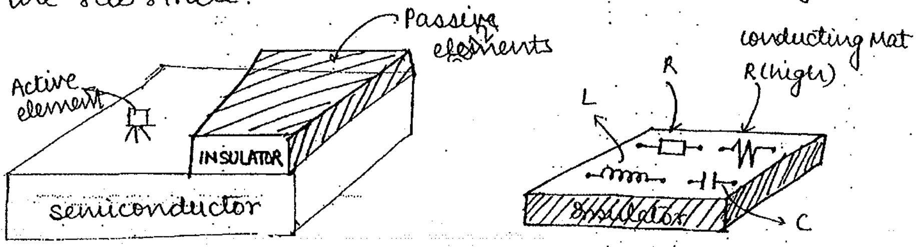
→ All the Active and Passive elements are formed on the top of the single S.C substrate.

→ Disadvantage: Heavy value of R-L-C is restricted in Monolithic IC's because heavy value of R,L,C occupy more area of substrate.

Thin and Thick Film Technology

→ By appearance, both Thick & Thin film ICs are very similar.

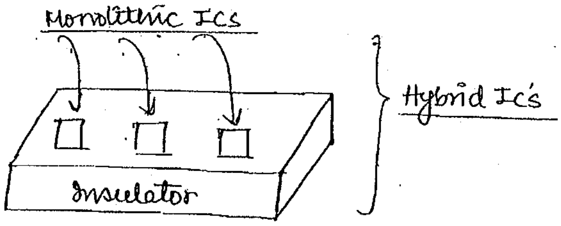
→ Active elements are fabricated on the top of the S.C substrate & passive elements are fabricated on the top of the insulating portion of the substrate.



Advantage: Heavy value of R,L and C we can get compared to Monolithic.

Thin Film	Thick Film
(1) conducting film is deposited by using sputtering process (or) Vapour deposition	(1) conducting film is deposited by using screen printing (or) silk screen printing

Hybrid ICs



Level of Integration

		No of transistors / unit area	Packing density
(1) Small scale integration	(SSI) :	1-10	$P<1$
(2) Medium " "	(MSI) :	$10-10^2$	$1<P<2$
(3) Large " "	(LSI) :	10^2-10^4	$2<P<4$
(4) Very large " "	(VLSI) :	10^4-10^6	$4<P<6$
(5) Ultra large " "	(ULSI) :	$>10^6$	$P>6$

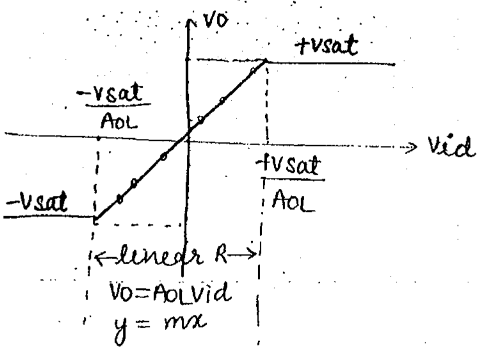
* Packing Density (P)

$\boxed{P = \log_{10}(Q)}$ Q: No of Tx in per unit Area

Analog And Digital ICs

Analog IC (Linear IC's)
i/p → Analog
o/p → Analog
eg: OpAmp IC (IC-741)
IC-555 timer

Digital IC (Non-Linear IC's)
i/p → Digital
o/p → Digital
eg: FlipFlop



# Bipolar ICs	CMOS ICs
(1) low packing density	(1) Higher packing density bcoz MOSFET occupies less Area compared to BJT.
(2) More Power consumption	(2) less Power consumption
(3) BW = high	(3) BW = low
(4) Gain = high	(4) gain = low
(5) speed = high	(5) speed = low

Gain

BJT: $g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{\eta V_T} = \frac{I_s e^{V_{BE}/\eta V_T}}{\eta V_T}$

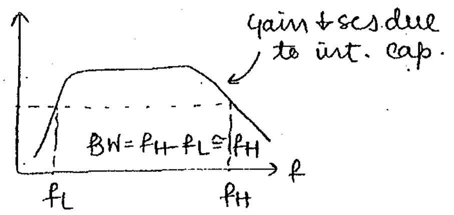
$\therefore$ $V_{BE}\uparrow$, $I_C\uparrow$ exponentially $\longrightarrow$ $g_m\uparrow$ exponentially

MOSFET: $g_m = \frac{\partial I_D}{\partial V_{GS}} = \sqrt{2 I_D \mu C_{ox}\left(\frac{W}{L}\right)}$

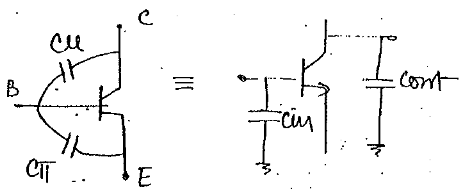
$\therefore$ $I_D \propto (V_{GS}-V_T)^2$ $V_{GS}\uparrow \rightarrow I_D\uparrow$ with square of $V_{GS} \Rightarrow g_m\uparrow$

$\boxed{g_m(BJT) > g_m(MOSFET)}$ $\therefore$ Gain (BJT) > Gain (MOSFET)

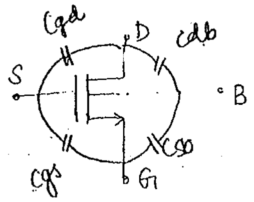
BW

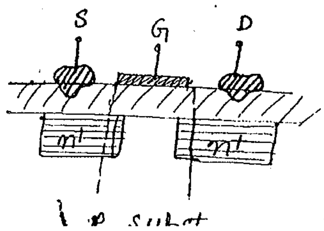


$BW = f_H - f_L \simeq f_H$.

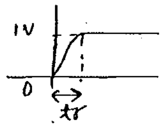


$f_H = \frac{1}{2\pi r_\pi (C_\pi + C_\mu)}$





Speed $\quad \text{RiseTime } (t_r) = \dfrac{0.35}{f_H}$



$\therefore \boxed{t_r\, BJT < t_r\, MOSFET}$

Speed of operation is high in BJT.

Note: • When speed, BW and Gain are important then we'll prefer Bipolar technology.

• If low power consumption & area are main concerns then we'll prefer CMOS technology.

• **BiCMOS** [Bipolar + CMOS]

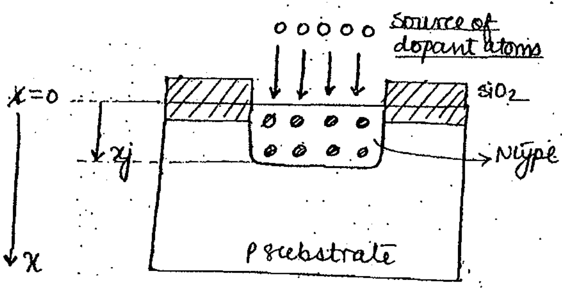
→ Some portion of the complete ckt is designed using Bipolar technology and some portion is designed using CMOS tech depending on requirements for a particular circuit.

Doping process

(1) Diffusion process of doping

(2) Ion implantation

(3) Epitaxy.



$x_j \rightarrow$ junction depth

(1) Diffusion Process of Doping

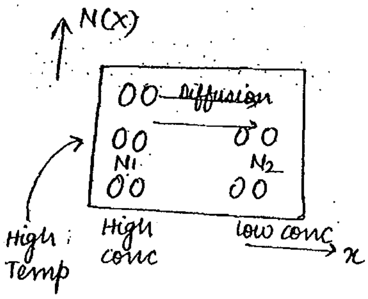
$\dfrac{dN}{dX} \neq 0$

$N(X) \Rightarrow$ conc of dopant atoms $\left[\dfrac{\text{atoms}}{cm^3}\right]$

$\dfrac{dN}{dX} \rightarrow$ change in conc of atoms

or

conc. gradient



Fick's First law of Diffusion

$$\boxed{J = -D\frac{dN}{dx}}$$

$D \rightarrow$ Diffusivity of atoms $\left(\frac{cm^2}{sec}\right)$

$J \rightarrow$ atomic flux $\equiv$ No of dopant atoms crossing unit cross sectional in per unit time.

Fick's second law of Diffusion

$$\boxed{\nabla . J = -\frac{dN}{dt}}$$

one dimension $\rightarrow \frac{dJ}{dx} = -\frac{dN}{dt}$

$$\frac{d}{dx}\left[-D\frac{dN}{dx}\right] = -\frac{dN}{dt} \Rightarrow \boxed{D\frac{\partial^2 N}{\partial x^2} = \frac{\partial N}{\partial t}}$$

(or)

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

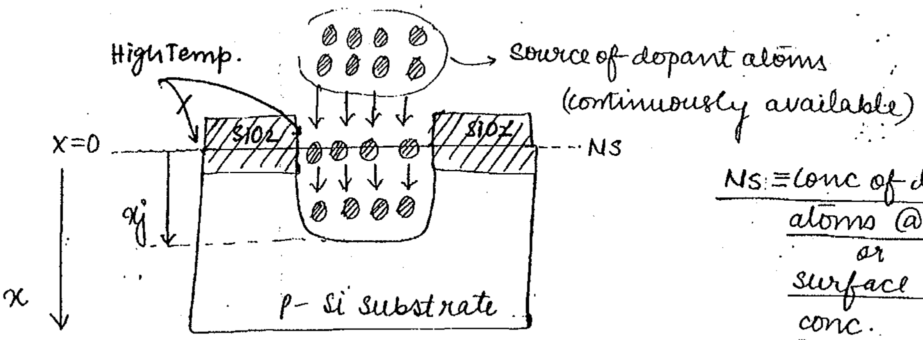
$\Rightarrow \boxed{\frac{\partial N}{\partial t} = D\frac{\partial^2 N}{\partial x^2}}$: Diffusion Equation

- Diffusion process of doping will take place in two steps:—

(1) Pre-deposition (infinite source diffusion)

(2) Drive-in (finite/limited source diffusion)

(1) Pre-Deposition (infinite source diffusion)



$N_S \equiv$ Conc of dopant atoms @ $x=0$ or surface atoms conc.

* Solid solubility limit: Extent upto which we can dissolve a solid

$N_S = N_0 \longrightarrow$ constant

it is limited by solid solubility test

$$\frac{\partial N}{\partial t} = D\frac{\partial^2 N}{\partial x^2} \longrightarrow N(x,t) = ?$$

Apply:

Boundary condition

(1) $N(0,t) = N_0$

(2) $N(\infty,t) = 0 \rightarrow$ very deep doping/jn is not possible by diffusion process of doping.

(3) $N(x,0) = 0$

$$\boxed{N(x,t) = N_0 \operatorname{erfc}\left(\frac{x}{2\sqrt{Dt}}\right)} \ cm^{-3} \ *$$

~~complementary error fn profile~~.

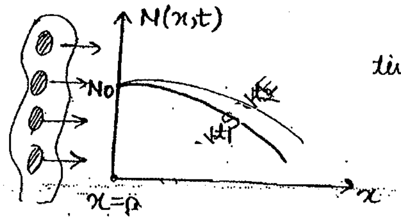
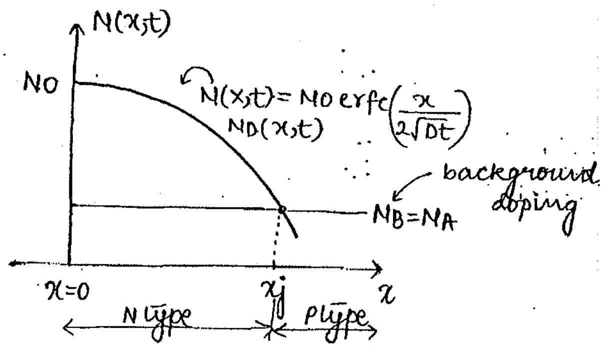


fig: complementary error fn profile

Suppose, P-sub is uniformly doped,



@ $x = x_j$,

$N(x,t) = N_B$

$$N_0 \operatorname{erfc}\left(\frac{x_j}{2\sqrt{Dt}}\right) = N_B$$

• Doping parameters → surface dopant conc
→ In depth
→ Doping profile
→ $\boxed{\text{Doping Dose}}$ *

Doping Dose : Total No of ~~atoms~~ Dopant atoms / cm^2 (Q) ;

$$Q = \int_0^\infty N(x,t)\,dx \quad \text{atoms/cm}^2$$

$$Q = \int_0^\infty N_0\,\mathrm{erfc}\left(\frac{x}{2\sqrt{Dt}}\right) dx = N_0 \int_0^\infty \mathrm{erfc}\left(\frac{x}{2\sqrt{Dt}}\right) dx$$

let $\frac{x}{2\sqrt{Dt}} = v$

$dx = 2\sqrt{Dt}\,dV$

$x=0 \;,\; x=\infty$

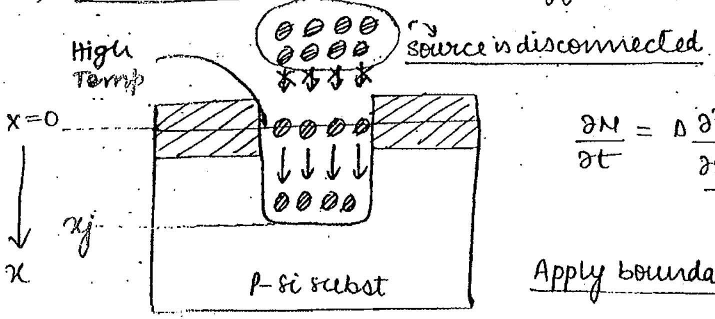
$v=0 \;,\; v=\infty$

$$Q = N_0 \int_0^\infty \mathrm{erfc}(V)\, 2\sqrt{Dt}\, dV$$

$$Q = 2N_0\sqrt{Dt} \int_0^\infty \mathrm{erfc}(V)\, dV \rightarrow \frac{1}{\sqrt{\pi}}$$

* $$\boxed{Q = 2N_0 \sqrt{\frac{Dt}{\pi}}} \quad \frac{\text{atoms}}{\text{cm}^2}$$

(2) Drive-in (finite source diffusion)



$$\frac{\partial N}{\partial t} = D\frac{\partial^2 N}{\partial x^2} \longrightarrow N(x,t) = ?$$

Apply boundary cond,

(1) $N(\infty,t) = 0$ deep doping not possible

(2) $Q = \int_0^\infty N(x,t)\,dx = \text{constant}$

$$\boxed{N(x,t) = \frac{Q}{\sqrt{\pi Dt}}\, e^{-x^2/4Dt}} \;*\quad \text{atoms/cm}^3$$

Gaussian profile