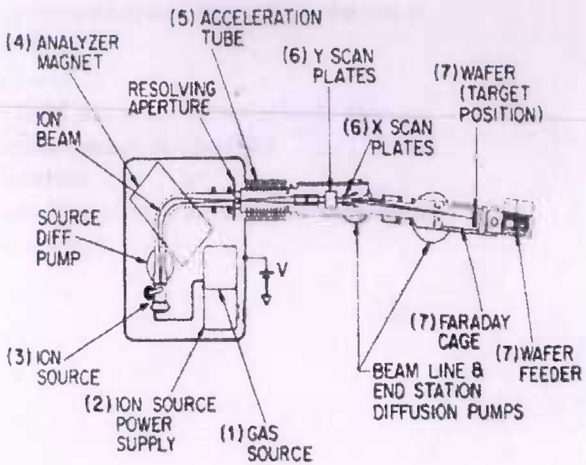
Selective doping - Ion Implantation-Machine

- (1) Gas source of material, such as BF3 or AsH3 at high accelerating potential; valve controls flow of gas to ion source
- (2) Power supply to energize the ion source
- (3) Ion source containing plasma with the species of interest (such as +As, +B, or +BF2), at pressures of ~ 10-3 torr
- (4) Analyzer magnet: allows only ions with desired charge/mass ratio through
- (5) Acceleration tube through which the beam passes
- (6) Deflection plates to which voltages are applied to scan the beam in x and y directions and give uniform implantation
- (7) Target chamber consisting of area-defining aperture, Faraday cage, and wafer feed mechanism

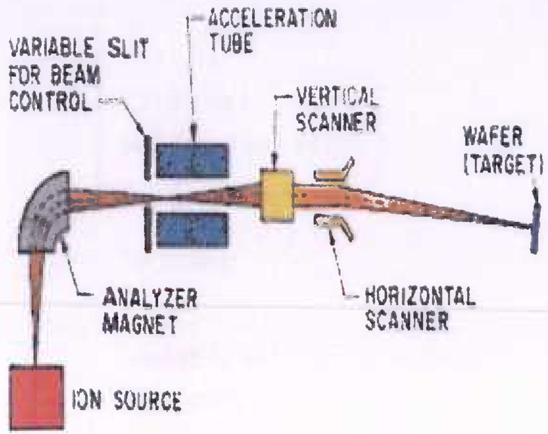


CDEEP
IIT Bombay

EE 669 L21 / Slide 01

Ref: Dept of EE
Sharif Technology University, Iran

Selective doping - Ion Implantation



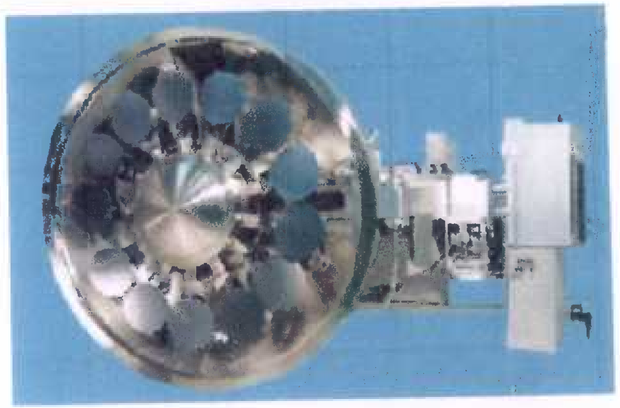
Principles of Ion Implant

- Generation of ions
  - dopant gas containing desired species
- BF3, B2H6, PH3, AsH3, AsF5
  - plasma provides positive ions
- (B11)+, BF2 +, (P31)+, (P31)++
- Ion Extraction
  - Ions are extracted from the source due to a high electric field
- Ion Selection
  - Magnetic field mass analyzer selects the appropriate ion (mass & charge)
- Ion Acceleration
  - Further accelerate ions giving the ions their final kinetic energy.

CDEEP
IIT Bombay

Ref : Dept of EE
STU, Iran

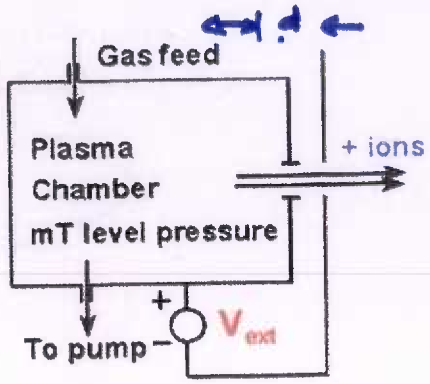
Selective doping - Ion Implantation



Multi-Wafer chuck

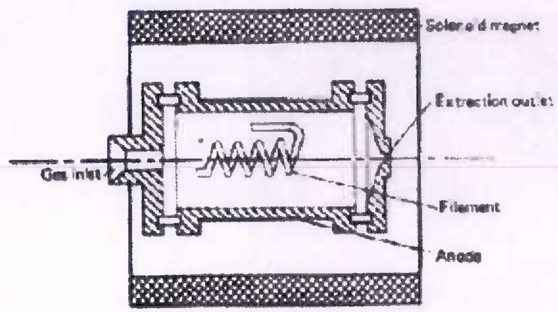
Ref :- Dept. of EE
STU, Iran

Selective doping - Ion Implantation- Plasma source



variable extraction voltage
(typically ~30KV)

Nielsen-type gaseous source



Pressure : 10^{-4} to 10^{-2} Torr

Ion source is characterised by

Ion current density

$$J_{ion} = \frac{5.5 \times 10^{-8} V_{ext}^{3/2}}{d^2 \cdot M^{1/2}} \text{ Amp/cm}^2$$

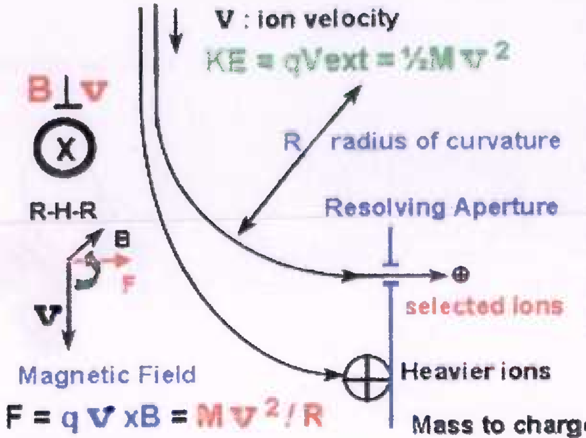
CDEEP
IIT Bombay

Ref : Dept of EE
STU, Iran

Selective doping - Ion Implantation-Mass analyzer

CDEEP
IIT Bombay

EE 669 L 21 / Slide 05



The ions are extracted from the source and analyzed in a magnetic field. The Lorentz force makes the ions take a curved path with a radius of curvature that depends on the mass of each ionic species. By adjusting the magnetic field strength, only the selected ions will enter the accelerating column.

Mass to charge ratio of the selected ions:

$$M/q = R^2 B^2 / (2\,V_{ext})$$

v = velocity

R = Radius of Curvature.

$$v = \sqrt{\frac{2q}{m} V_{ext}}$$

$$B \cdot R = \sqrt{\frac{2q}{m} V_{ext}} \Big/ (q/M)$$

$$= 4.55 \sqrt{M\,V_{ext}} \quad \text{KG.cm}$$

B.R is called Magnetic Rigidity.

Conclusion:

For a Magnet, R is Fixed.

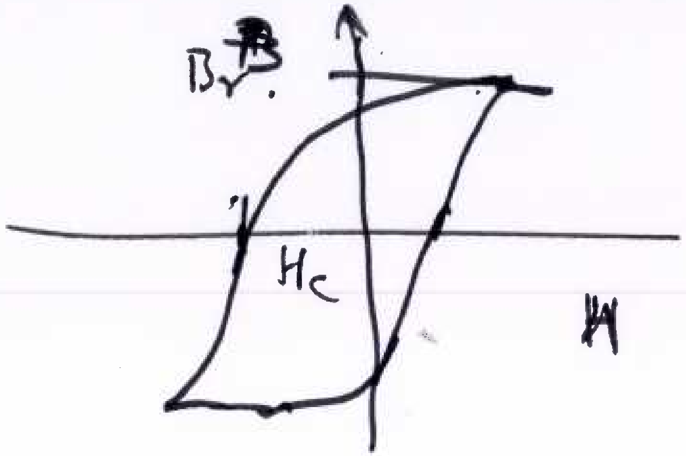
Hence for a given Extractor Voltage

$$B \propto \sqrt{M}$$

B is Controlled by Coil Current, which can then fix species of One Mass.

Ref: Dept of EE, STU, Iran

CDEEP
IIT Bombay



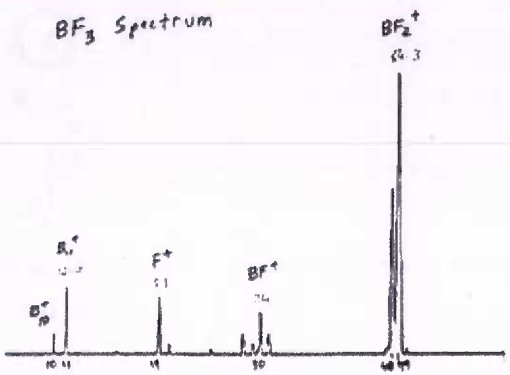
Hysterisis is seen in B-H curve of Magnets

Magnetisation Curve for a Magnet

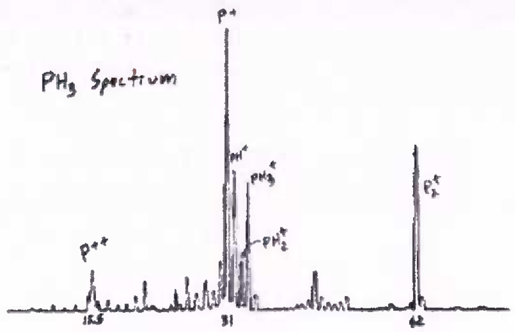
1. Parmanent Magnet
2. Electromagnet
3. Temporary Magnet

Selective doping - Ion Implantation- Mass analyzer

BF_3 Gas Spectrum



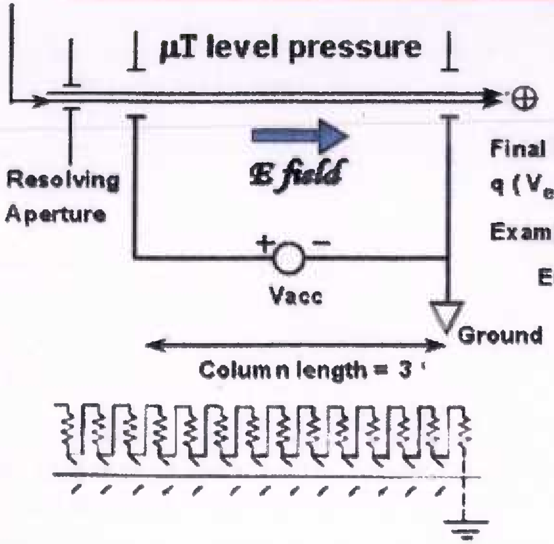
PH_3 Gas Spectrum



Ref: - Dept of EE STU, Iran

Selective doping - Ion Implantation- Accelerator

Ion Acceleration



Final Kinetic Energy of the Ion = $q\,(V_{ext} + V_{acc})$

Example: V_{ext} = 30 KV V_{acc} = 70 KV

Energy of the Ion = 100 KeV

CDEEP
IIT Bombay

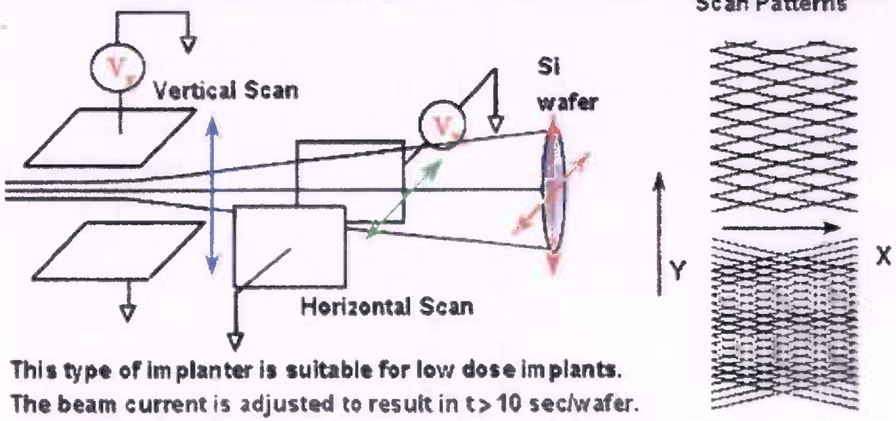
EE 669 L21 / Slide 08

Ref Dept of EE
STU, Iran

Selective doping - Ion Implantation- Scanner

Beam Scanning

Electostatic scanning (low/medium beam current implanters (I < 1mA)



This type of implanter is suitable for low dose implants. The beam current is adjusted to result in t > 10 sec/wafer. With scan frequencies in the 100 Hz range, good implant uniformity is achieved with reasonable throughput.

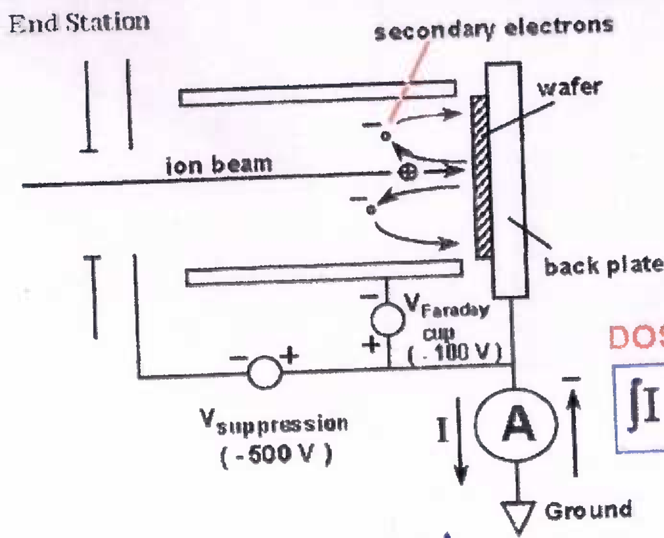
CDEEP
IIT Bombay

Ref : Delft 7 & E
STU, Iran

Selective doping - Ion Implantation-Wafer cage (Faraday Cup)

CDEEP
IIT Bombay

In-situ Dose Control



DOSE MONITORING

$$\int I\,dt = Q = A\,q\,\phi$$

$$N_s = \text{Dose} = \frac{1}{qA}\int_0^{t'} I(t)\,dt$$

Ref:- Dept of EE
Sharif Technology University, Iran

CDEEP
IIT Bombay

EE 669 L 21 / Slide 11

Silicon Integrated Circuit Process Flow for CMOS Technology