Physics of a Solar Cell – What to pay attention to as we develop the models from elementary solid state physics.

Step 1: Light hitting the solar cell

- Reflection:
  - Anti-reflection coatings (alternating dielectric layers)
  - Texturing to increase number of bounces before reflecting (works against surface recombination)
- Wavelength of light (energy content per photon)
- Angle of incidence
- Cover glass/module optics
- Full metal back coverage can be used to give non-absorbed photons a “second chance” but the metal also creates strong points for electron-hole-pair recombination
Physics of a Solar Cell – What to pay attention to as we develop the models from elementary solid state physics.

Step 2: Absorbing Light and generating carriers

• Energy bandgap:
  • Determines which photons get absorbed and how soon
  • Direct vs. indirect bandgaps determine how thick the device has to be (thicker absorbs more light but thinner tends to produce more voltage)
• Where in the device the light is absorbed relative to the collecting junction—toward the front or back
Physics of a Solar Cell – What to pay attention to as we develop the models from elementary solid state physics.

Step 3: Diffusion of electron-hole pairs

• Recombination (electron killing off a hole) is key.
• Semiconductors “Minority carrier diffusion length”
  • Determined by the materials “mobility” and “minority carrier lifetime”
• Recombination at Internal defects: “trap states” at point defects (missing, extra or displaced atoms), extended defects (missing/extra columns or planes of atoms such as grain boundaries)
• Surfaces represent “enormous defects”
• Metal contacts kill off minority carriers.
Physics of a Solar Cell – What to pay attention to as we develop the models from elementary solid state physics.

Step 4: Collection or “separation” of electron-hole pairs

• Requires a force, most often resultant from an internal electric field. Can separate the electron from the hole to create a voltage.
  • Treating the region of the device that has an electric field as a dielectric, \( Q = CV \) (capacitor, but in a solar cell, \( C \) is a highly non-linear function of \( V \))
  • Separated charge can be “discharged” to drive current into an external circuit, i.e. generating power.
  • Local defects near the “junction” or weak electric fields will result in poor isolation of adjacent sides causing Shunting (partial shorting) of the electric fields.
• After “separation of the electrons from the holes, the carriers are now “majority carriers ready to enter the metal wires.
Physics of a Solar Cell – What to pay attention to as we develop the models from elementary solid state physics.

Step 5: Driving current into solar cell metal wires and external wiring

- Metal “Ohmic Contacts” only carry majority carriers.
  - Separated electrons/holes can enter wires
  - Yet – to – be separated electrons-hole pairs will recombine if they get near the metal

- Resistive losses (series resistances) waste the generated power and are engineered to be minimum

- Metal-semiconductor contacts are a major source of series resistance, long term failure and manufacturing headaches.