Construction Paper Solar Cells

Subject: Modeling the structure and manufacturing process of silicon solar cells

Grade Levels: Elementary and Middle School

Lesson length: 40 to 75 minutes

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After learning about how solar cells are made in a solar lab, students re-create the multi-step process of making a silicon-based solar cell. Following a diagram with labels and a key of materials used in the manufacturing of solar cells, students use construction paper and other materials (e.g., silver pens, saran wrap) to represent the materials in each layer of a solar cell. Students then make connections between their PV cell and a real PV cell.

Objectives

➛ *Students will demonstrate the steps involved in making a silicon solar cell and explain the purpose of each step for optimizing solar cell efficiency.*

Materials

Each participant needs the following materials to create a construction paper model representing the structure of a silicon solar cell:

- Front panel grid paper template = the metal conductor strips (found at the end of this lesson; created by Cody Anderson, QESST RET)

- Construction paper colors:

  Aqua (bottom layer) lightly shaded with white or gray colored pencil (shade one entire side with colored pencil) = Metal Backing

  Green & Red = Silicon Layers

  Light Blue = Antireflective Coating

  Dark Blue w/ Grid = Top of Solar Cell
- Silver Ribbon = Busbars (metal strips to connect to receiver to allow electricity to flow)
- Silver Pen = Metal Fingers of Silver (these can be shared)
- White or Gray Pencil = Metal Backing (these can be shared)
- Transparent sheet protector = Glass Lamination (optional)
- Glue stick
- PowerPoint file "Captain Planet_Part 2" found on the QESST Education website.
- One or more examples of a construction paper solar cell model
- One or more examples of real silicon solar cells (with varying numbers of busbars, if possible)

Instructor Content Background Information

Video Energy 101: Solar Power produced by Energy Now:

https://youtu.be/NDZzAIcCQLQ

Video Bill Nye's video on Solar Power:

http://www.discoveryeducation.com/auth/STEM-Camp/energy/video-solar-power.cfm

Richard Komp's video, "How Do Solar Panels Work?":

https://youtu.be/xKxrkht7CpY

Nova created a useful image of the layers of a solar cell:

http://www-tc.pbs.org/wgbh/nova/solar/images/insi-01.gif

There are also interactive and printable versions of the image, along with text describing the anatomy of a solar cell and explaining how a solar cell works:

http://www.pbs.org/wgbh/nova/tech/how-solar-cell-works.html

Setup

Pre-cut and make materials ahead of time to save time in class. A lot of time for cutting is required to prepare for this activity, so you may want to gain access to a paper cutter.

Print and cut out a front grid panel or copy onto a transparency sheet for each student to use as the top of the solar cell. Draw small vertical lines connecting orange squares from top

to bottom using a silver pen to represent the "fingers" of the solar cell, which are made of silver.

Cut the construction paper layers. Each layer should be wider than the next so that each later can be seen from the top. In other words, the dark blue construction paper should be slightly wider on all sides than the front grid panel, the light blue construction paper should be slightly wider than the dark blue paper, the red should be wider than the light blue, the green should be wider than the red, and the aqua should be widest of all.

Finally, cut the silver ribbons into "busbars" long enough to span the length of the widest, lowest layer of the "cell", with some overhang. Cut enough ribbon that all participants can decide whether they want to design cells with between two and five evenly-spaced busbars.

Instructions

This lesson can be divided in two parts. Part I introduces students to ways to use the sun for energy, focusing in on solar cells. Part II helps students understand how a solar cell is made.

Part I: Using the Sun for Energy

In this part of the lesson, participants learn how photovoltaic engineers design ways to generate electricity from the sun. They will then focus on one particular device, solar cells,.

Discuss questions such as the following in order to help participants orient to the task and recall relevant prior knowledge.

- What is energy?
- Who uses energy and how?
- Why do we need energy?
- Where does energy come from?
- How is energy stored?
- What do you know about solar energy?
- How do we use the sun for energy?
- What would the earth be like without the sun?

More participants will have the opportunity to talk if this discussion activity occurs in small groups of three to four participants rather than in a whole-group setting. The discussion can be organized using the Kagen structure, *Talking Chips*: each person chooses two questions or is assigned two questions to answer to the best of their ability.

Discuss the sun as a source of energy, citing fun solar facts, the optimal global locations to capture solar energy, and how photovoltaic engineers generate electricity from the sun. You might want to show the video, *Energy 101: Solar Power.* The video introduces and explains how different types of solar devices work: (~4 minutes).

1) Photovoltaic (solar) cells, panels, and arrays
2) Solar thermal electric power plants (solar concentrators)

Then, focus in more detail on how solar cells turns sunlight into energy. One place to start is Bill Nye's video on solar power and its applications (~6 minutes).

You might want to pause here for a check of understanding. Have participants talk to a partner, in small groups to answer basic knowledge questions such as the following:

- Referring to the word *photovoltaic*, what do the terms *photo* and *volt* mean?
- What is the difference between a solar cell, solar panel, and solar module?
- How does the sun's light and a solar panel work together to make electricity?
- Why aren't more people using solar panels? What are some restrictions?

Part II: How to Make a Solar Cell

In this part of the lesson, participants learn how current is generated in a solar cell. They then learn the steps involved in making a silicon solar cell. Finally, they make a model of a silicon solar cell using construction paper and other everyday materials.

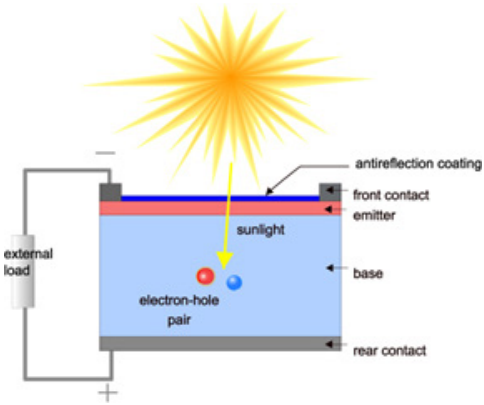
Teach participants how current is generated in a solar cell. Generating current in a solar cell involves two processes:

1) Incident photons are absorbed and electron-hole pairs created.
2) Light-generated carriers are collected by the p-n junction.

For a quick guide to a PV cell in action, see Richard Komp's TedEd video, "How Do Solar Panels Work?" https://youtu.be/xKxrkht7CpY (~4 minutes)

You might show this explanation and animation of the ideal short circuit flow of electrons and holes at a p-n junction: http://pveducation.org/pvcdrom/light-generated-current

The next step is to teach participants how solar cells are manufactured. You can use Jill's PowerPoint, "Captain America Part 2", to introduce the processes involved in manufacturing silicon solar cells. You might also use this interactive animation of how screen printed solar cells are manufactured (explains the steps modeled in the construction paper solar cell: http://pveducation.org/pvcdrom/manufacturing/screen-printed).



Another resource is Alex Killam's PowerPoint on "Solar Cells for Beginners", posted

to the QESST Education website. It includes photos of actual tools used in the pilot line of the industrial solar cell laboratory at the ASU Solar Power Lab.

Now guide participants in making a model of a solar cell. Tell participants that they are going to create a model of a silicon solar cell. Pass out materials and walk participants through each step in the manufacturing process. You can use using the "Captain Planet Part 2" PowerPoint slides found on the QESST Education website to guide participants through the steps in the solar cell manufacturing process. Do NOT explain the whole process at once. Because learners can only process a small amount of information at one time, the outreach leader or teacher should describe each step of the process along the way. It is important to connect your explanation of the processes and purposes involved in manufacturing to each action the participants make in adding a layer to their model of a solar cell. Use the supporting visuals found at the end of this lesson.

Each participant will layer the construction paper to match the Nova image. They will add another component (busbars) not featured in the diagram. On the top, students can paste the solar cell front panel grid on top or the transparency of the front panel. On the bottom of the solar cell model, students can color the entire back with a gray or white pencil. Then, they can use the silver pens to draw the three columns of dashed lines that represents the silver etching. They use the silver ribbon to represent busbars that connect on the right side and another set that connects on the top. (Note: Do not glue one silver ribbon all the way down to show silver etching on aluminum backing. Silver etching (3 dashes) are under the busbars when tabbing i.e., soldering).

Finally, participants insert the model into a sheet protector, representing glass lamination.

Along the way, ask questions to prompt thinking and check understanding. Here are some examples:

- How does the silver ribbon, "busbar" connect to the receiver, such as a lightbulb? How does this connection generate electricity? (connect to knowledge of circuits)
- Looking at the examples of real solar cells: Why are some of the busbars on different sides? How does that affect the flow of electricity? Discuss how a conductor is made of metal which allows the energy to flow (conduct)

Assessment

Jigsaw activity: Assign groups one question to reflect upon by using the Kagan structure, *Jot Thoughts*. Participants independently generate as many responses as possible by writing one response to the assigned question on a sticky note (one response per sticky note). As a group, participants pick out 2-4 essential responses to share with the class. Each group will choose a representative to share responses. Create an anchor chart ("Connections: Making a PV Cell") to post their sticky note responses.

- What connections can you make from your PV cell to a real PV cell?
- How much energy can one PV cell generate electricity?
- How much energy can an array of PV cells generate electricity?

- What items could you connect to a PV cell to generate electricity?
- What items could you connect to an array of PV cells?
- Why do solar panels cost so much? Think about the time & materials that go into building PV cells and arrays.

Deepen your Knowledge

Participants can also use the following materials to create food PV cell: bread as the wafer, mayo as the aluminum, spray butter as the phosphorus, lettuce as the anti-reflective, and mustard as silver busbars. In a science notebook, students create a Venn diagram showing the similarities and differences between the construction paper PV cell and the food PV cell. Encourage students to take pictures and email them to the teacher for a class share session.

Next Generation Science Standards

This lesson was designed around the middle school Next Generation Science Standards (NGSS) and covers the following standards:

- 4-ESS3 Earth and Human Activity

  4-ESS3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

  4-ESS3-2: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

  ESS3.A: Energy and fuels that humans use are derived from natural resources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not.