$$R = \frac{1}{2kN} E_0^{1/2} \simeq 20\sqrt{E_0} \ \text{Å}$$

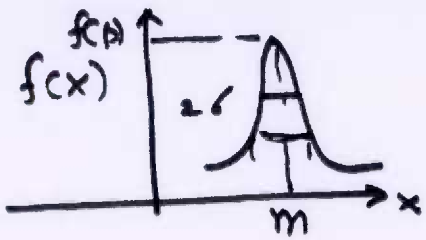
We have used $k_{Si} = 2 \times 10^{-16}\ eV^{1/2}\ cm^2$

And again $R_p = \dfrac{R_{ES}}{1 + \dfrac{M_2}{3M_1}}$

Some Data:

		Z	M
1.	Phosphorous	15	30.973
2.	Arsenic	33	74.92
3.	Aluminium	13	26.98
4.	Boron	5	10.82
5.	Indium	49	114.82
6.	Silicon	14	28

Probability :



i $f(x)$ is Gaussian with mean m is

$$= \int_{-\infty}^{+\infty} x\, f(x)\, dx$$

ii Standard deviation $\sqrt{\sigma^2}$ is given

$$\sigma^2 = \text{expt. value}\left[(x-m)^2\right]$$

$$= \int_{-\infty}^{+\infty} (x-m)^2 f(x)\, dx$$

$$= E(x^2) - 2m^2 + m^2$$

$$= E(x^2) - m^2$$

$f(\sigma) = 0.606\,P$

$f(2\sigma) = 0.135\,P$

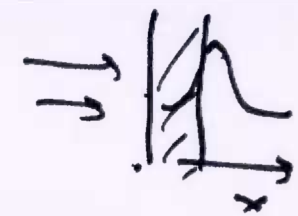
$f(4\sigma) = 1.81\,P$

P is Peak value of $f(P) = \dfrac{1}{\sqrt{2\pi\sigma^2}}$ at $x = m$

& $f(x) = \dfrac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-(x-m)^2 / 2\sigma^2\right]$

The Implantation process puts ions (atoms) below the surface and these ions come to rest at points which leads to Gaussian distribution. The Gaussian Profile is given by

$$N(x) = \frac{N_S}{\sqrt{2\pi}\,\Delta R_p} \exp\left[-\frac{1}{2}\frac{(x-R_p)^2}{\Delta R_p^2}\right]$$

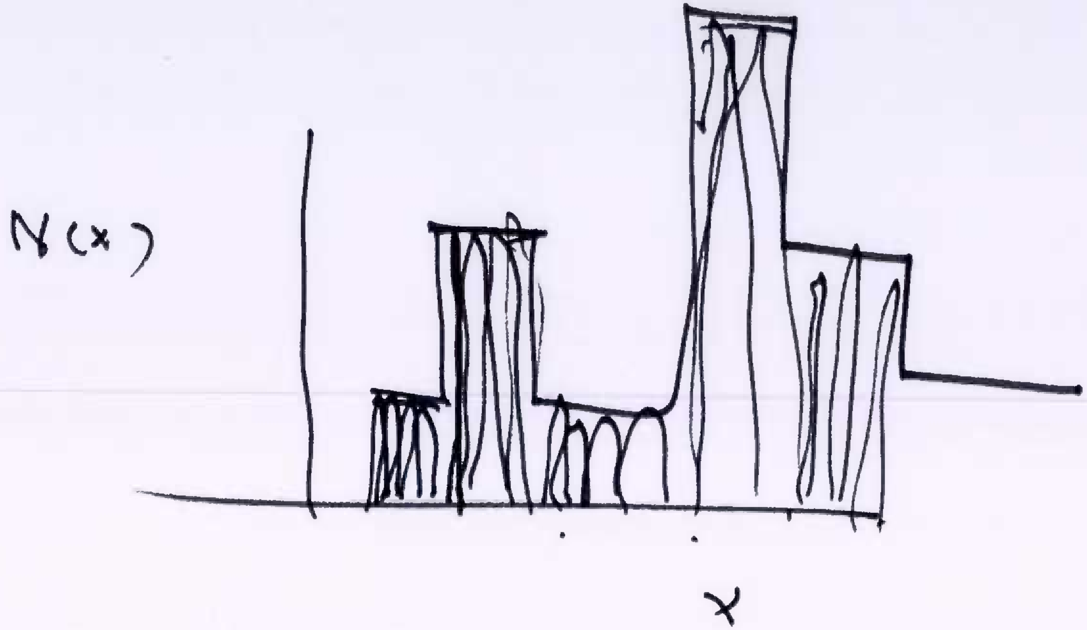


Here i ΔR_p is standard deviation called Straggle.

& ii R_p is mean range and is called Projected Range.

iii Peak concentration $N_p = N(R_p)$

The total ions/atoms implanted per unit area is called DOSE $N_S = \int_{-\infty}^{+\infty} N(x)\,dx$ & $N_p = \frac{0.4\, N_S}{\Delta R_p}$



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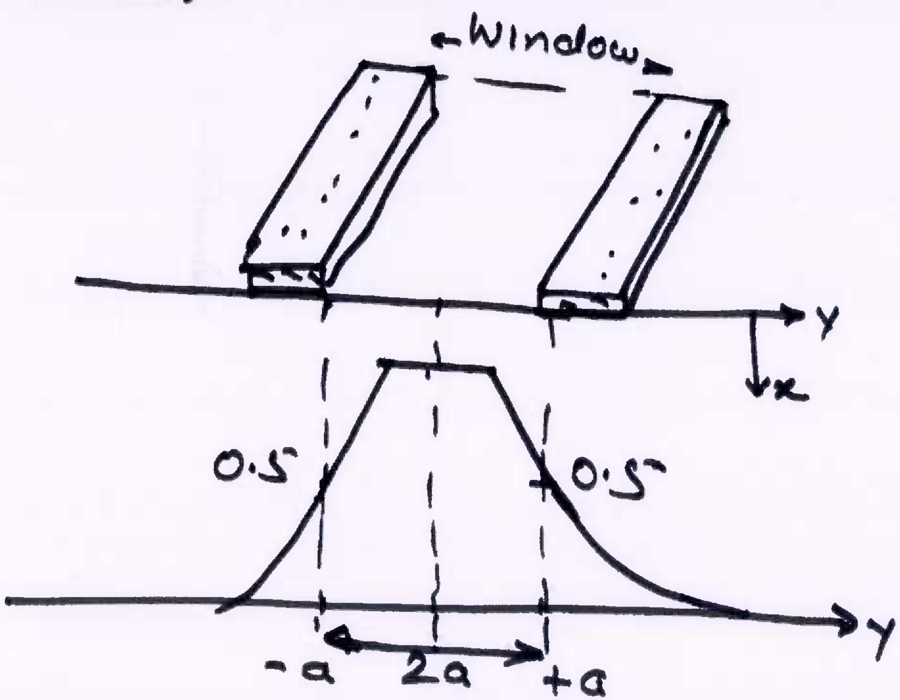
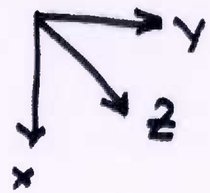
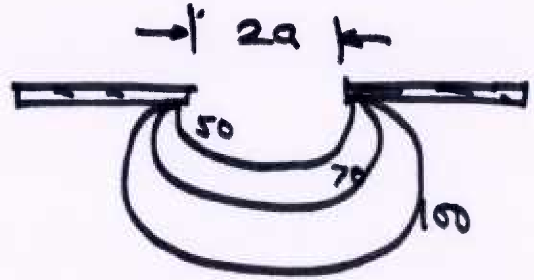
If Implantation is done through a Masked window, then there is Gaussian profile of ions even along lateral directions, and implanted species are mostly going vertically down.







Then

$$f(x,y,z) = \frac{1}{(2\pi)^{3/2}\Delta R_p \Delta x \Delta y} \times$$

$$\times \ \mathrm{Exp}\left[-\frac{1}{2}\left\{\frac{(x-R_p)^2}{\Delta R_p^2} + \frac{y^2}{\Delta y^2} + \frac{z^2}{\Delta z^2}\right\}\right]$$

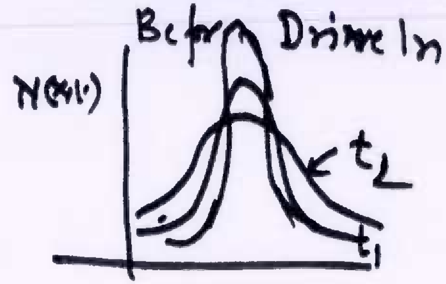
We assume $\Delta y = \Delta z = \Delta R_t$ – Transverse Straggle

$$N(x,y,z) = \frac{N_s}{\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\frac{(x-R_p)^2}{\Delta R_p}\right\}\left\{\frac{1}{\sqrt{\pi}}\,\mathrm{erfc}\,\frac{(y-a)}{\sqrt{2}\,\Delta R_t}\right\}$$

For $y \gg a$ $\quad \mathrm{erfc}(\infty) = \sqrt{\pi}$

Drive-In of Implanted Impurities.

Thermal Cycle after implant, just flattens the Gaussian Profile, which essentially means that one will have lower Peak conc. and larger Standard Deviation σ or extra ΔR_p



We know that Diffusion distances $\propto \sqrt{Dt}$

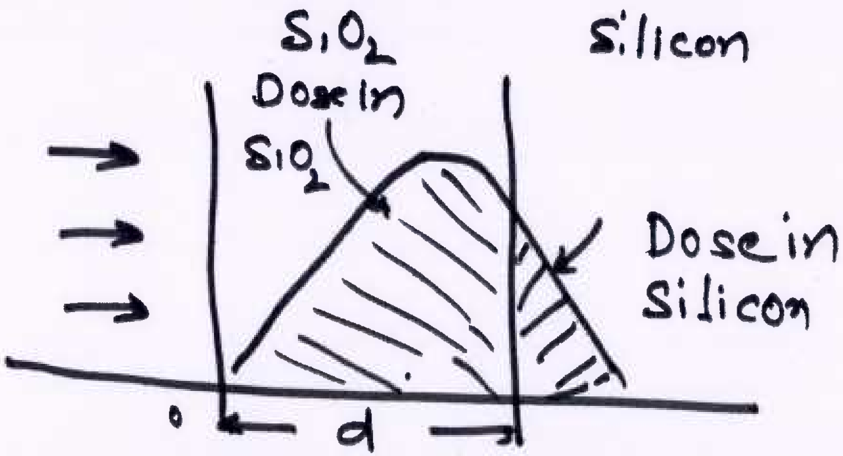
Hence the new Profile is

$$N(x,t) = \frac{N_s}{\sqrt{2\pi}\,(\Delta R_p^2 + 2Dt)^{1/2}} \exp\left\{-\frac{1}{2}\left[\frac{(x-R_p)^2}{\Delta R_p^2 + 2Dt}\right]\right\}$$

where Drive-In is performed at temp. T_1 where $D = D(T_1)$ and time of Drive-In is t.

Masks for Implantation:

1. Photoresist
2. Silicon dioxide
3. Silicon Nitride
4. Heavy Metals like Gold, Tungsten, Platinum & Vanadium.



We take 'd' as thickness of the Mask-layer (In Fig. it is SiO_2) Ions can be stopped in SiO_2 if d is large. However some 'tail' of Profile will allow a few impurity dose will enter Si.

Hence we can find 'd' for a given Stopping dose.

If Q is the residual dose of Ions in Silicon after being mostly in Mask material of thickness d, then

$$Q = \int_d^\infty \frac{N_s}{\sqrt{2\pi}\,\Delta R_p}\left[-\frac{1}{2}\frac{(x-R_p)^2}{\Delta R_p^2}\right]dx$$

We define $y = \frac{x-R_p}{\sqrt{2}\Delta R_p}$, then $dy = \frac{1}{\sqrt{2}\,\Delta R_p}dx$

Also $x = d$ $\quad y(d) = \frac{(d-R_p)}{\sqrt{2}\,\Delta R_p} = y_0$ & $x = \infty$ $\quad y < \infty$

$$\therefore Q = \int_{y_0}^{\infty} \frac{N_s}{\sqrt{2\pi}\,\Delta R_p} \cdot (\sqrt{2}\,\Delta R_p)\exp[-y^2]\,dy$$

$$= \frac{N_s}{\sqrt{\pi}}\int_{y_0}^{\infty} e^{-y^2}dy = \frac{N_s}{\sqrt{\pi}}\left[\int_0^\infty e^{-y^2}dy - \int_0^{y_0} e^{-y^2}dy\right]$$

Or $$Q = \frac{N_s}{\sqrt{\pi}}\left[\frac{\sqrt{\pi}}{2} - \frac{\sqrt{\pi}}{2}\,\mathrm{erf}(y_0)\right]$$

$$= \frac{N_s}{2}\left[1 - \mathrm{erf}(y_0)\right] = \frac{N_s}{2}\,\mathrm{erfc}(y_0)$$

$$= \frac{N_s}{2}\,\mathrm{erfc}\left(\frac{d - R_p}{\sqrt{2}\,\Delta R_p}\right)$$

or $$\frac{2Q}{N_s} = \mathrm{erfc}\left(\frac{d - R_p}{\sqrt{2}\,\Delta R_p}\right)$$

or $$d = R_p + \sqrt{2}\,\Delta R_p\,\mathrm{erfc}^{-1}\left(\frac{2Q}{N_s}\right)$$

If we say, we need 6 nines Blocking (99.9999 %) in Mask, then Dose in Silicon $= \frac{Q}{N_s} = 0.000001$

or $\frac{2Q}{N_s} = 0.000002$