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Center for Renewable Energy Advanced Technological Education

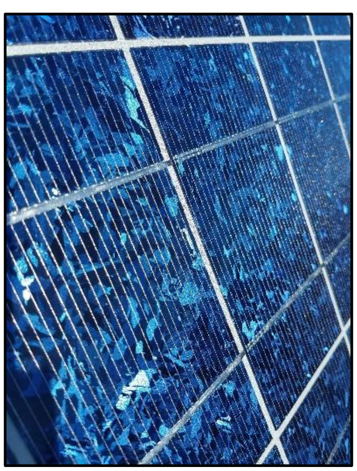
Name: ____________________________

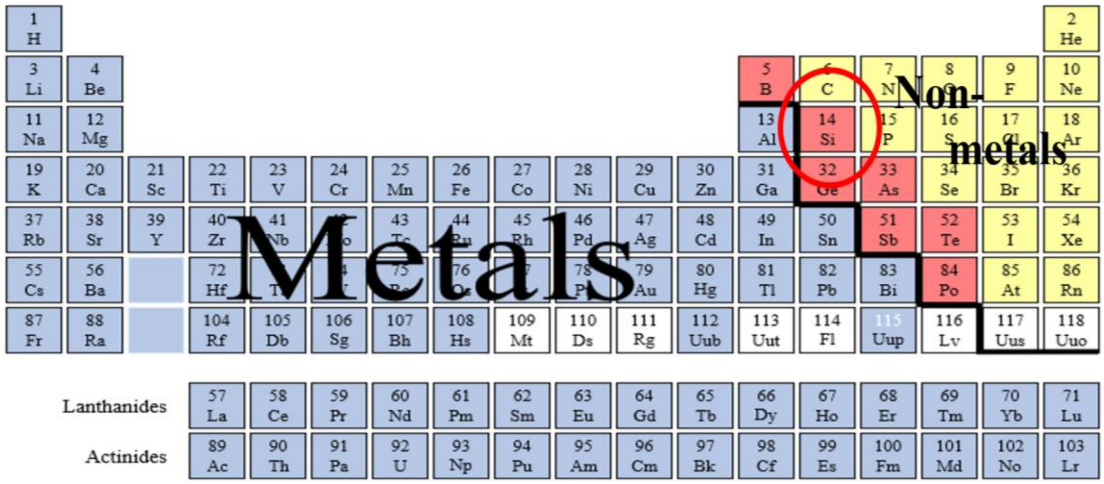
Date: ___ / ___ / ___ Class Hour: ___

SOLAR PV:

SILICON


The element silicon is a great place to begin any study of solar power (solar electricity, solar photovoltaics, or solar PV). The dark material just below the protective glass on the top of a solar module is silicon--silicon and tiny wires to conduct the electricity they produce. As you'll learn, that silicon is highly purified. Silicon also comes from one of the simplest and most readily available substances on earth--sand. Finally, silicon has very special properties that make it the element of choice for use in solar PV panels. Turn the page to find out more about this special, but common element, and how it may lead the way to an expanded renewable energy economy.





Resume: Uniquely Ordinary Silicon

Objective: Seeking to provide clean, efficient, and cost-effective renewable electricity to larger numbers of people in the United States, and across the world.

Profile: Discovered in 1824, I am the fourteenth element on the periodic table. I am both ordinary and unique. I am *ordinary* because I am the 8th most common element in the universe, and the 2nd most common element in the earth’s crust. Found just about everywhere, I am combined with other elements in ordinary sand. In pure form, I am a hard, brittle, dark colored crystal. I am *unique* because when purified, I am a metalloid, having properties between those of metals and nonmetals. One of the most important of those properties is that I am a semiconductor. This means I have an electrical conductivity between that of a non-conducting insulator, and that of a good conducting metal. This semiconducting property provides me, Silicon, with just the right conductivity for the controlled flow of electrons—electricity!

Background and Experience: I have long been used in clays, cement, mortar, and concrete, as well as various ceramics and glass applications. I am heavily used in the making of many metals, such as steel and aluminum. As you might expect, I am an important component in Silicone, which is most often used as a sealer or caulk.

It is my semiconductor property that makes me especially valuable, though. Today I am used in nearly every digital and electronic device common to daily life. I am at work in almost every computer chip, digital processor, and transistor across the planet. You’ll find me in products ranging from televisions to microwave ovens, laptop computers to supercomputers, cell phones to smart watches, and many, many, more.

Summary: Because of my special combination of properties, I am used to produce an electric current when exposed to sunlight in most solar photovoltaic panels today. With improved efficiency in converting light to electricity and several decades of experience in this field, I am ready and available for greater employment in the renewable energy economy.

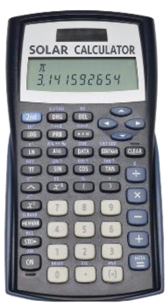
References:

- **Jöns Jacob Berzelius** (Sweden) who discovered me in 1824.
- **Alexander Edmond Becquerel** (France) who as a nineteen year old in 1839, discovered that I can develop a voltage when exposed to light--the “photovoltaic effect”.
- **Charles Edgar Fritts**, (United States) who made the first working solar module, producing a current "that is continuous, constant, and of considerable force" in 1883,
- **Gerald L. Pearson, Daryl M. Chapin, and Calvin S. Fuller** (United States) who in 1954, using a silicon “solar cell,” converted sunlight directly into electricity.

The Growth of Silicon in Solar PV, 1950’s to the Present

Pearson, Chapin, and Fuller gave birth to the solar economy in the 1950’s. Like any new technology, it was expensive and needed improvement. In the early years, its best use was in remote locations--places to which it was expensive to run electrical wires. At locations like these, solar PV was cost effective in its early years.

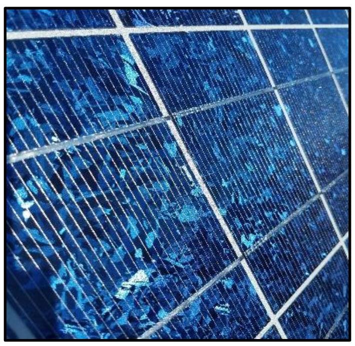
Among the first solar PV applications on the planet was to supply power for telephone use in remote rural locations. The most remote location of all soon followed--space. Solar PV has powered virtually every satellite since the mid-1950's. As efficiency improved and costs crept down, solar PV showed up on toys, radios, and calculators, and on boats and campers.



In time solar PV, along with related battery storage technology, was scaled up to power entire homes in distant locations. Living "off the (electricity supply) grid" was becoming a reality for some. Today, solar PV systems without expensive battery storage are popular in urban locations. Taking advantage of improved efficiency and much lower installation costs, these PV systems are engineered to interact with the utility electric supply grid.

Solar has plainly come a long way since the 1950’s. But silicon is still at the heart of solar photovoltaic technology today. It’s unique blend of properties have yet to be surpassed by any other substance.

Found universally in sand, silicon must be refined to above 99.9% purity to be useful as a semiconductor. The most highly refined silicon is sliced into ultra-thin sheets (called “wafers”) and made into monocrystalline solar cells. These cells are made from a single, large crystal of silicon. About 20% of the energy in sunlight is converted to electricity when using monocrystalline silicon. This makes monocrystalline silicon solar panels the most efficient solar panels on the market. Monocrystalline solar cells are usually easy to spot. Their deep, dark color is uniform, and there are usually small notches in the corners of each solar cell.

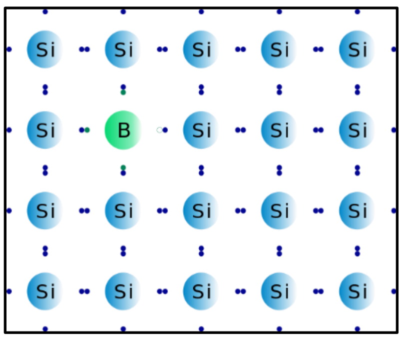


Solar panels made of polycrystalline silicon cells are a little less effective at converting sunlight into electricity. Polycrystalline cells are sliced into wafers from many fragments of silicon crystals that have been melted together. Less efficient at around 15 %, they are also notably less expensive. They are usually easy to distinguish from their monocrystalline counterparts. Polycrystalline solar cells will almost always be fully square (no notched corners). Look closely at the surface of a polycrystalline solar cell and many separate silicon crystals will be easy to see.

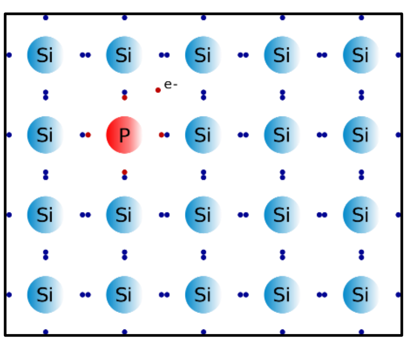
Thin film or amorphous solar panels are quite different. They are made by depositing a thin layer (or several thin layers) of silicon on glass, plastic, or metal. Their efficiency range is around 10%, but once again, they are less expensive to produce. Thin films can also be applied to a variety of materials, and these materials may be pliable. This makes amorphous or thin film solar technology especially useful in applications that require flexibility.

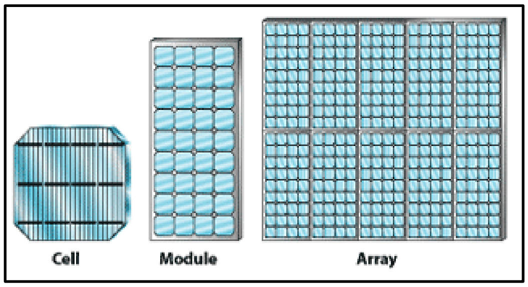
Most solar modules are rectangular with a metal frame. A typical module has a protective back sheet, an anti-reflective coating, and high strength glass over the top

By itself, silicon is not effective enough at producing usable electric current to be useful. It needs to be “doped” to produce a useful, one-way flow of electrons. “Doping” is done by adding small amounts of other elements to a semiconductor to improve and control its electrical conductivity.



Two of the most common “dopants” are phosphorus and boron. The addition of these dopants enables the silicon to behave like a diode. A diode is a material or device that allows electrical current to flow in one direction only. Doped PV cells and diodes contain two regions, one of which has an excess of electrons (n-type or negative-type). The other region has a shortage of electrons (p-type or positive-type). When sunlight strikes the surface of a PV cell, it causes electrons to become “excited” and move in one direction (negative to positive) through the cell. The energy of these moving electrons produces a usable electric current.





Tiny electrical contacts enable the electric current to run through each PV cell. Somewhat larger contacts are attached to the side of each PV cell. Many PV cells are then connected together to form a solar panel, or module. Each module has a junction box on the back with wires available to connect one module to another. Modules can be connected to an array of almost any size to meet a range of electrical demands.

Follow-up Questions

Some of these questions may require you to do a little additional research to answer.

1. What "ordinary" property of silicon makes it unusually well suited for use in producing solar photovoltaic power. In your answer explain how, or why, that property matters.

***Answer**

2. What "unique" property of silicon makes it unusually well suited for use in producing solar photovoltaic power. In your answer explain how, or why, that property matters.

***Answer**

3. What are the differences between monocrystalline silicon, polycrystalline silicon, and thin film solar PV? In your answer explain how you can tell the three apart from each other.

***Answer**

4. Why does silicon need to be doped for it to become useful in producing electricity? In your answer, explain how doping silicon improves silicon's usefulness in solar PV.

***Answer**