EE580 – Solar Cells
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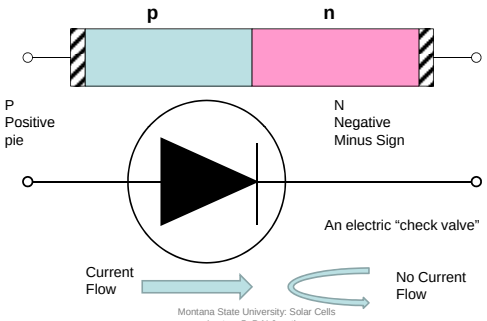
- Lecture 05
- P-N Junction

P-N Junction

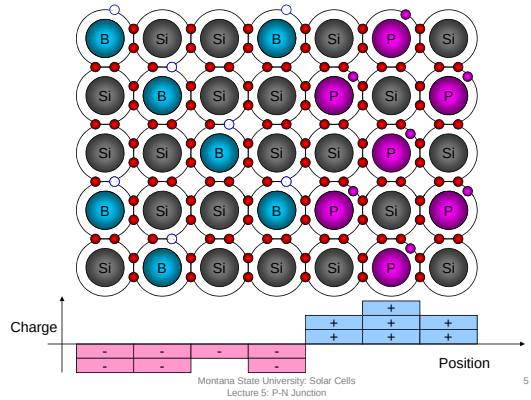
- Solar Cell is a large area P-N junction or a diode: electrons can flow in one direction but not the other (usually)
- Created by a variation in charge carriers as a function of position
- Carriers (electrons & holes) are created by doping the material
  - N: group V (Phosphorus) added (extra electron→ negative)
  - P: Group III (Boron)added (short electron (hole)→ positive)

p-n Junction



Creation of PN Junction

- High concentration of electrons in n-side
- High concentration of holes in p-side
- Electrons diffuse out of n-side to p-side
- Electrons recombine with holes (filling valence band states)
- The neutral dopant atoms (P) in the n-side give up an electron and become positive ions
- The neutral dopant atoms (B) in the p-side capture an electron and become negative ions



Creation of Electric Field

- Electric fields are produced by charge distributions
- Fields flow from positive charges (protons, positive ions, holes) and flow toward negative charges (electrons, negative ions)
- Free charges move in electric fields
  - Positive in the direction of field (holes)
  - Negative opposite to the electric field (electrons)

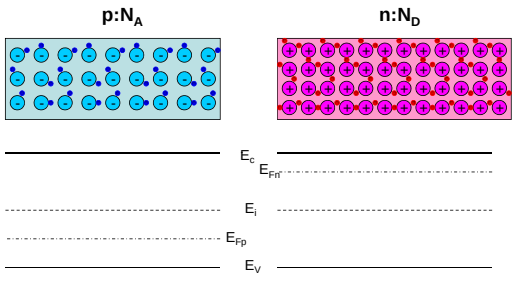
Creation of Depletion Region

- The local dopant ions left behind near the junction create an electric field area called the depletion region
- Any free carriers would be swept out of the depletion region by the forces created by the electric field (depleted of free carriers)
- The depletion area grows until it reaches equilibrium where the created electric field stops the diffusion of electrons

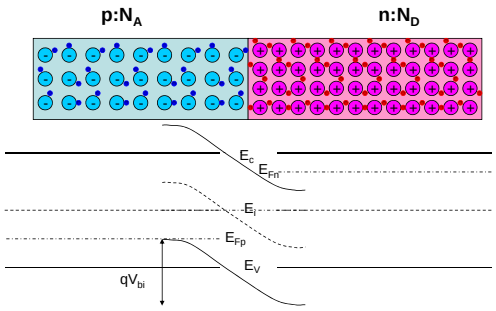
Creation of a Potential

- Changes in the electric field create a potential barrier to stop the diffusion of electrons from the n-side to the p-side
- The p-n junction has a built-in potential (voltage) that is a function of the doping concentrations of the two areas

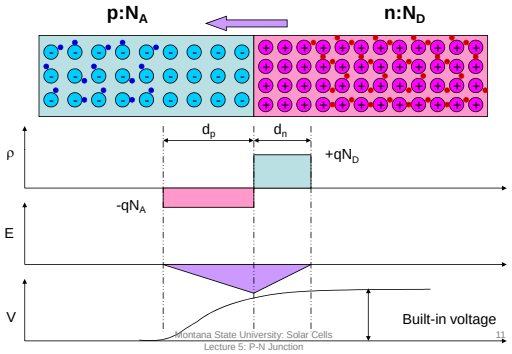
pn Junction in Thermal Equilibrium



pn Junction in Thermal Equilibrium



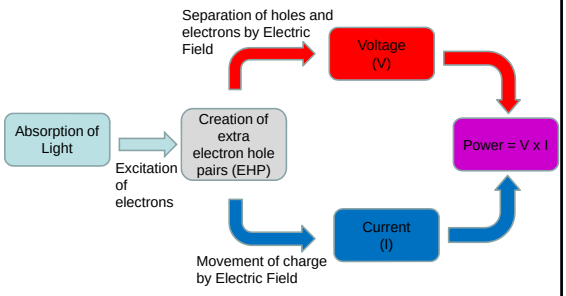
pn Junction in Thermal Equilibrium



Operation of PN Junction

- When sunlight is absorbed by the cell it unbalances the equilibrium by creating excessive electron-hole pairs.
- The internal field separates the electrons from the holes
- Sunlight produces a voltage opposing and exceeding the electric field in the internal depletion region, this results in the flow of electrons in the external circuit wires

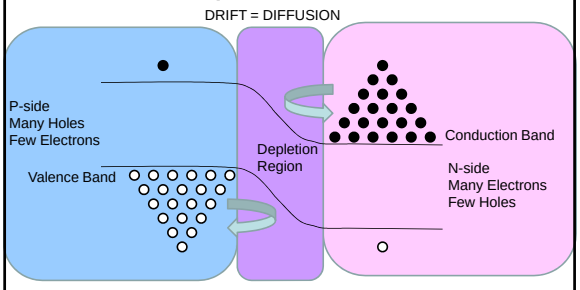
Photovoltaic Effect



Solar Cell Voltage

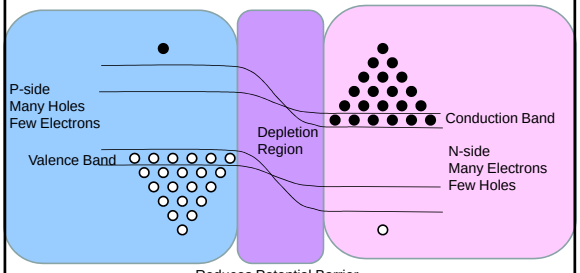
- In silicon, the electrons will need to overcome the potential barrier of 0.5 - 0.6 volts → any electrons(electricity) produced will be produced at this voltage

Diode Equilibrium Behavior



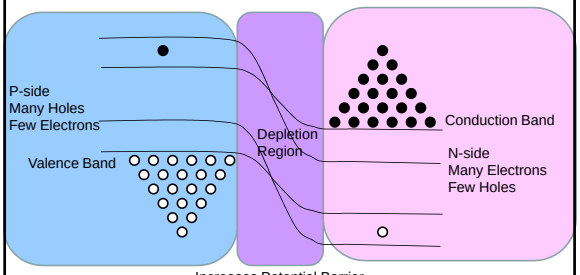
Potential Barrier Stops Majority of Carriers from Leaving Area

Forward Bias Behavior



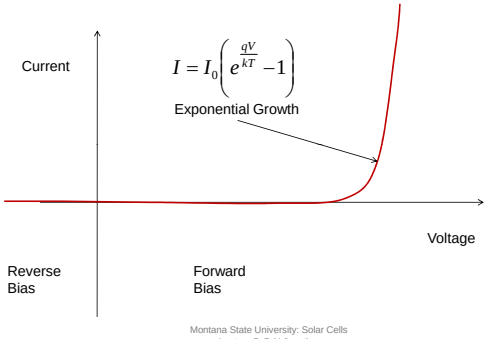
Reduces Potential Barrier
Allows Large Diffusion Current

Reverse Bias Behavior

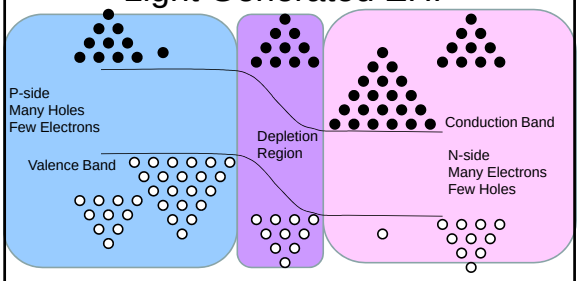


Increases Potential Barrier
Very Little Diffusion Current

Diode I-V Characteristics

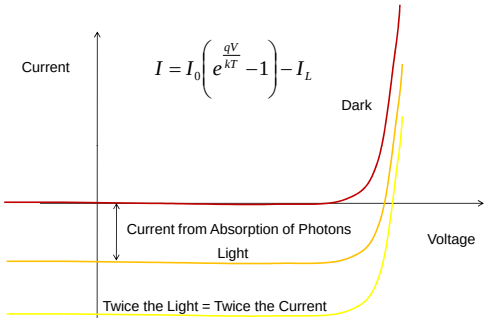


Diode Nonequilibrium Behavior Light Generated EHP

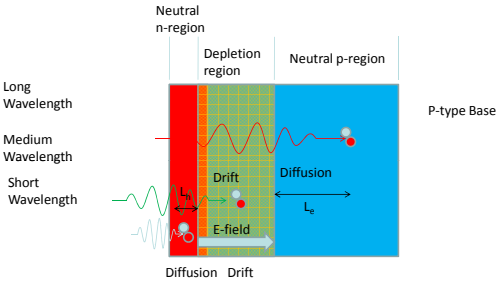


EHP are generated throughout the device breaking the equilibrium causing current flow

Solar Cell I-V Characteristics



Active Region



$$I_L = qAG\left(L_e + W + L_h\right)$$

Light Current

- Proportional to:
  - The Area of the solar cell (A)
    - Make cells large
  - The Generation rate of electron hole pairs (G)
    - Intensity of Light
  - The active area (L_e + W + L_h)
    - Make diffusion length long (very pure materials)

$$I_L = qAG\left(L_e + W + L_h\right)$$