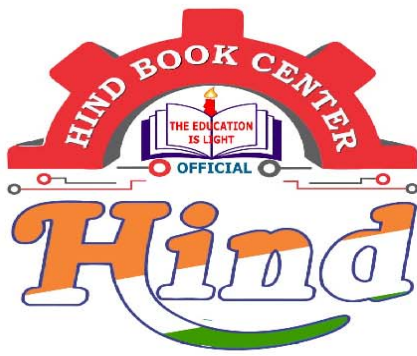




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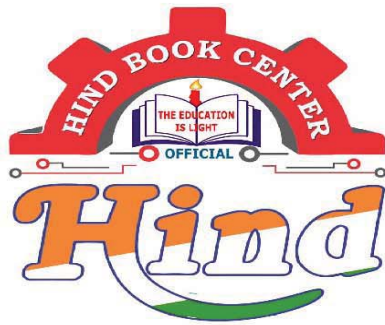
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Integrated ckt

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

- (1) Small size
- (2) small power consumption
- (3) low cost ($\because$ IC fabrication is a batch process)
- (4) More durable

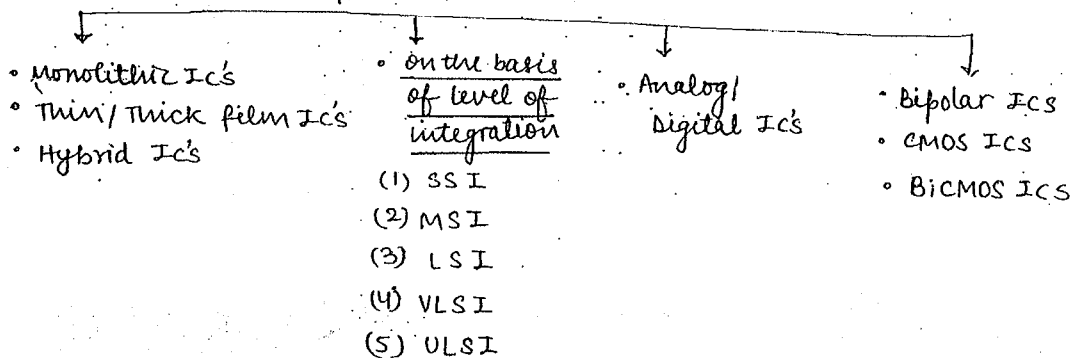
Discrete ckt

- (1) More size
- (2) large power consumption.
- (3) High cost
- (4) less durable

Disadvantage:

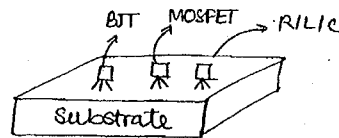
ICs cannot be repaired but can only be replaced

Classification of ICs



Monolithic IC's

Mono $\rightarrow$ Single
lithos $\rightarrow$ Stone

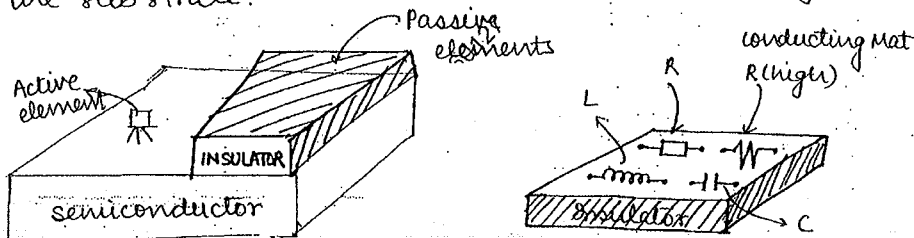


$\rightarrow$ All the Active and Passive elements are formed on the top of the single s.c. substrate.

$\rightarrow$ 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

- $\rightarrow$ By appearance, both Thick & Thin film ICs are very similar.
- $\rightarrow$ 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.

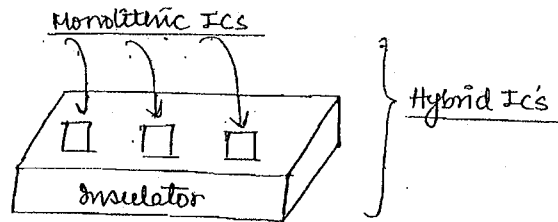
Thin Film

- (1) conducting film is deposited by using sputtering process
(or)
vapour deposition

Thick Film

- (1) conducting film is deposited by using screen printing
(or)
silk screen printing

Hybrid ICs



Level of Integration

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

* Packing Density (P)

$$P = \log_{10}(\theta)$$

θ : No. of Tx in per unit Area

Analog And Digital ICs

Analog IC (Linear ICs)

i/p $\rightarrow$ Analog

o/p $\rightarrow$ Analog

eg: OP Amp IC (IC-741)

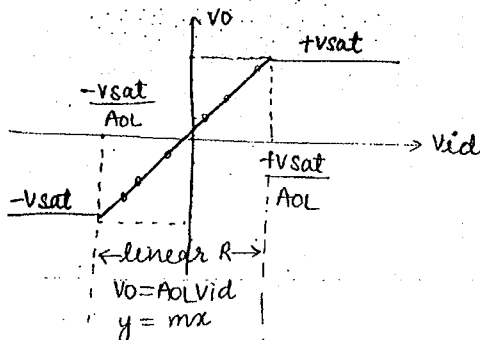
IC-555 timer

Digital IC (Non-linear ICs)

i/p $\rightarrow$ Digital

o/p $\rightarrow$ Digital

eg: Flip Flop



Bipolar ICs

(1) low packing density

(2) More Power consumption

(3) BW = high

(4) Gain = high

(5) speed = high

CMOS ICs

(1) Higher packing density
bcz MOSFET occupies less Area compared to BJT.

(2) less Power consumption

(3) BW = low

(4) Gain = low

(5) speed = low

Gain

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

$V_{BE} \uparrow, I_C \uparrow$ exponentially $\rightarrow g_m \uparrow$ exponentially

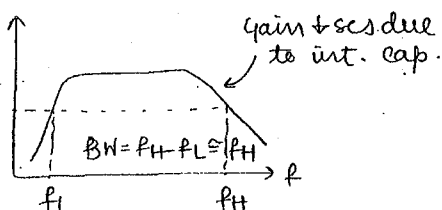
MOSFET: $g_m = \frac{\partial I_D}{\partial V_{GS}} = \sqrt{2 I_D \mu C_{ox} \left(\frac{W}{L} \right)}$

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

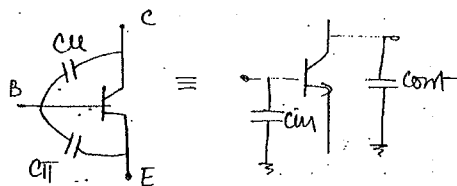
$g_m(\text{BJT}) > g_m(\text{MOSFET})$

$\therefore \text{Gain}(\text{BJT}) > \text{Gain}(\text{MOSFET})$

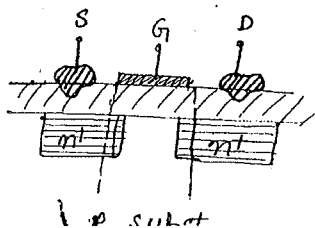
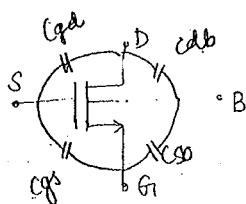
BW



$BW = f_H - f_L \approx f_H$



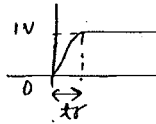
$f_H = \frac{1}{2\pi \tau_{in} (C_{in} + C_u)}$



Speed

$$\text{Rise time } (t_r) = \frac{0.35}{f_H}$$

$$t_{r \text{ BJT}} < t_{r \text{ MOSFET}}$$



Speed of operation is high in BJT.

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

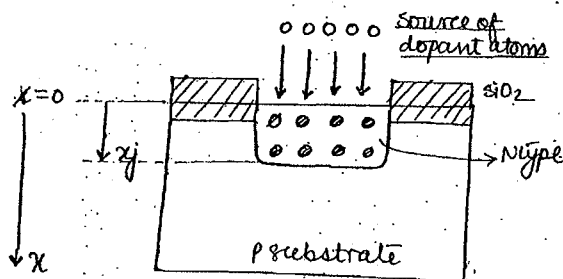
• If low power consumption & area are main concerns then we'll prefer CMOS technology.

• 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.



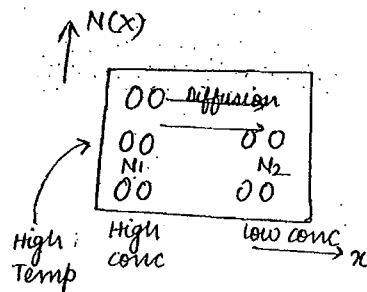
$x_j \rightarrow$ junction depth

(1) Diffusion Process of Doping

$$\frac{dN}{dx} \neq 0$$

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

$\frac{dN}{dx} \rightarrow$ change in conc of atoms
or
conc. gradient



Fick's First law of Diffusion

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

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

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

Fick's second law of Diffusion

$$\nabla \cdot J = -\frac{dN}{dt}$$

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

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

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

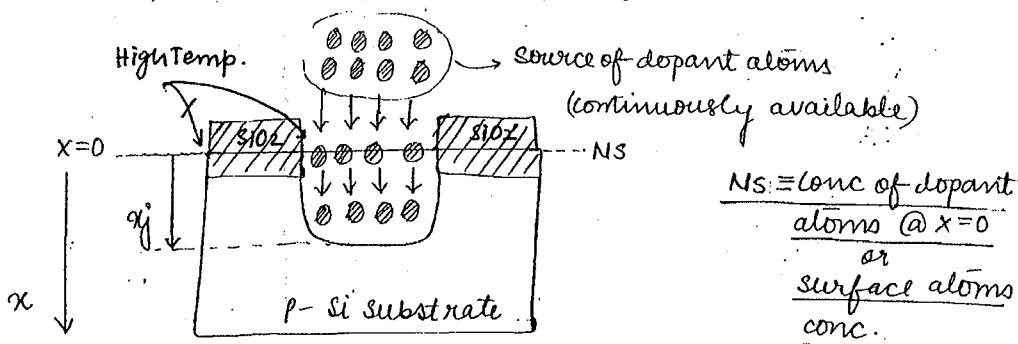
$$\frac{\partial N}{\partial t} = D \frac{\partial^2 N}{\partial x^2}$$

$$\Rightarrow \frac{\partial N}{\partial t} = D \frac{\partial^2 N}{\partial x^2} \quad \therefore \text{Diffusion Equation}$$

• 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)



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

$$N_s = N_0 \rightarrow \text{constant}$$

it is limited by solid solubility test

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

Apply: $N(x,t) = ?$
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.

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

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

~~complementary error fn profile.~~

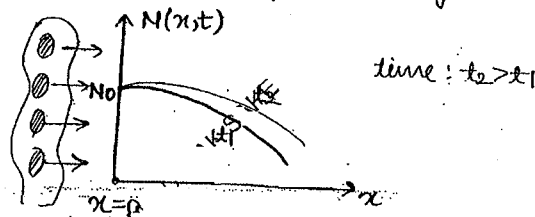
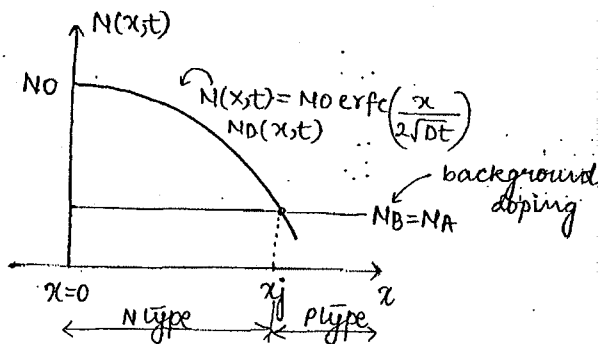


Fig: Complementary error fn profile

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
 - x_n depth
 - Doping profile
 - Doping Dose*

Doping Dose: Total NO of ~~atoms~~ dopant atoms/cm² (Q);

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

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

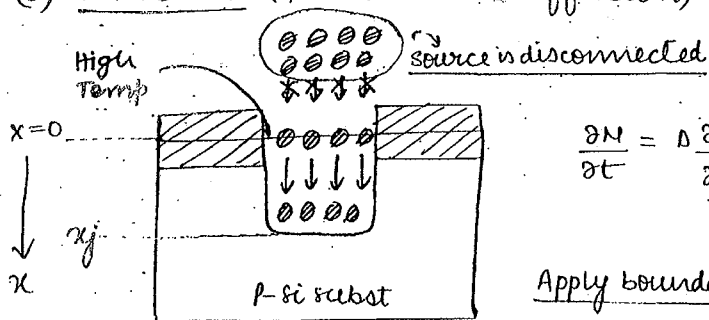
$$\left. \begin{aligned} \text{let } \frac{x}{2\sqrt{Dt}} &= v \\ dx &= 2\sqrt{Dt} dv \\ x=0, x=\infty \\ v=0, v=\infty \end{aligned} \right\}$$

$$Q = N_0 \int_0^{\infty} \operatorname{erfc}(v) 2\sqrt{Dt} dv$$

$$Q = 2N_0\sqrt{Dt} \left(\int_0^{\infty} \operatorname{erfc}(v) dv \right) \rightarrow \frac{1}{\sqrt{\pi}}$$

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

(2) Drive-in (finite source diffusion)



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

Apply boundary cond,

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

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

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

Gaussian profile