Ion Implantation

Ion Implantation is a Process wherein one can incorporate Dopant Impurities in a Substrate (In our case it is Silicon).

Dopant Impurities are created in their Ionic form, and these charged Ions are accelerated using Electric Field. This causes increase in Energy of Ions. These Ions are focussed into a Beam and they Impinge on the Substrate (Normal incidense). Due to High Energy Ions enter Substrate and come to rest at a distant called "Range". The energy loss mechanism is interaction of Ions with nuclei of atoms of the Substrate, as well as with Free electrons available. Thus Energy-Range relation Is Created. Time for which Ions imping on the Substrate, decides the total amount of Impurities which resides in the substrate.

Amount of Impurities is measured as 'Dose' which Is no./area.

As impurities rest inside the Substrate after random interactions, the Impurity Profiles are Gaussian or Normal Distribution of Impurities is observed.

Dopant Incorporation in Semiconductors

a) Solid State Diffusion

b) Doping during Crystal Growth

c) Doping during Epi-Growth

d) Doping using At. Pressure CVD for Doped Glasses.

→ e) Ion Implantation

Advantages of Ion Implantation :

(i) Precise Control on Impurity Dose and at Depth
(ii) Impurities directly below Surface – Burried Profile
(iii) Relatively Low Temperature Process (wrt Diffusion)
(iv) Choice of Mask-Material

(v) Self Aligned structures are possible

(vi) Order of Impurity incorporation is not an Issue.

(vii) Arbitary Impurity Profile is Possible.

Disadvatages :-

(i) Low Throughput Rate

(ii) Self Passivation (Like SiO_2 creation in Drive-In Cycle) is not Possible

(iii) Crystal Damage

(iv) Anomolous Transient Enhanced Diffusion

(v) charging of Insulators

(vi) Very Costly Equipment

What Implantion Machine must provide for VLSI Fabrication Process? :

(i) Uniform Doping

(ii) Dose control from 10^{10} to 10^{16} $/cm^2$

(iii) Energy of Ions required between 10 KeV to 300 KeV.

(iv) Different impurity Incorporation

(v) Automated Dose Control

(vi) Angular Implantation

(vii) Moderate to High Throughput

In MOS Technologies (CMOS, FINFET & others)

One needs:

(a) P-Well (b) N-Well

(c) Channel Stopper

(d) Depletion Implant for Depletion Transistor

(e) Source & Drain Impurity Implant with Higher Doses

(f) Threshold Correction

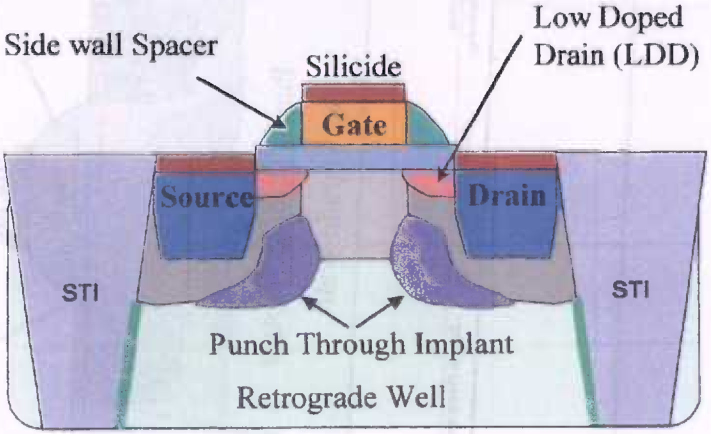
Few Terms of Interest in Implantation

(i)- DOSE = Ions/cm^2 $\simeq \frac{1}{qA}\int_0^{t'} I(t)\,dt$

(ii) Range and Projected Range

Lec-19
Note-8

Advanced CMOS Technology



(iii) Impurity Profile

(iv) Standard deviation – Straggle

(v) Energy

(vi) Nuclear Stopping

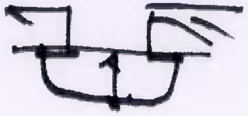
(vii) Electronic Stopping

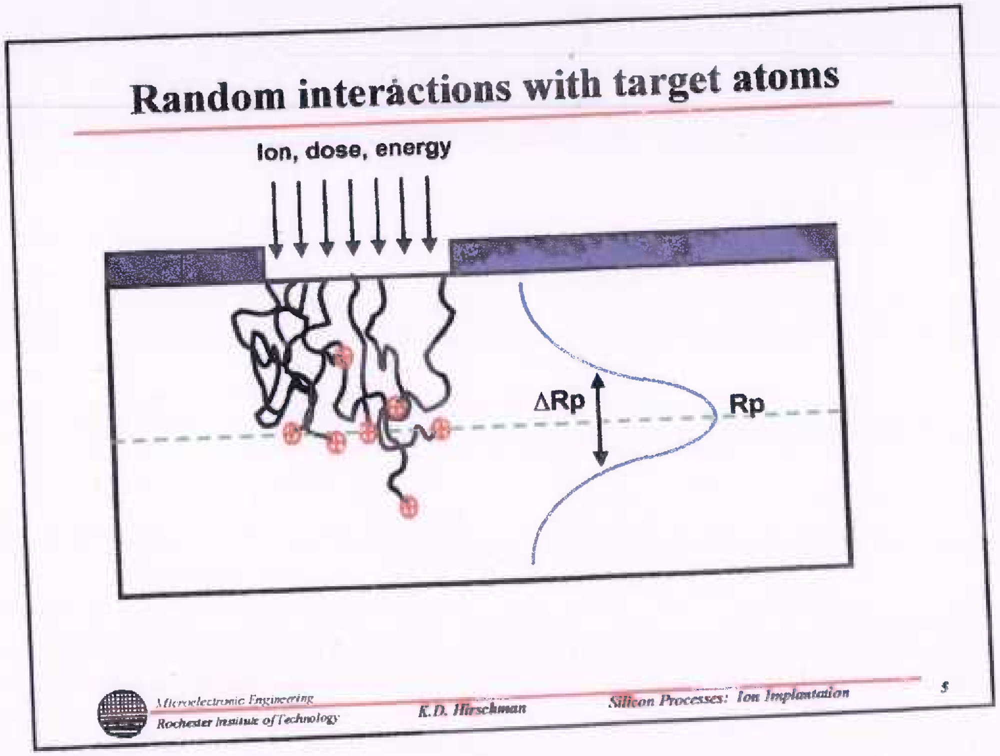
(viii) Transverse Straggle

(ix) Annealing & Drive-In

(x) Channeling

(xi) Masking

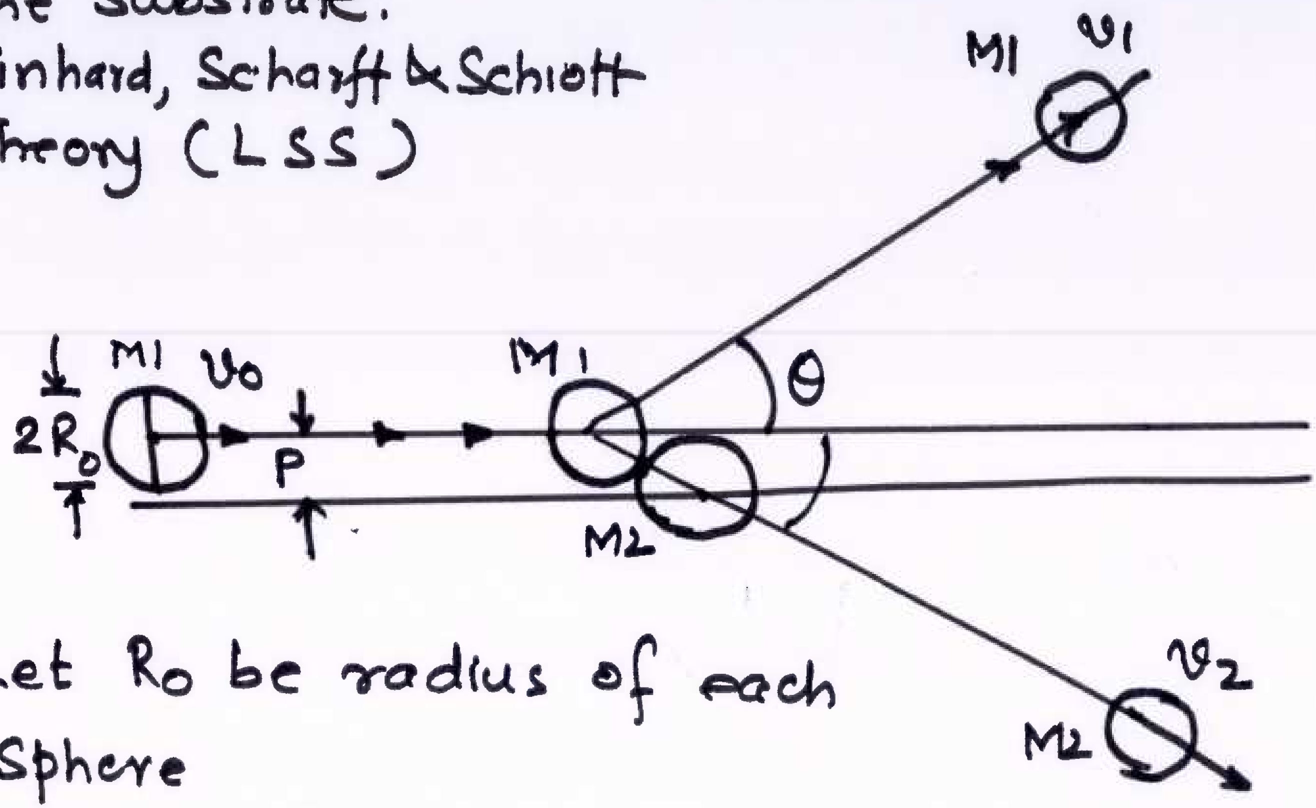




Random interactions with target atoms

Energy Loss Mechanism for Ions inside the Substrate.

Linhard, Scharff & Schiott Theory (LSS)



Let R_0 be radius of each Sphere

Let v_0 and E_0 be velocity and Energy (KE) of the moving sphere (M_1 here). Let M_1 is the mass of the sphere. This sphere impinges on <u>Stationary</u> (atom) Sphere which has Mass M_2 but $KE = 0.0$.