Solar Technology and the SmartFlower @ BJM High School

Developed for Chemistry 30
How do Solar Panels make Electricity?
Photovoltaic Cells

• A photovoltaic (PV) cell is an energy harvesting technology that converts solar energy into electricity.

• This is accomplished through a process called the photovoltaic effect.

• There are several different types of PV cells which all use semiconductors to interact with incoming photons from the Sun in order to generate an electric current.
Semiconductors

- Most metals are substances that conduct electricity and are called **conductors**
- Most non-metals are substances that do not conduct electricity and are called **insulators**
- Metalloids are substances with properties somewhere between them and most metalloids are **semiconductors**
Semiconductors

- Integrated circuits (computer chips and processors), diodes, and transistors are made of semiconductors.
- The semiconductors within them are often made of silicon or germanium.
Most Solar Panels are Made of Silicon
Parts of a Solar Panel

- Encapsulant is used to prevent the panels exposure to oxygen, moisture, UV rays, and to control temperature
- All things that could reduce the lifetime of the solar cells by increasing the rate of corrosion of the components
- Note: The parts of a solar panel are 90% recyclable by mass
Silicon has HUGE availability!!

- The Earth’s crust is the top 1% of the Earth
  - the surface of the Earth
- 59% of Earth’s crust is silica (SiO$_2$), 28% silicon.
- Silica does not require difficult or expensive mining, drilling, or extraction procedures.
  - Usually available as a byproduct of other mining processes that are already done.
Silicon and Valence Electrons

- Most Photovoltaic cells are made of silicon
- Silicon has 4 valence electrons and likes to form four covalent bonds
Silicon Crystal Lattice

- In a sample of pure silicon atoms it can form a tightly knit crystal structure that involves the formation of 4 perfect covalent bonds with other silicon atoms.
- This bonding pattern leaves few (or no) free electrons floating about.
- To make electricity we need to have a flow of free flowing electrons, so this cannot create electricity.
How Solar Panels Make Electricity

- Pure silicon can’t create electricity so we ‘dope’ it with other atoms
- **N-type doping of a silicon crystal** - When a silicon crystal forms with a small amount of phosphorus present the phosphorous gets included in the crystal lattice.
How Solar Panels Make Electricity

• Since phosphorous has 5 valence electrons it has a free floating electron that can’t bond within the silicon crystal.

• The ‘doped’ silicon becomes a semiconductor of N-type (negative, with an extra electron)
How Solar Panels Make Electricity

- Pure silicon can’t create electricity so we ‘dope’ it with other atoms
- P-type doping of a silicon crystal - When a silicon crystal forms with a small amount of boron present, the boron gets included in the lattice.
How Solar Panels Make Electricity

- Since boron has 3 valence electrons it has an electron hole and can’t bond with all 4 silicon atoms in the crystal.
- The silicon becomes a P-type semiconductor. P = positive (missing an electron)
A P-N Junction

- Most solar cells consist of two layers.
- A P-type silicon semiconductor can be placed on top of N-type silicon semiconductor.
- There is a transfer of electrons into the holes, creating and electron-hole pair.
- Electrons can only flow in one direction.
Is Electricity Created?

• **NO!**
• Over time the holes will be filled with electrons and the electrons from the N-type will be depleted.
  • Electrons will stop flowing

• Similar to a battery, a P-N Junction does not do work on its own.
  • Both need an external circuit so that electrons can flow

• A semiconductor is not a source like a battery though
  • We need to find a way to excite electrons so that they will conduct electricity!
Photoelectric Effect

• In 1905, Albert Einstein noted that when a material is exposed to photons of light it absorbs the light and gives off electrons.

• This was called the photoelectric effect. (Einstein won the 1921 Nobel Prize for this discovery.)
Photoelectric Effect and Photovoltaic Effect

- In the **photoelectric effect**, electrons are ejected from the material and no work can be done.
- If the excited electron is not ejected from the material but rather flows through the material then it is called the **photovoltaic effect**.
  - If that flow is harnessed to do work then we can create electricity
How do Solar Cells Work Exactly?

• When the silicon atoms absorb light, electricity generation begins.
  • Photon energy knocks some electrons out of the atoms (photoelectric effect).

• This causes them to migrate from the negative n-type layer to the positive p-type layer.
How do Solar Cells Work Exactly?

- This migration (movement) of electrons through the P-N Junction makes an electric field.
- A solar cell usually has metal contacts on its tops and bottoms. Electric current flows out of these metal plates and into an external circuit.
- The electricity, in direct current form, can then leave the solar cell through the metal contacts and be utilized by devices that can operate on direct current.
AC/DC?

- In order to power your home’s devices, the DC (Direct Current) electricity is then converted to AC (Alternating Current) electricity using a device called an inverter.
- The AC electricity can then be used to power your home’s electrical devices.
The Need for Battery Storage of Generated Solar Power

- Solar Output is the highest between 11 AM and 3 PM.
- Energy Demand is the highest between 8 AM and 10 AM and then again between 6 PM and 9 PM.
  - This does not align!
The Need for Battery Storage of Generated Solar Power

- Fields of Solar Panels need substantial battery storage.
SmartFlower Widens the Power Production Window with its DualAxis Tracking Technology

- Stationary Solar Panels
  - Point in only one direction
  - Are installed at a specific tilt angle
SmartFlower Widens the Power Production Window with its DualAxis Tracking Technology

- Dual Axis Tracker
  - SmartFlower tilts and rotates to follow the sun
Sunny Day Data Output from BJM SolarFlower Compared with Stationary Solar Cell Output

June 26th, 2022 (SmartFlower @ BJM)

Stationary Solar Panel Output (external source)

The area under the curve will be equal to the amount of power produced.
SmartFlower – The All-in-One Solution

- To combat the problem of energy usage not aligning with solar energy production, the SmartFlower is equipped with its own integrated battery storage system.
  - The energy stored in the batteries can be used at peak usage time if solar production is lower than demand.
- It also has its own battery charger and control box.
- These components would usually be installed inside of the building it would be trying to power.
SmartFlower –
The All-in-One Solution

- Solar panels also create DC (direct current) that must be changed to AC (alternating current) by an inverter
- The SmartFlower is equipped with an AC/DC inverter within the structure itself
- This component would usually be installed inside of the building it would be trying to power.
  - Often requiring engineers to create plans for wiring around existing infrastructure and electricians to install