# Principles of Ion Implant

- Generation of ions
  - dopant gas containing desired species
    - $BF_3$, $B_2H_6$, $PH_3$, $AsH_3$, $AsF_5$
  - plasma provides positive ions
    - $(B^{11})^+$, $BF_2^+$, $(P^{31})^+$, $(P^{31})^{++}$
- 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.
- Beam Scan / Disk Scan
  - Provides a uniform dose of ions over the wafer surface.
- In-situ Dose Monitoring



# Implant Mechanics

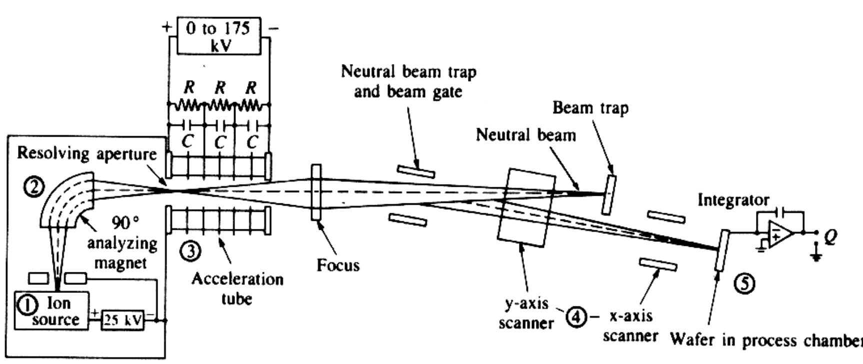
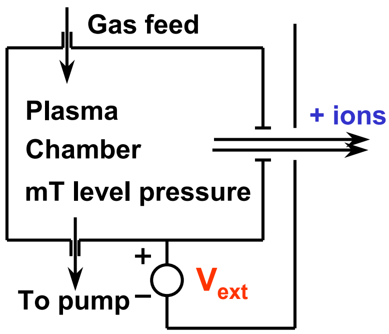
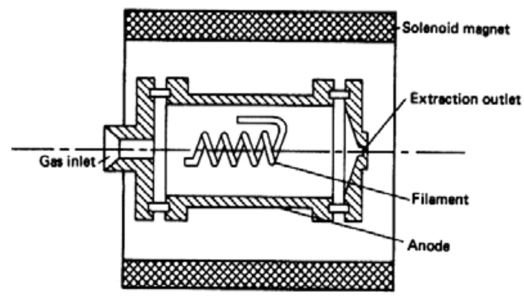



**Fig. 5.1** Schematic drawing of a typical ion implanter showing (1) ion source, (2) mass spectrometer, (3) high-voltage accelerator column, (4) *x*- and *y*-axis deflection system, and (5) target chamber.

# Plasma source and ion extraction



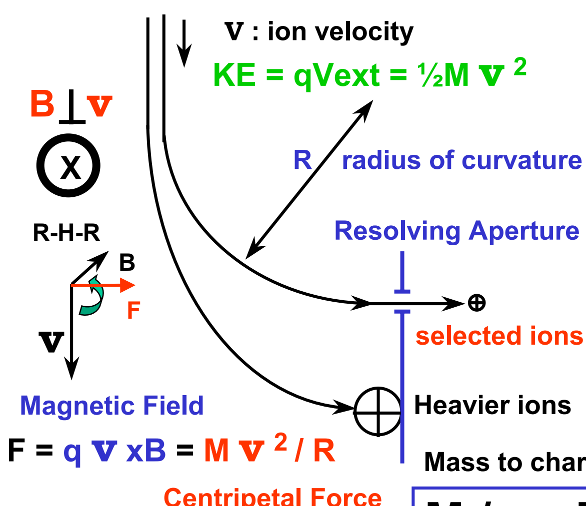

Nielsen-type gaseous source




variable extraction voltage
(typically ~30KV )



# Ion selection ( Analyzing Magnet)

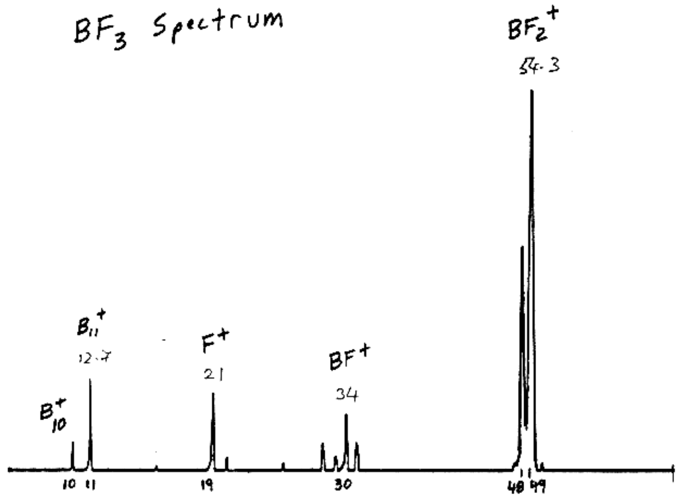



The ions are extracted from the source and analyzed in a magnetic field. The Lorentz force makes the ions take a curved path with a radius of curvature that depends on the mass of each ionic species. By adjusting the magnetic field strength, only the selected ions will enter the accelerating column.

Mass to charge ratio of the selected ions:

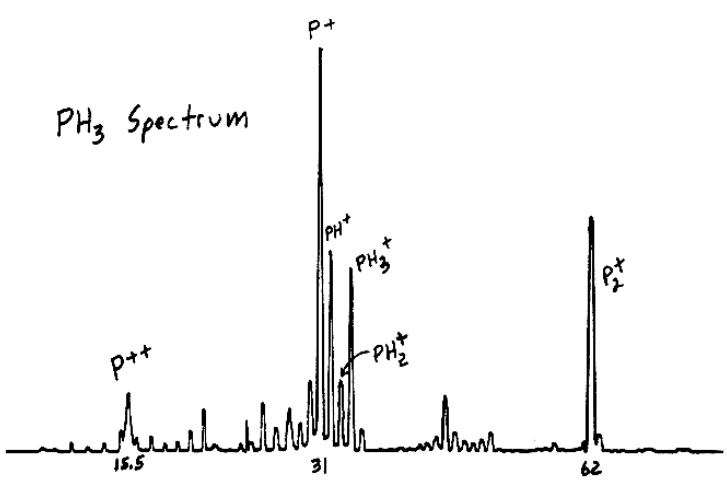
$$M/q = R^2 B^2 / (2\ Vext)$$

# $BF_3$ Gas Spectrum

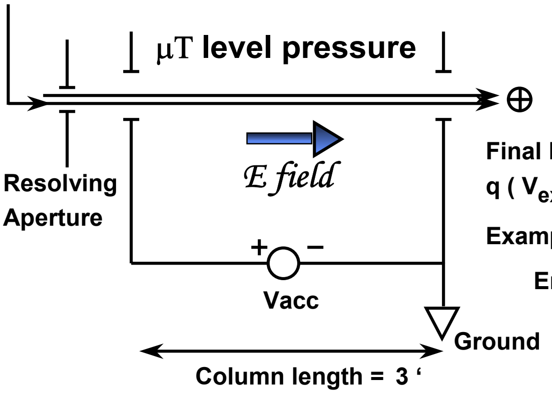





# $PH_3$ Gas Spectrum

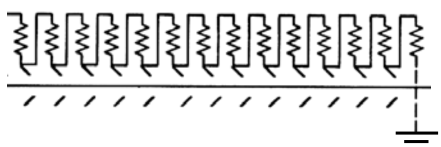


# Ion Acceleration




**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**

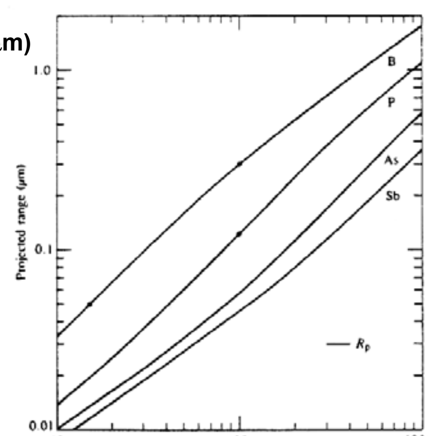




# Projected Range (Rp)

**Rp of Boron, Phosphorous, Arsenic and Antimony in Silicon as a function of the ion energy**

**Rp (μm)**

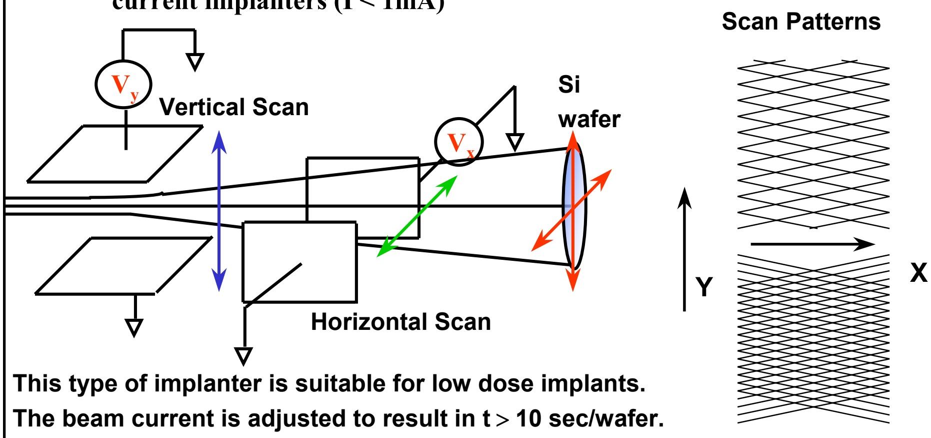



**Ion Energy (KeV)**

**Rp depends on incident and target atomic masses (complex)**

# Beam Scanning

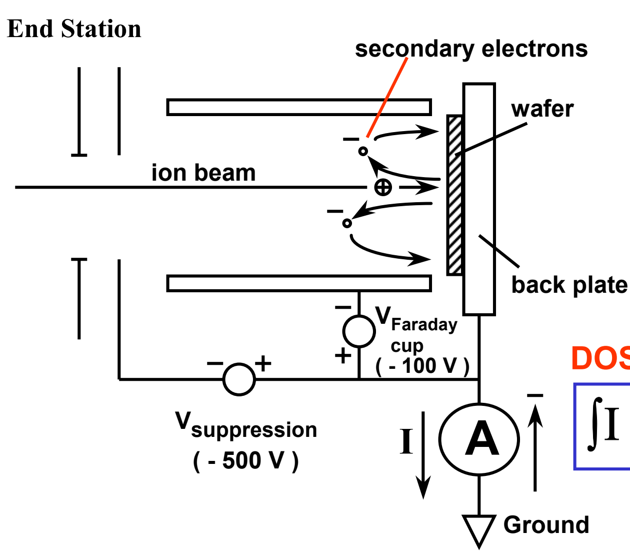
Electostatic scanning (low/medium beam current implanters (I < 1mA)




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.



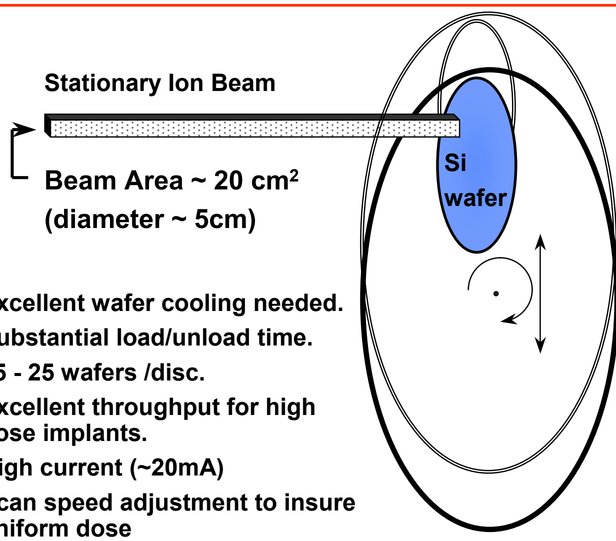
# In-situ Dose Control




**DOSE MONITORING**

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

# Mechanical Scanning




- Excellent wafer cooling needed.
- Substantial load/unload time.
- 15 - 25 wafers /disc.
- Excellent throughput for high dose implants.
- High current (~20mA)
- Scan speed adjustment to insure uniform dose