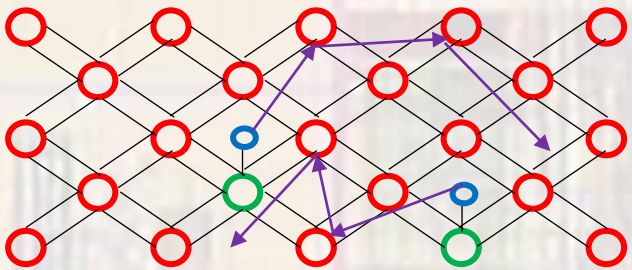
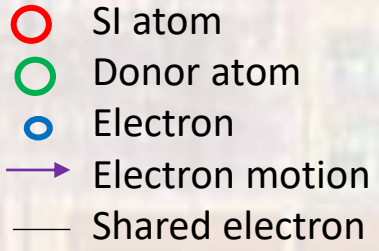
Carrier Action

Last updated 2/10/23

Carrier Action

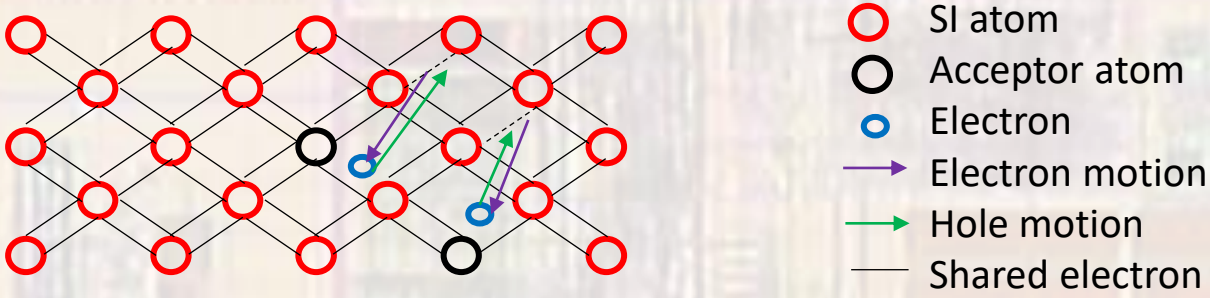
- Mobility
  - Measure of how easy(hard) it is to move a charged particle through a solid
  - Lots of physics here – but to simplify – for Si
    - Conduction electrons represent an excess electron in the shared 3sp band
      - Free electron generation requires breaking a relatively weak bond
      - Movement is limited by collisions





Carrier Action

- Mobility
  - Measure of how easy(hard) it is to move a charged particle through a solid
  - Lots of physics here – but to simplify – for Si
    - Valence holes represent a missing electron in the shared 3sp band
      - Hole generation requires breaking a relatively strong “normal” electron bond
      - Electrons must ‘find’ an open bond to move



Carrier Action

- Mobility
  - Measure of how easy(hard) it is to move a charged particle through a solid
  - For Si:

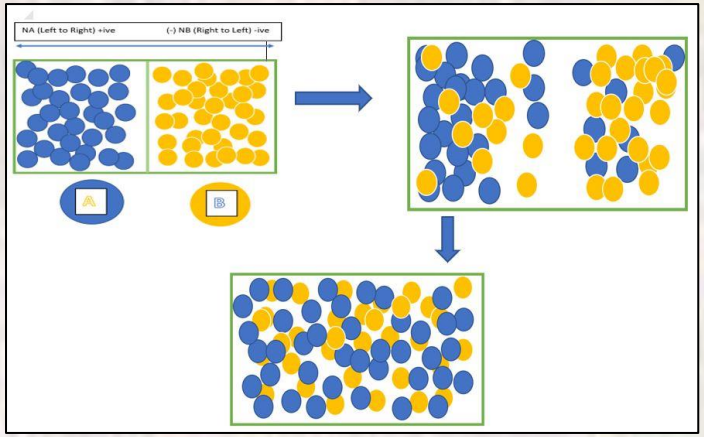
$$\mu_n \approx 1500 \frac{cm^2}{Vs}$$

$$\mu_p \approx 500 \frac{cm^2}{Vs}$$

This 3:1 ratio is critical to understand for good electronic circuit design

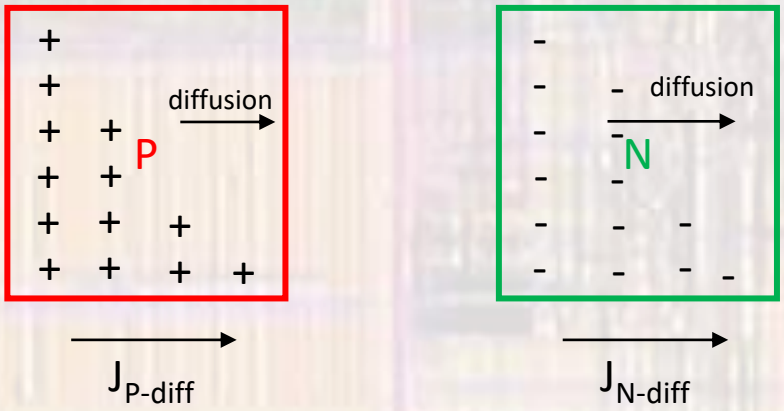
Carrier Action

- Diffusion
  - Process in which particles re-distribute due to their random thermal motion
  - In the end – the particles will be uniformly distributed



Carrier Action

- Diffusion – electrons and holes
  - Charged particles in motion → current
  - Current density: J (A/cm^2)



$$J_{P-diff} = -qD_P\nabla_P \qquad J_{N-diff} = qD_N\nabla_N$$

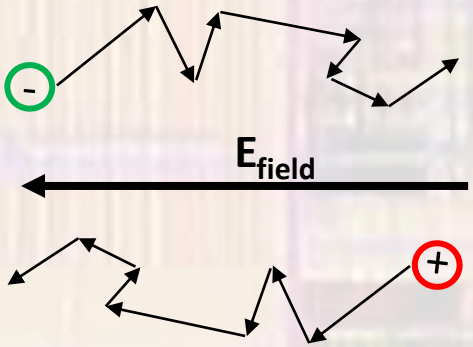
D – diffusion constant (cm^2/sec)
∇ – concentration gradient

$D_N \leq 36$ cm2/s
$D_P \leq 12$ cm2/s

Note: ∇_P and ∇_N are both negative in this illustration

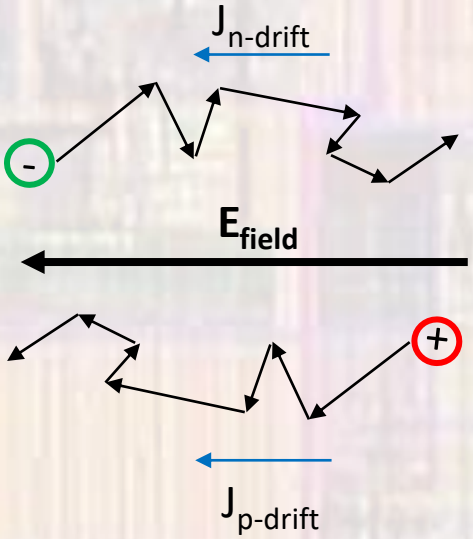
Carrier Action

- Drift
  - Motion of a charged particle due to an electric field
  - Subject to collisions and random thermal motion



Carrier Action

- Drift



$$J_{p-drift} = qp\mu_p \mathrm{E}$$

p – hole density
μ_p – hole mobility

$$J_{n-drift} = qn\mu_n \mathrm{E}$$

n – electron density
μ_n – electron mobility

Carrier Action

- Resistivity
  - Proportionality constant between J_{drift} and E
  - Resistivity – ρ, Conductivity – σ
  - σ = 1/ρ

$$J_{p-drift} = qp\mu_p E \qquad J_{n-drift} = qn\mu_n E$$

$$J_{p-drift} = \sigma E = \frac{1}{\rho} E \qquad J_{n-drift} = \sigma E = \frac{1}{\rho} E$$

- N_{type}
  - $n = N_D$

$$\rho = \frac{1}{q\mu_n N_D}$$

- P_{type}
  - $p = N_A$

$$\rho = \frac{1}{q\mu_p N_A}$$

Carrier Action

- Generation and Recombination
  - Generation – spontaneous creation of a hole/electron pair by the freeing of an electron from a normal atom
    - Thermal energy
    - Particle collisions (including photons)
  - Recombination – spontaneous combination of a hole and an electron to return an atom to its normal state
    - Statistical process – chance?