CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
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Lecture 16
Ion Implantation, part 1

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Reading:
Chapter 5, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell

Ion Implantation

- Since the late 1970s, ion implantation has been the preferred method of introducing dopants into a silicon wafer
  - Fine dose control
  - Shallow and well controlled junctions
  - Tailored dopant profiles
- Major implant settings
  - Ion species
  - Ion energy
  - Implant dose

Ion Implantation

- In a modern CMOS device, ion implantation is performed dozens of times
  - N-Well and P-Well formation
  - Creating p-n junctions to prevent current flow to substrate
  - Contacts (to lower contact resistance, prevent diode formation)
  - Gate doping to improve polysilicon conductivity
  - Threshold voltage adjustment
  - Source and drain formation (including LDD)

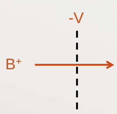
Ion Implanter Basics

- Generate an ion of the desired dopant species (As^+, B^+, etc.)
- Accelerate the ions into a beam at a specified energy
- Scan the wafer under the beam
- Stop when a set dose is achieved

Note: this is a relatively low-temperature process, and must be followed by a high-temperature anneal step

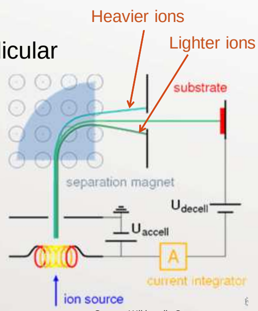
Ion Implanters

- Ion source
  - Gas or sputtered solid
  - Arsine (AsH_3), Arsenic Pentafluoride (AsF_5), Phosphine (PH_3), Diborane (B_2H_6), Boron Trifluoride (BF_3)
  - Apply a high current to create a plasma
- Ion accelerator
  - Kinetic energy $= \frac{1}{2}mv^2 = qV$



Ion Implanters (2)

- Mass spectrometer
  - Magnetic field perpendicular to ion velocity
  - $F = q(\vec{v} \times \vec{B}) = \frac{mv^2}{R}$
  - $K.E. = \frac{1}{2}mv^2 = qV$
  - result: $\frac{m}{qR^2} = constant$



Source: Wikimedia Commons

Ion Implanters (3)

- Ion accelerator to desired energy
  - Includes a bend to trap neutrals
- Beam sweeper
  - 2D parallel plates, 1D plus wafer scanning, or a stationary beam/ribbon plus 2D wafer scanning
  - Multiple wafer camber, wafer rotation
- Dose control
  - measure current through the grounded wafer
  - Typical doses: 10^{12} – 10^{16} cm^{-2}
- Wafers are typically cooled

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Ion Implanters

- Moderately expensive equipment ($5M)
- Tools are optimized for low, medium, and high energy (1 – 3000 keV)

Source: Applied Materials website

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Lecture 16: What have we learned?

- What are the three major process parameters for ion implantation?
- How many CMOS process steps can you name that use ion implantation?
- Describe how a mass spectrometer (mass analyzer) works
- How is dose controlled?