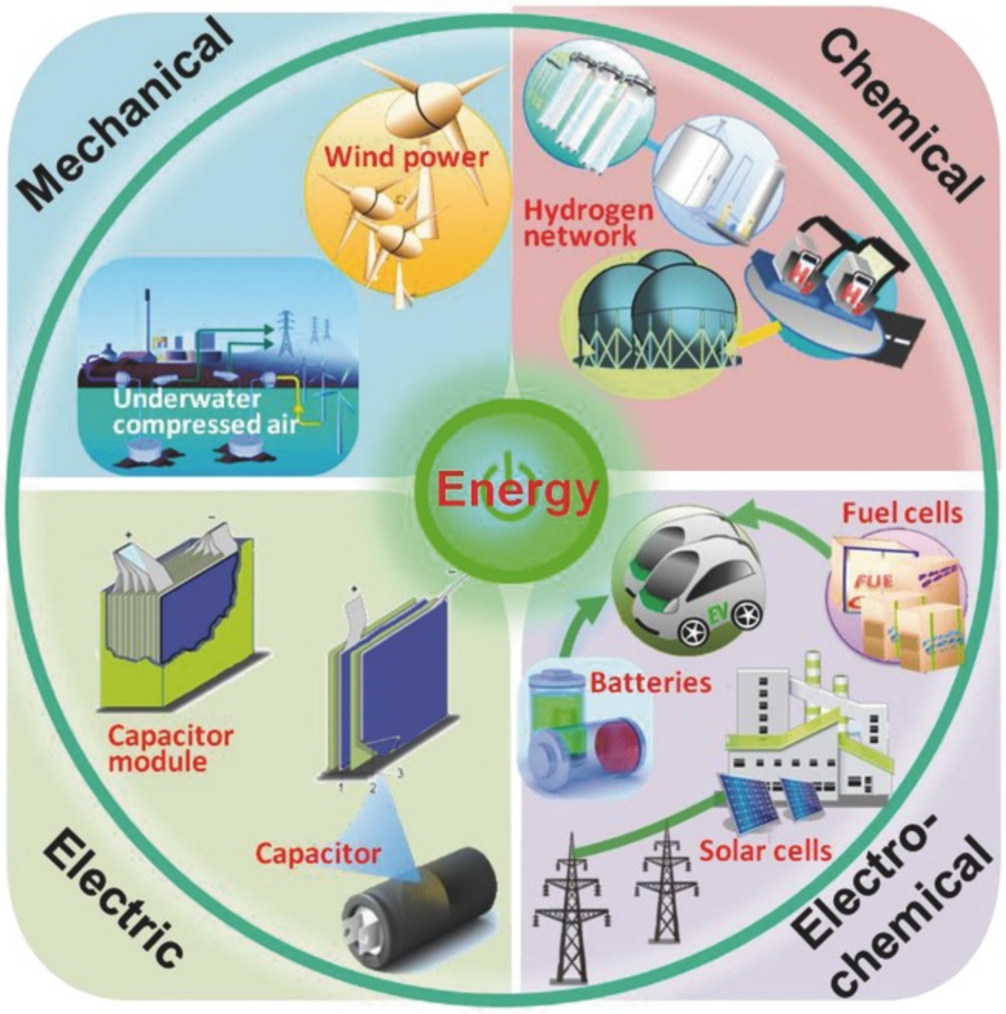
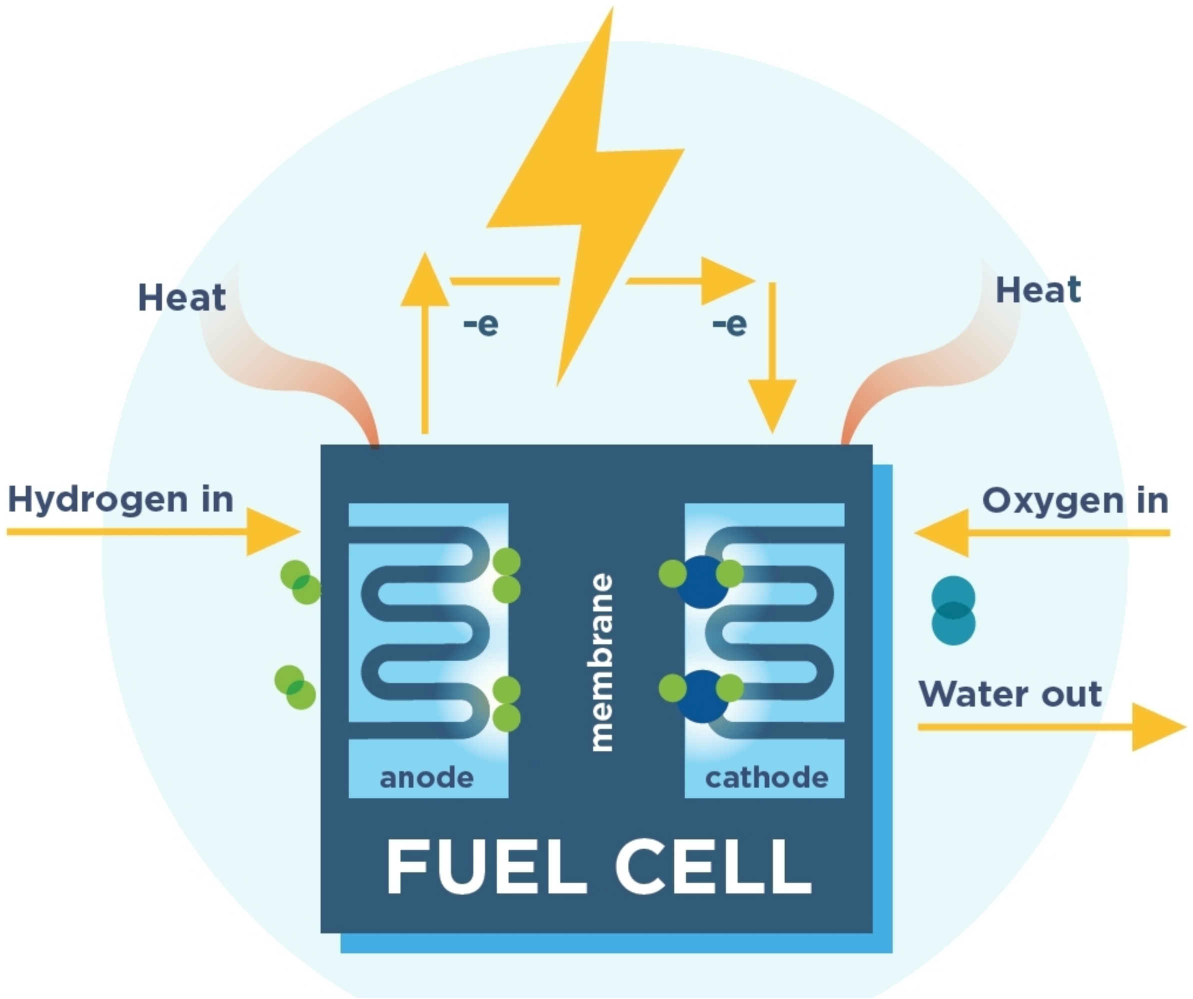
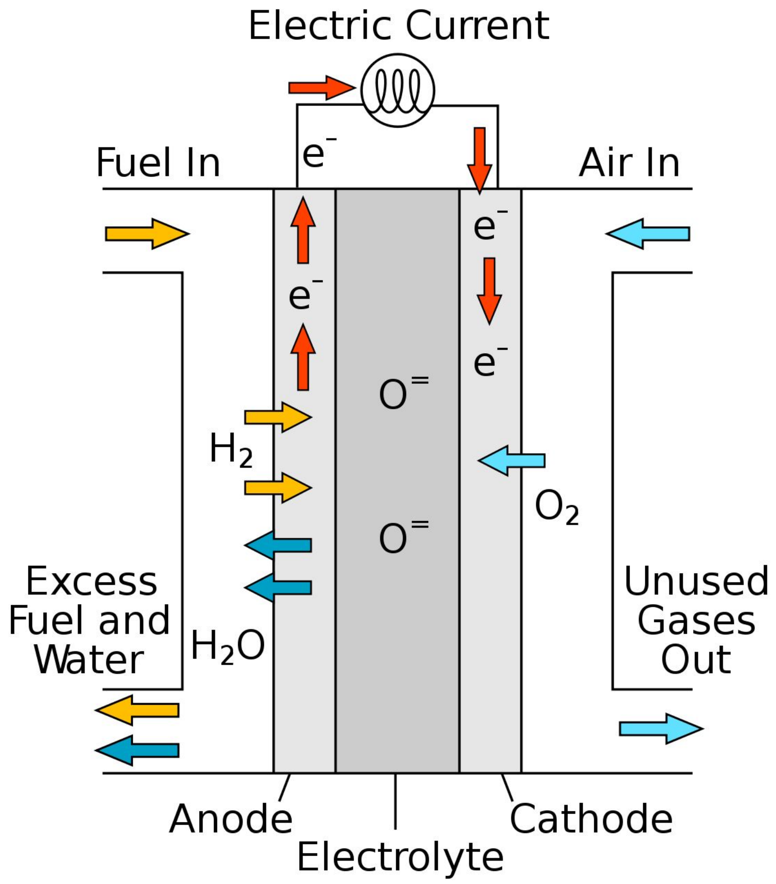
Energy devices




Heat
-e
-e
Heat
Hydrogen in
Oxygen in
membrane
Water out
anode
cathode
FUEL CELL

What are Fuel Cells?

Fuel cells are electrochemical devices that convert chemical energy from the reactants directly into electricity and heat. The device consists of an electrolyte layer in contact with a porous anode and cathode on either side. An illustration of a fuel cell with reactant/product gasses and the ion conduction flow directions through the cell is shown in Figure.



In a standard fuel cell, gaseous fuels are fed continuously to the anode (negative electrode), while an oxidant (oxygen from the air) is fed continuously to the cathode (positive electrode). Electrochemical reactions take place at the **electrodes** to produce an electric current.

How Fuel Cells Work

Fuel cells work like batteries, but they do not run down or need recharging

They produce electricity and heat as long as fuel is supplied. A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte.

A fuel, such as hydrogen, is fed to the anode, and air is fed to the cathode. In a polymer electrolyte membrane fuel cell, a catalyst separates hydrogen atoms into protons and electrons, which take different paths to the cathode.

The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they reunite with oxygen and the electrons to produce water and heat

Types of Fuel Cells

Although the basic operations of all fuel cells are the same, special varieties have been developed to take advantage of different electrolytes and serve different application needs.

The **fuel and the charged species migrating through the electrolyte** may be different, but the principle is the same.

An **oxidation occurs at the anode, while a reduction occurs at the cathode**.

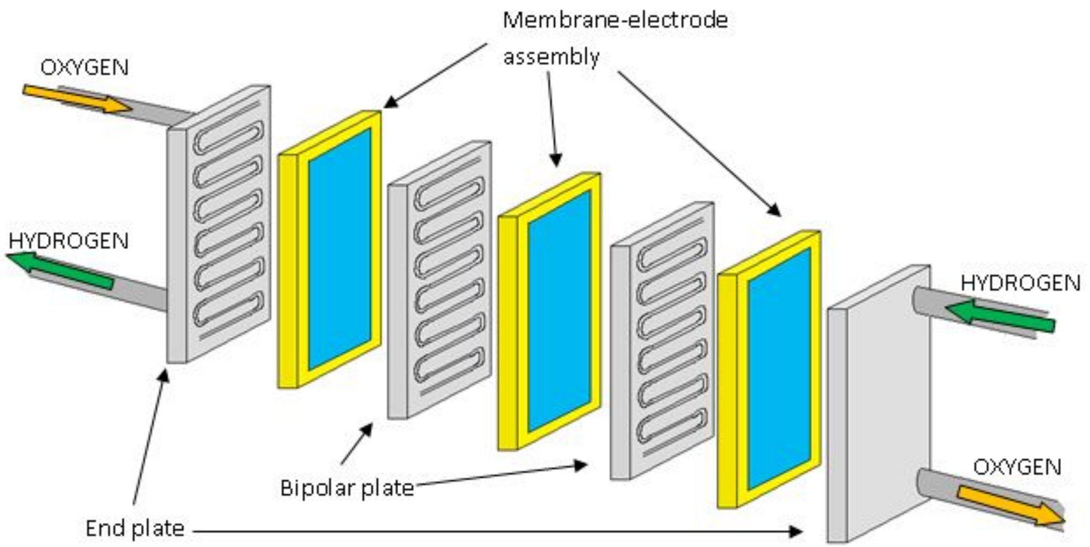
The two reactions are connected by a charged species that migrates through the electrolyte and electrons that flow through the external circuit

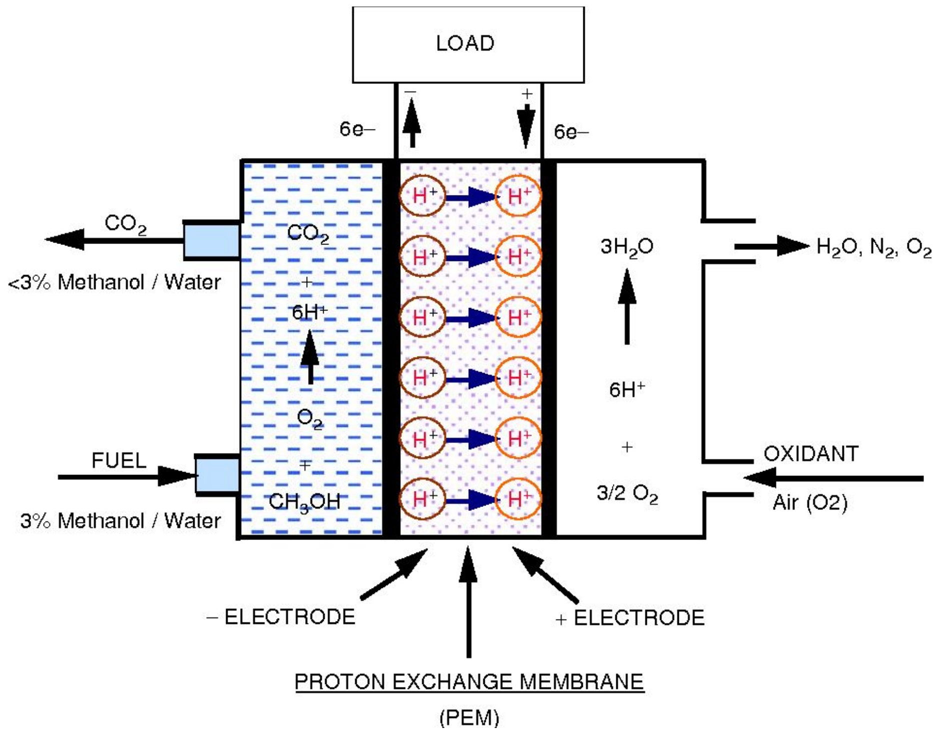
❑POLYMER ELECTROLYTE MEMBRANE FUEL CELLS

Polymer electrolyte membrane (PEM) fuel cells, also called proton exchange membrane fuel cells, use a proton-conducting polymer membrane as the electrolyte. Hydrogen is typically used as the fuel. These cells operate at relatively low temperatures and can quickly vary their output to meet shifting power demands. PEM fuel cells are the best candidates for powering automobiles. They can also be used for **stationary power production**. However, due to their low operating temperature, they cannot directly use hydrocarbon fuels, such as natural gas, liquefied natural gas, or ethanol. These fuels must be converted to hydrogen in a fuel reformer to be able to be used by a PEM fuel cell.

❑DIRECT-METHANOL FUEL CELLS

The direct-methanol fuel cell (DMFC) is similar to the PEM cell in that it uses a proton conducting polymer membrane as an electrolyte. However, DMFCs use methanol directly on the anode, which eliminates the need for a fuel reformer. DMFCs are of interest for powering portable electronic devices, such as laptop computers and battery rechargers. **Methanol provides a higher energy density than hydrogen,** which makes it an attractive fuel for portable devices.


Membrane-electrode
assembly
OXYGEN
HYDROGEN
HYDROGEN
OXYGEN
Bipolar plate
End plate

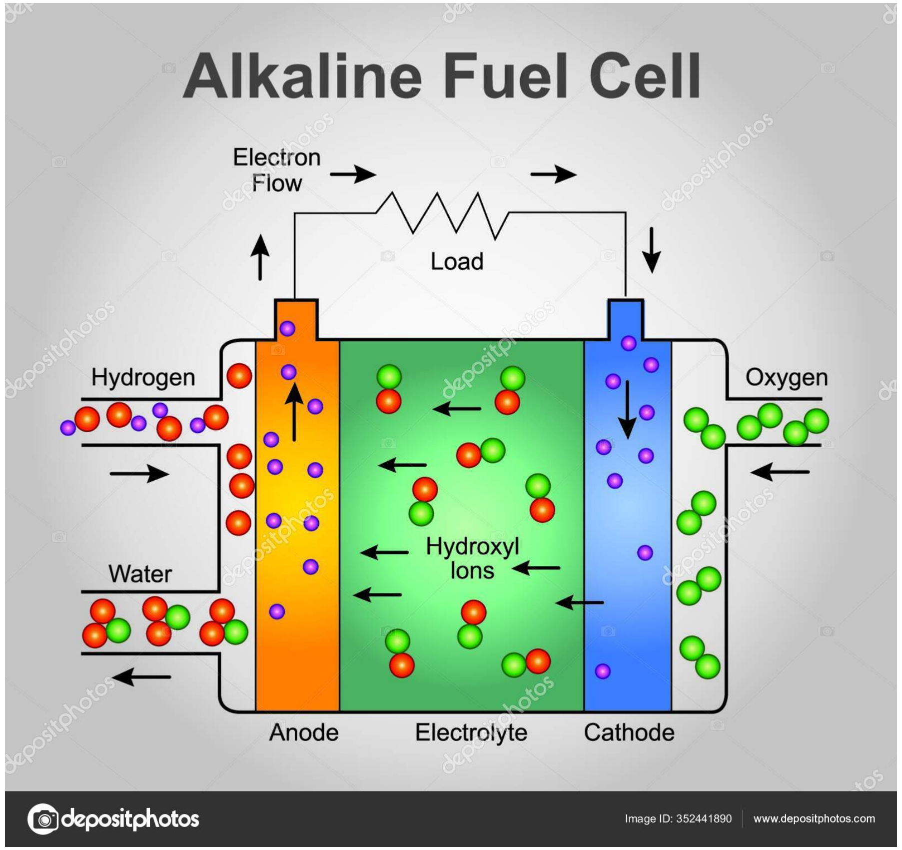

LOAD
6e–
6e–
CO2
<3% Methanol / Water
CO2
+
6H+
O2
+
CH3OH
FUEL
3% Methanol / Water
H+
3H2O
6H+
+
3/2 O2
H2O, N2, O2
OXIDANT
Air (O2)
– ELECTRODE
+ ELECTRODE
PROTON EXCHANGE MEMBRANE
(PEM)

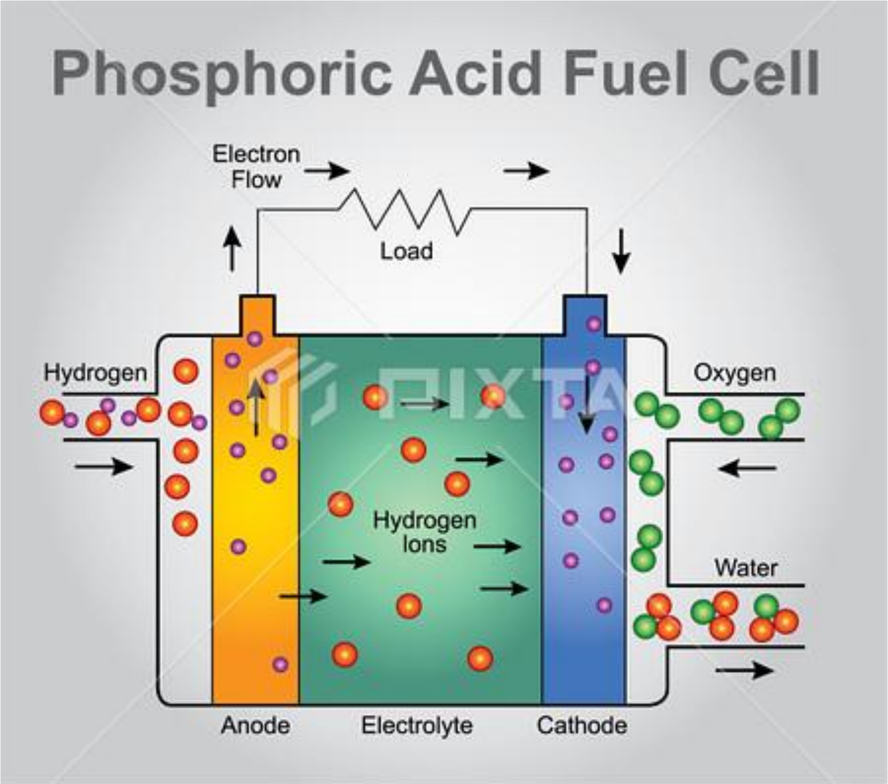
❑ALKALINE FUEL CELLS

Alkaline fuel cells use an **alkaline electrolyte such as potassium hydroxide** or an alkaline membrane that conducts hydroxide ions rather than protons. Originally used by the National Aeronautics and Space Administration (NASA) **on space missions**, alkaline fuel cells are now finding new applications, such as in portable power.

❑PHOSPHORIC ACID FUEL CELLS

Phosphoric acid fuel cells use a **phosphoric acid electrolyte** that conducts protons held inside a porous matrix, and operate at about 200°C. They are typically used in modules of 400 kW or greater and are being used for stationary power production in **hotels, hospitals, grocery stores, and office buildings, where waste heat can also be used.** Phosphoric acid can also be immobilized in polymer membranes, and fuel cells using these membranes are of interest for a variety of stationary power applications.





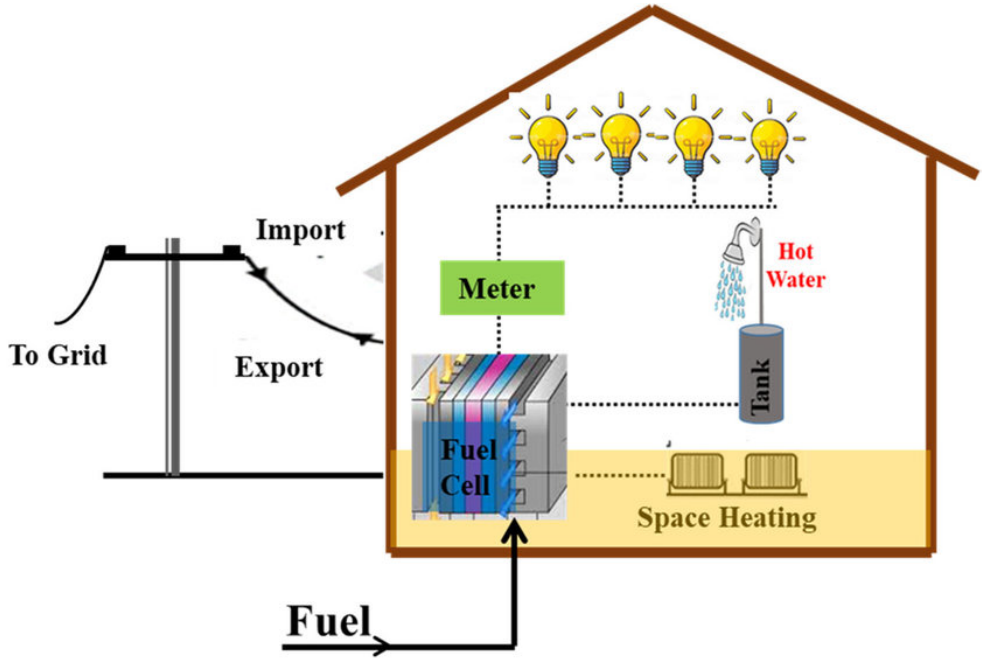
pixtastock.com - 31746636

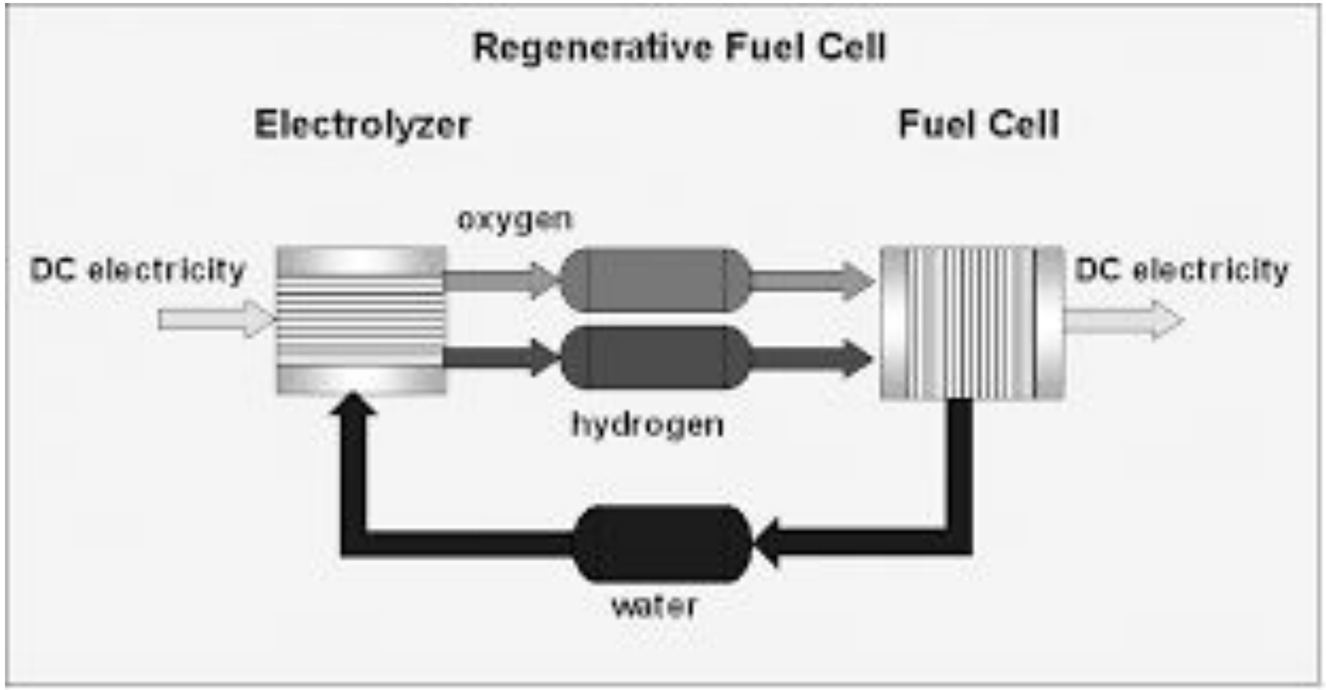
- **COMBINED HEAT AND POWER FUEL CELLS**

  In addition to electricity, fuel cells produce heat. This heat can be used to fulfill heating needs, including hot water and space heating. Combined heat and power fuel cells are of interest for powering houses and buildings, where total efficiency as high as 90% is achievable. This high-efficiency operation saves money, saves energy, and reduces greenhouse gas emissions.

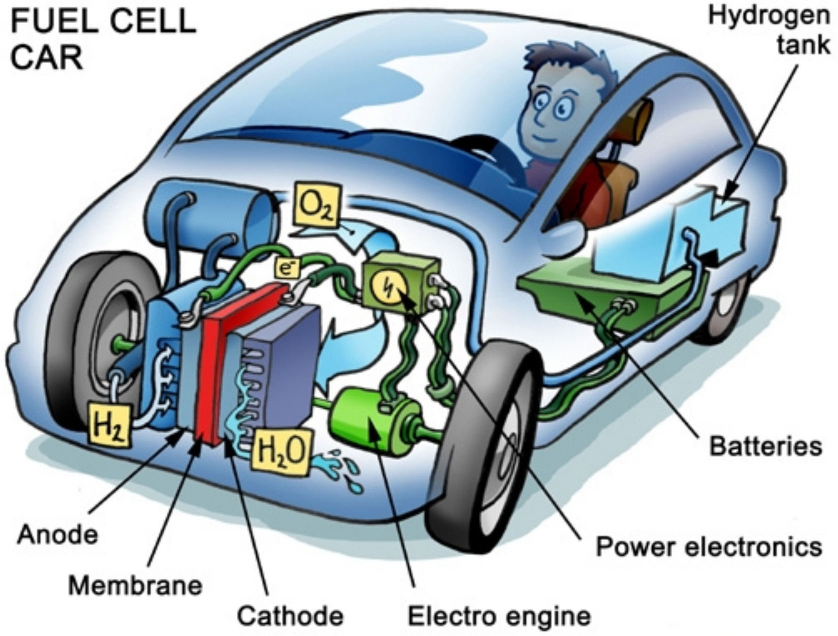
- **REGENERATIVE OR REVERSIBLE FUEL CELLS**

  This special class of fuel cells produces electricity from hydrogen and oxygen, but **can be reversed and powered with electricity to produce hydrogen and oxygen**. This emerging technology could provide storage of excess energy produced by intermittent renewable energy sources, such as wind and solar power stations, releasing this energy during times of low power production.


Import
To Grid
Export
Meter
Hot
Water
Tank
Fuel
Cell
Space Heating
Fuel


Regenerative Fuel Cell
Electrolyzer
Fuel Cell
oxygen
DC electricity
DC electricity
hydrogen
water


NANOGRAFI EXPLAINS
FUEL CELLS DEVELOPMENT WITH NANOTECHNOLOGY


FUEL CELL CAR
Hydrogen tank
Batteries
Power electronics
Electro engine
Cathode
Membrane
Anode

Nanotechnology in Fuel Cells

How can nanotechnology improve fuel cells?

Catalysts are used with fuels such as hydrogen or methanol to produce hydrogen ions. Platinum, which is very expensive, is the catalyst typically used in this process. Companies are using nanoparticles of platinum to reduce the amount of platinum needed, or using nanoparticles of other materials to replace platinum entirely and thereby lower costs.

Fuel cells contain membranes that allow **hydrogen ions to pass through the cell** but do not allow other atoms or ions, such as oxygen, to pass through. Companies are using nanotechnology to create more efficient membranes; this will allow them to build lighter weight and longer lasting fuel cells.

Small fuel cells are being developed that can be used to replace batteries in handheld devices such as laptop computers. Most companies working on this type of fuel cell are using methanol as a fuel and are calling them DMFC's, which stands for direct methanol fuel cell. DMFC's are designed to last longer than conventional batteries. In addition, rather than plugging your device into an electrical outlet and waiting for the battery to recharge, with a DMFC you simply insert a new cartridge of methanol into the device and you're ready to go.

Fuel cells that can replace batteries in electric cars are also under development. Hydrogen is the fuel most researchers propose for use in fuel cell powered cars. In addition to the improvements to catalysts and membranes discussed above, it is necessary to develop a lightweight and safe hydrogen fuel tank to hold the fuel and build a network of refueling stations. To build these tanks, researchers are trying to develop lightweight nanomaterials that will absorb the hydrogen and only release it when needed. The Department of Energy is estimating that widespread usage of hydrogen powered cars will not occur until approximately 2020.

Fuel Cells: Nanotechnology Applications

Researchers at the Technical University of Munich developed a model to predict the optimum size for platinum nanoparticle catalysis and then verified that particles one nanometer in diameter and containing approximately 40 platinum atoms showed increased catalytic effectivness.

Researchers at Brookhaven National Lab are reporting the development of a "nanoplate" catalyst using platinum and lead that has both a high level of oxygen reduction and a long lifetime.

Researchers at the University of Copenhagen have demonstrated the ability to significantly reduce the amount of platinum needed as a catalyst in fuel cells. The researchers found that the spacing between platinum nanoparticles affected the catalytic behavior, and that by controlling the packing density of the platinum nanoparticles they could reduce the amount of platinum needed.

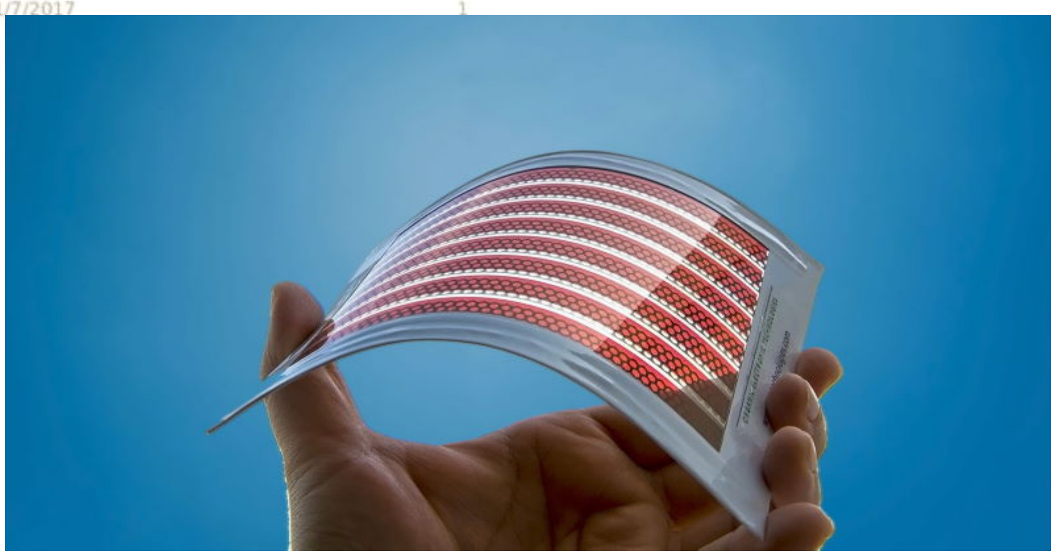
Researchers at Brown University are developing a catalyst that uses no platinum. The catalyst is made from a sheet of graphene coated with cobalt nanoparticles. If this catalyst works out for production use with fuel cells it should be much less expensive than platinum based catalysts.

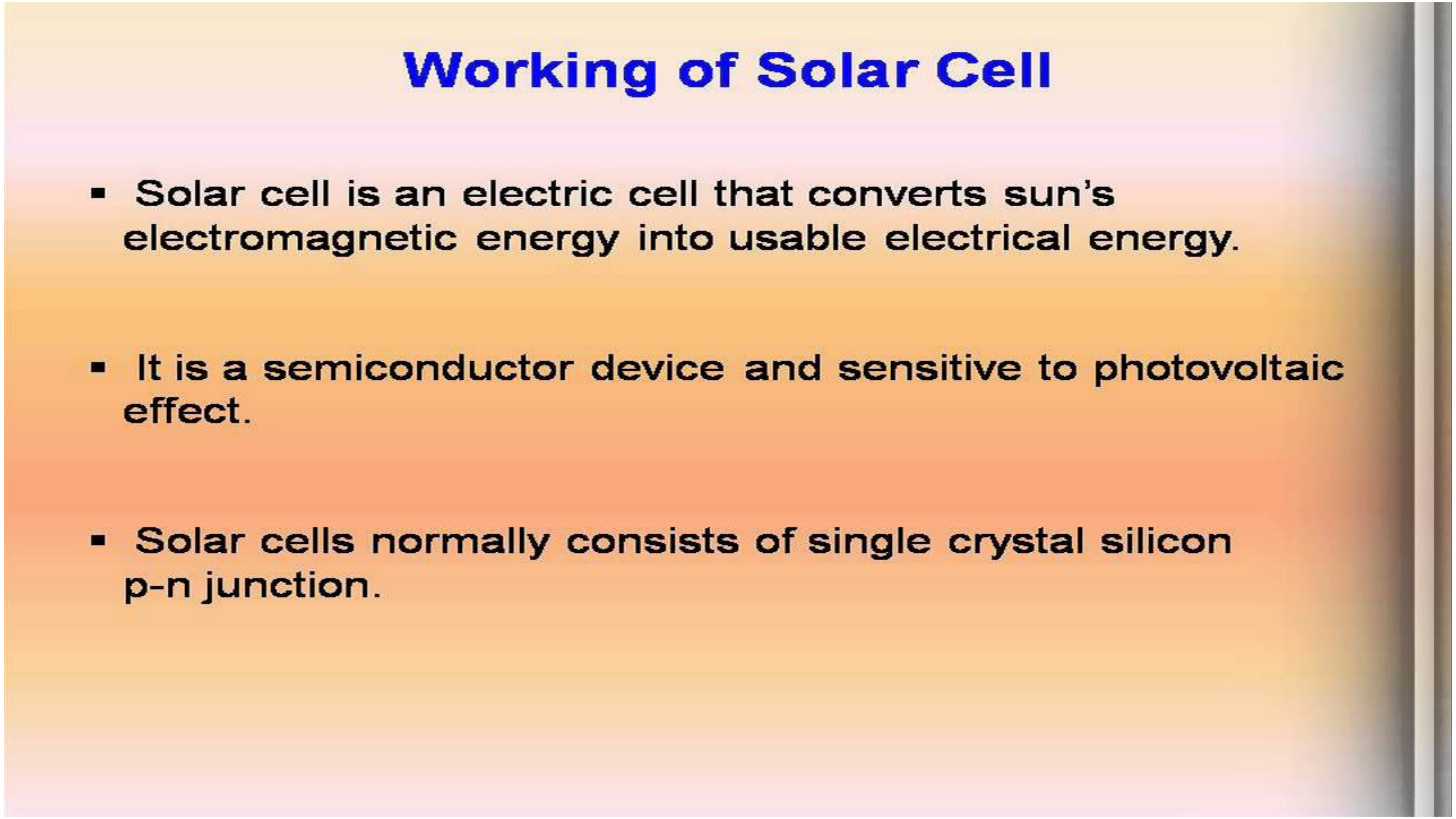
Researchers at Indiana University have demonstrated a modified emzyme encapsulated by a protein shell that can function either as a fuel cell catalyst or as a catalyst to produce hydrogen.

Researchers at Cornell University have developed a catalyst using platinum-cobalt nanoparticles that produces 12 times more catalytic activity than pure platinum. In order to achieve this performance the researchers annealed the nanoparticles so they formed a crystalline lattice which reduced the spacing between platinum atoms on the surface, increasing their reactivity.

Researchers at the University of Illinois have developed a proton exchange membrane using a silicon layer with pores of about 5 nanometers in diameter capped by a layer of porous silica. The silica layer is designed to insure that water stays in the nanopores. The water combines with the acid molecules along the wall of the nanopores to form an acidic solution, providing an easy pathway for hydrogen ions through the membrane. Evaluation of this membrane showed it to have much better conductivity of hydrogen ions (100 times better conductivity was reported) in low humidity conditions than the membrane normally used in fuel cells.

Solar cell

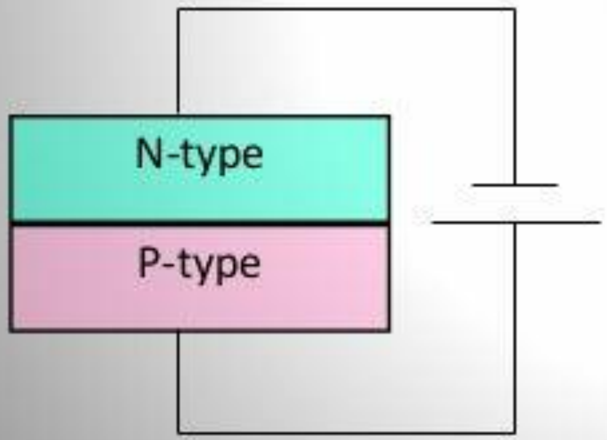


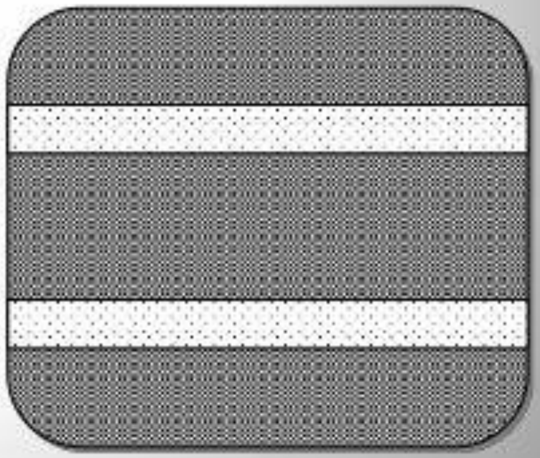

Working of Solar Cell
▪ Solar cell is an electric cell that converts sun's electromagnetic energy into usable electrical energy.
▪ It is a semiconductor device and sensitive to photovoltaic effect.
▪ Solar cells normally consists of single crystal silicon p-n junction.

Principle of Solar Cell

The solar cells are based on the principles of photovoltaic effect. The ***Photovoltaic Effect*** is the photogeneration of charge carriers in a light absorbing materials as a result of absorption of light radiation.

Single Solar cell

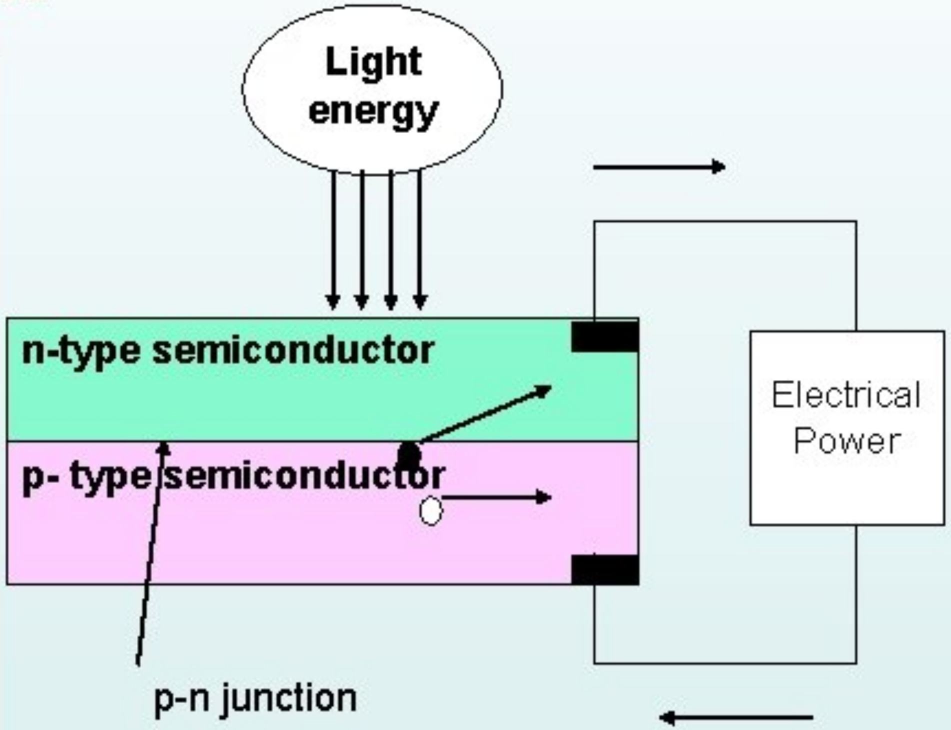




2. Photovoltaic effect

Definition:

The generation of voltage across the PN junction in a semiconductor due to the absorption of light radiation is called photovoltaic effect. The Devices based on this effect is called photovoltaic device.



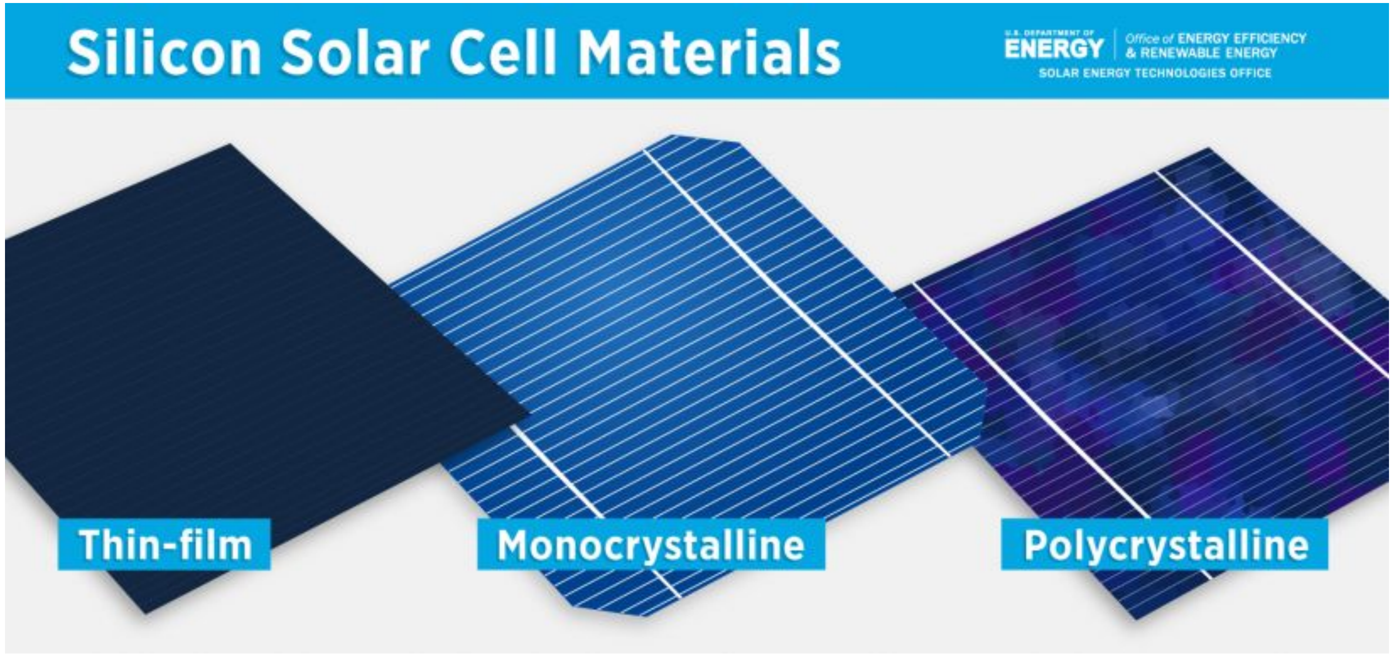
Photovoltaics:
Fundamental concepts and novel systems

First practical photovoltaic cell:
Chapin, Fuller, Pearson,
Bell Labs, 1954: 6% efficiency

Conventional solar cells are called photovoltaic cells. These cells are made out of semiconducting material, usually silicon.

The energy conversion consists of absorption of light (photon) energy producing electron–hole pairs in a semiconductor and charge carrier separation. A p–n junction is used for charge carrier separation in most cases.

The process was discovered as early as 1839. Silicon wafers are doped and the electrical contacts are put in place to connect each solar cell to another. The resulting silicon disks are given an anti-reflective coating



What is the Photovoltaic Effect?

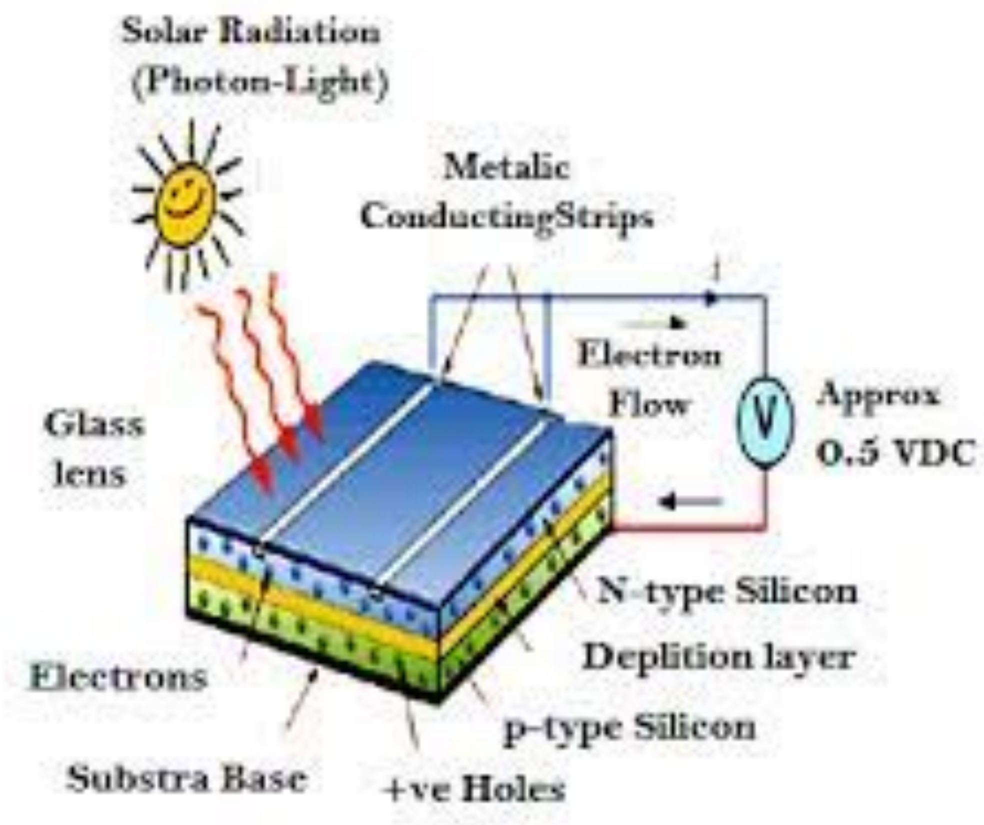
In 1839, while experimenting with an electrolytic cell made up of two metal electrodes, a French experimental physicist named Edmund Becquerel, only nineteen years old at the time, discovered that when exposing certain materials to sunlight he could generate a weak electrical current.

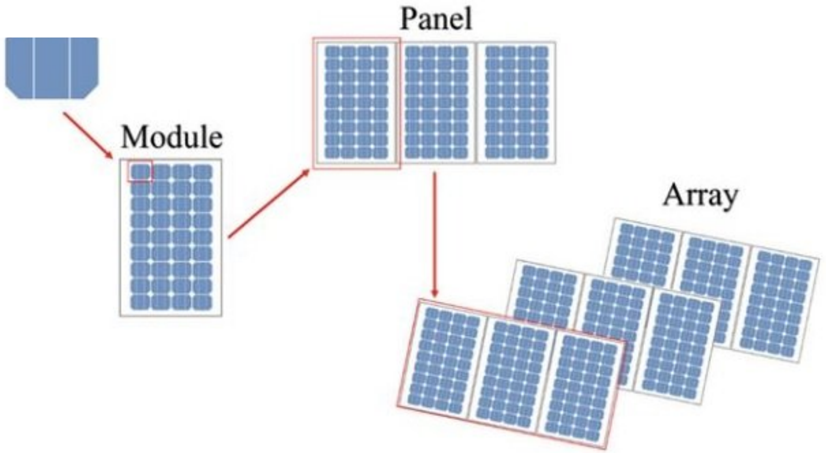
He named this phenomenon the \"photovoltaic effect\". The photovoltaic effect is the basic process in which a solar cell converts sunlight into electricity.

When photons are absorbed by a photovoltaic cell, which contains a semiconducting material such as silicon or platinum, the energy from the photon is transfered to an electron in an atom of the \"solar cell\".

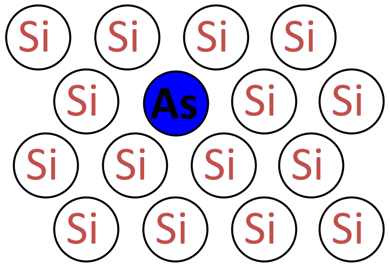
The energized electron is then able to escape its bond with the atom and generates an electric current.

This leaves behind a \"hole\". Combined with a P-N junction, which is a layer within the photovoltaic cell that is formed by the intimate contact of P-type and N-type semiconductors that create an electric field, holes move in the opposite direction from electrons, thereby producing an electric current.

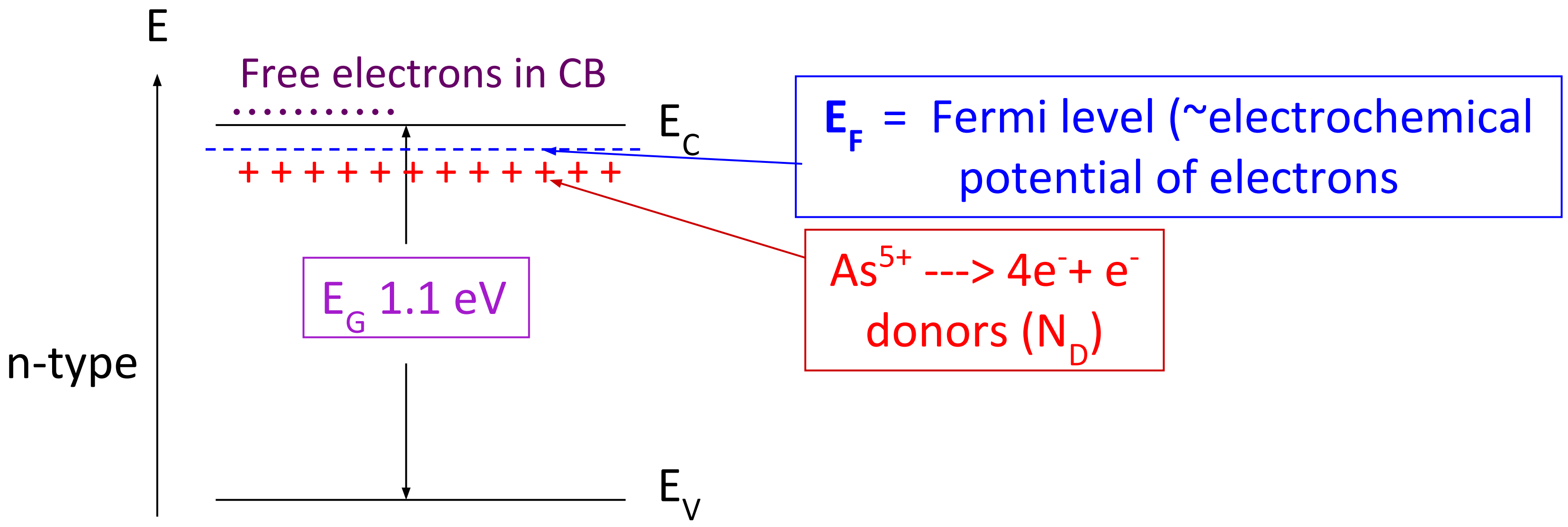

Solar Radiation
(Photon-Light)
Metalic
ConductingStrips
Electron
Flow
V
Approx
0.5 VDC
Glass
lens
N-type Silicon
Deplition layer
Electrons
p-type Silicon
Substra Base
+ve Holes


Panel
Module
Array

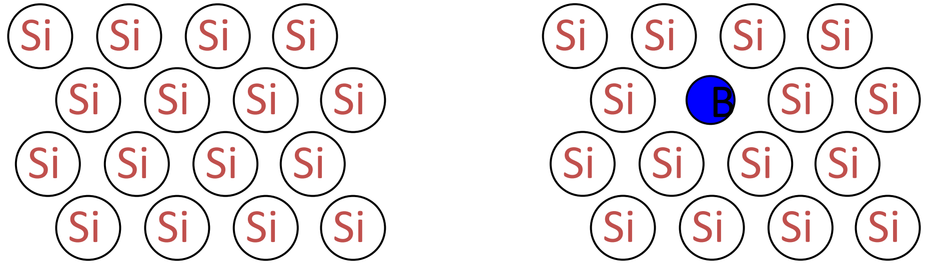
Doping of semiconductors



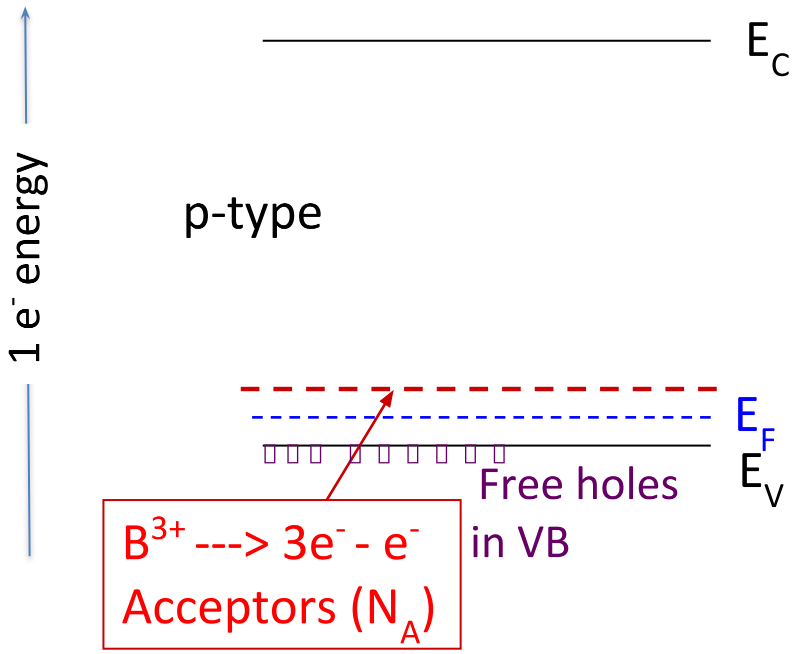
B	C	N
Al	Si	P
Ga	Ge	As

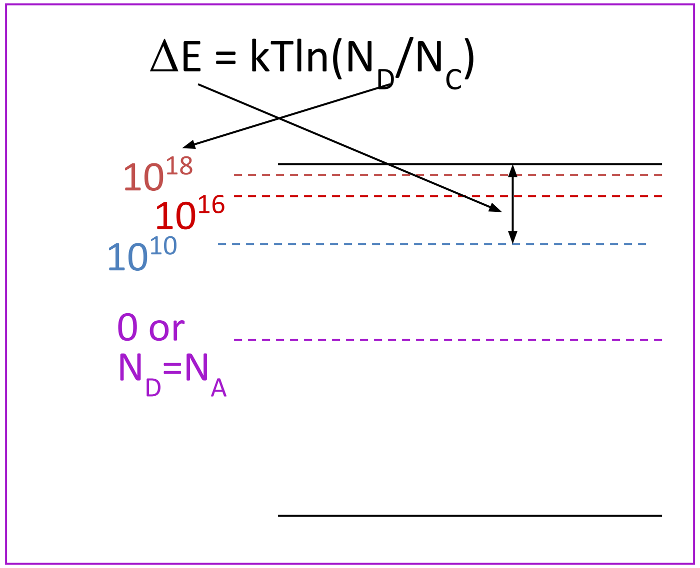


Doping of semiconductors -2



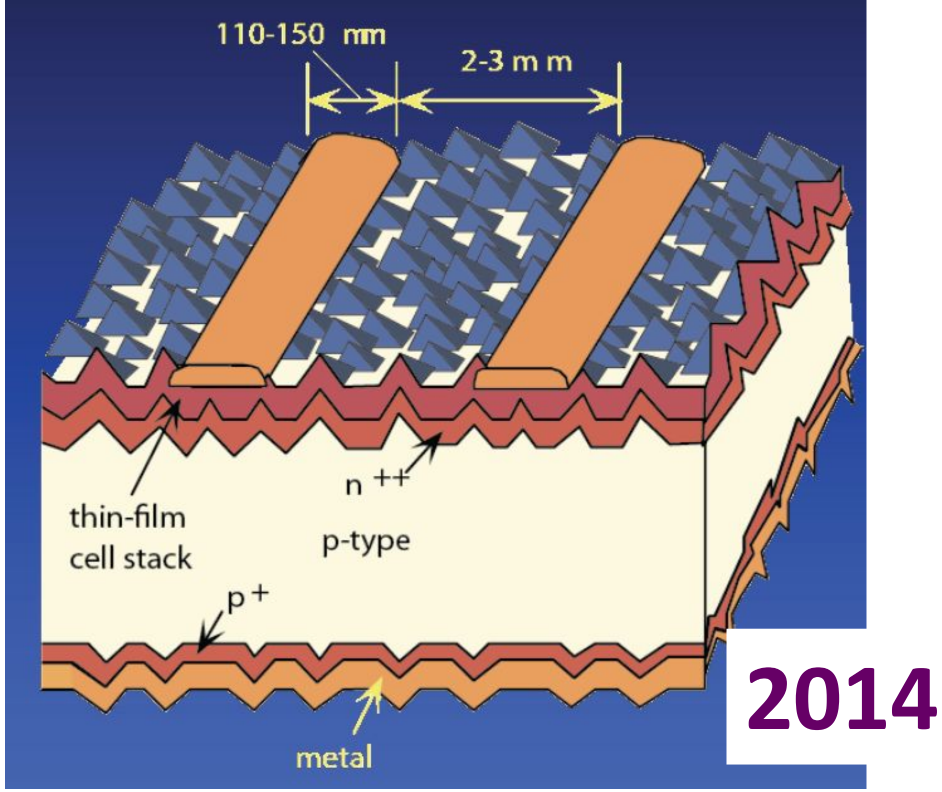
B	C	N
Al	Si	P
Ga	Ge	As



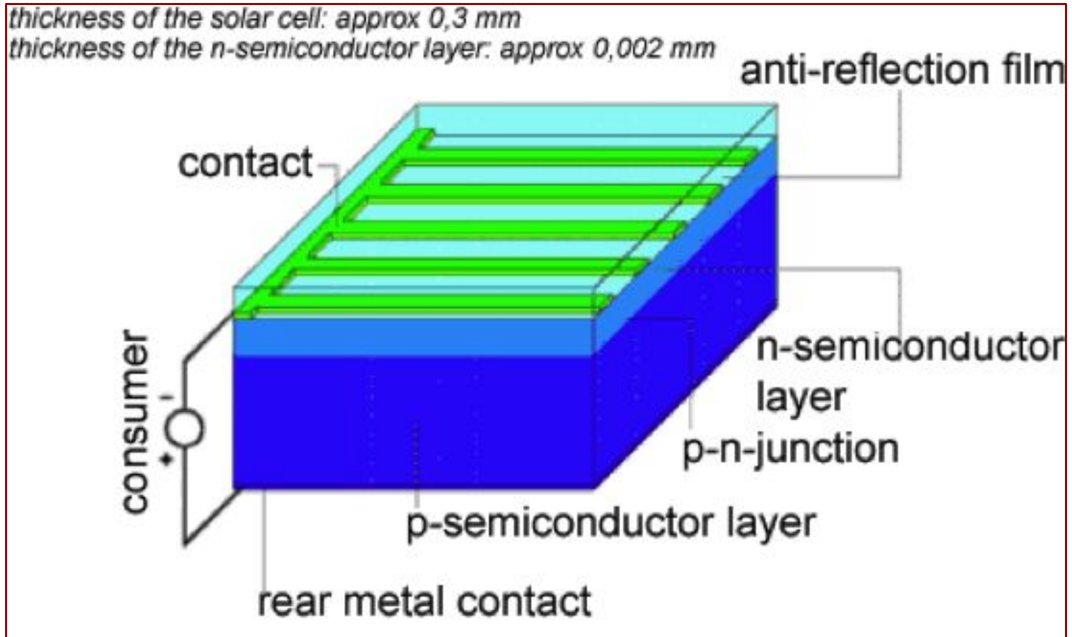


Something New Under the Sun. It's the Bell Solar Battery, made of thin discs of specially treated silicon, an ingredient of common sand. It converts the sun's rays directly into usable amounts of electricity. Simple and trouble-free. (The storage batteries beside the solar battery store up its electricity for night use.)

Bell System Solar Battery Converts Sun's Rays into Electricity!



Chapin
Fuller
Pearson



C 6/24/06
Atwater Caltech

Solar cell generations

Si (crystalline) cells : 1st generation cells

(thin film) CdTe, CIGS, α-Si : 2nd generation cells

Dye cells, organic cells and related ones : 3rd generation cells

There are newer ones and 'generation number' becomes fuzzy at this stage

Conventional solar cells have two main drawbacks:

- They can only achieve efficiencies around ten percent and their expensive manufacturing cost.

- The first drawback, inefficiency, is almost unavoidable with silicon cells. This is because the incoming photons, or light, must have the right energy, called the band gap energy, to knock out an electron.

- If the photon has less energy than the band gap energy then it will pass through. If it has more energy than the band gap, then that extra energy will be wasted as heat. These two effects alone account for the loss of around 70 percent of the radiation energy incident on the cell

- One of the biggest disadvantages of solar energy is the high cost associated with manufacturing solar cells, especially when compared to the cost of utilizing coal and gas for energy.

- Furthermore, modern solar cells can lose as much as 10% of acquired power as a result of direct optical loses, since the surface of these cells will reflect anywhere between 2% - 10% of incoming sunlight. **Nanotechnology offers the ability to solve this problem.**

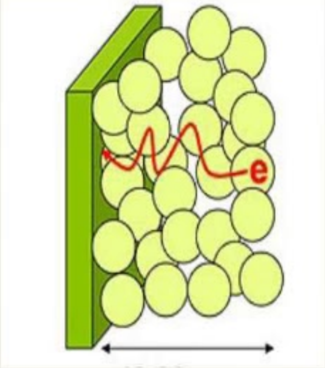
- Current solar cells cannot convert all the incoming light into usable energy because some of the light can escape back out of the cell into the air.

- Lower energy light passes through the cell unused. Higher energy light does excite electrons to the conduction band, but any energy beyond the band gap energy is lost as heat.

- If these excited electrons aren’t captured and redirected, they will spontaneously recombine with the created holes, and the energy will be lost as heat or light

NANOTECHNOLOGY IN SOLAR ENERGY

(a) Solar Cell



(b) CNTs

NANO-SIZED PARTICLES :

- In solar cells, **bulk silicon** is **converted into discrete, Nano-sized particles.**
- These particles will show distinct colors depending upon their sizes
  - ✓ Films of 1 nm blue fluorescent
  - ✓ Films of 2.85 nm red fluorescent silicon nanoparticles
- They **produce large voltage enhancements** with improved power performance.

CARBON NANO-TUBES (CNTS) :

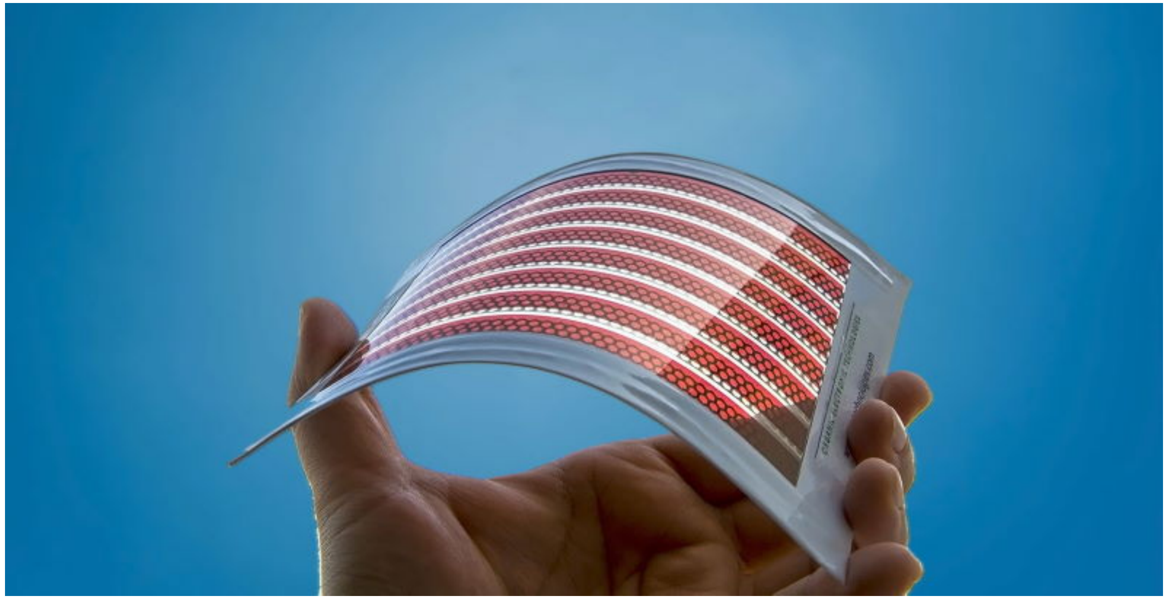
- Incorporated to a titanium oxide nanoparticles-based solar cells
- **Provide a direct route** i.e. the escape route to the electrons moving toward electrodes
- Collect these electrons and show them a distinct path (red line shown in the figure below).

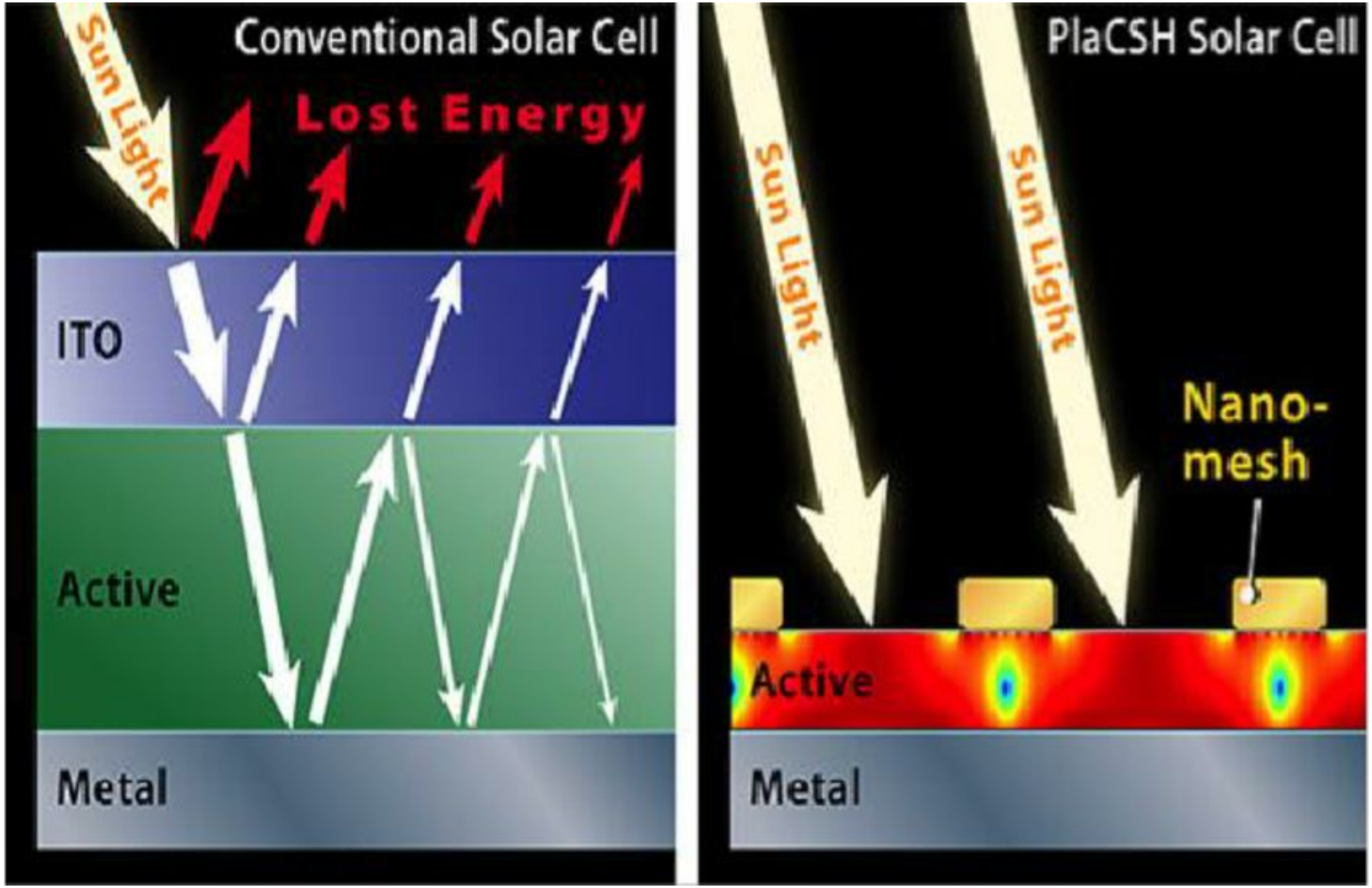
How can nanotechnology improve solar cells

Many nanostructured materials are now being investigated for their potential applications in photovoltaic.

Reduced manufacturing costs as a result of using a low temperature process similar to printing instead of the high temperature vacuum deposition process typically used to produce conventional cells made with crystalline semiconductor material.

Reduced installation costs achieved by producing flexible rolls instead of rigid crystalline panels





Conventional Solar Cell
Sun Light
Lost Energy
ITO
Active
Metal
PlaCSH Solar Cell
Sun Light
Sun Light
Nano-
mesh
Active
Metal

Nano-structured layers in thin film solar cells offer three important advantages.

First, due to multiple reflections, the effective optical path for absorption is much larger than the actual film thickness.

Second, light generated electrons and holes need to travel over a much shorter path and thus recombination losses are greatly reduced.

As a result, the absorber layer thickness in nanostructured solar cells can be as thin as 150 nm instead of several micrometers in the traditional thin film solar cells.

Third, the energy band gap of various layers can be tailored to the desired design **value by varying the size of nano-particles**. This allows for more design flexibility in the absorber and window layers in the solar cells.

Third-generation photovoltaics are thin, light and semitransparent and come in different colors. Furthermore, nanotechnology enables printing of flexible solar power panels with endless applications.

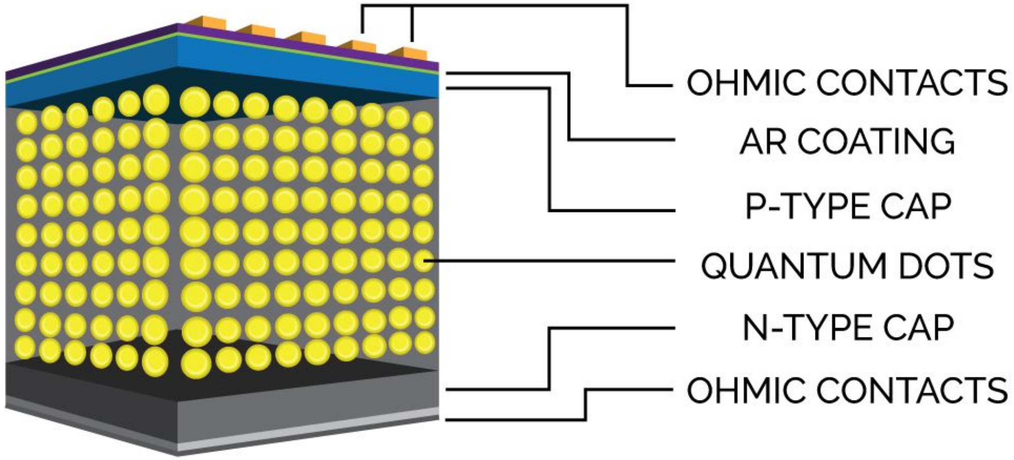
Improving the Efficiency of Solar Cells by Using Semiconductor Quantum Dots (QD)

One of the starting point for the increase of the con-version efficiency of solar cells is the use of semiconductor quantum dots (QD).

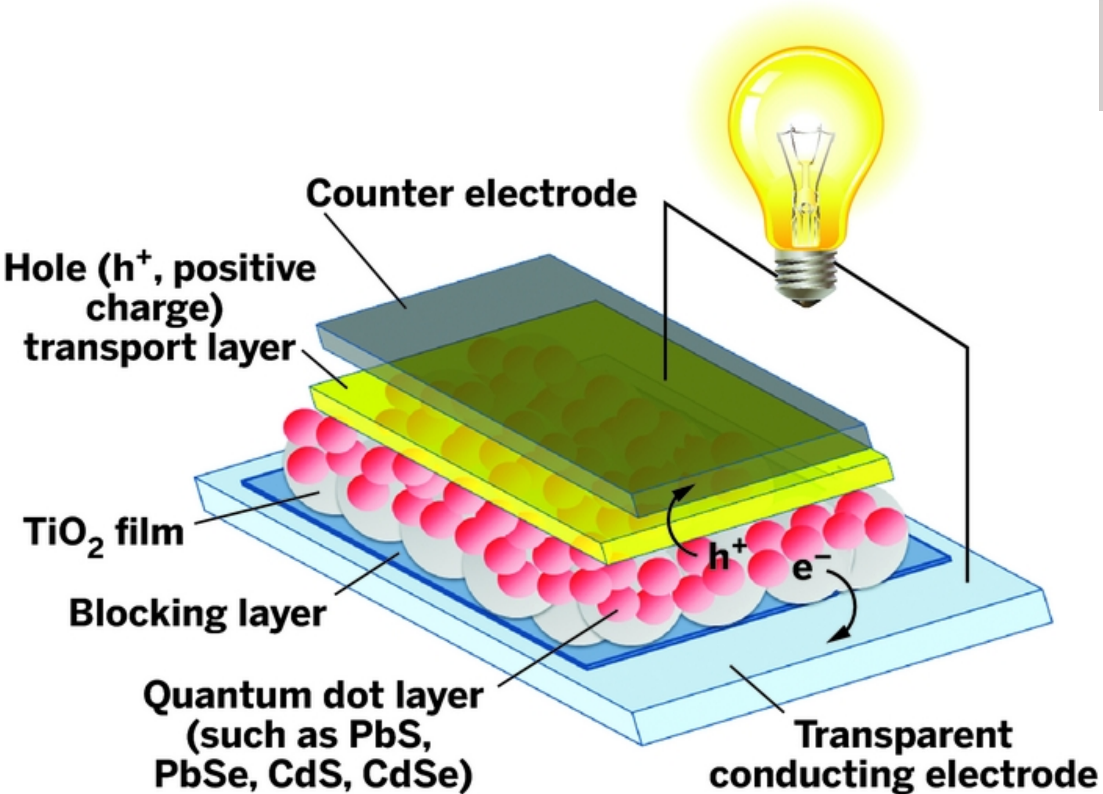
By means of quantum dots, the band gaps can be adjusted specifically to convert also longer- wave light and thus increase the efficiency of the solar cells.

These so called quantum dot solar cells are, at present still subject, to basic research. As material systems for QD solar cells, III/V semiconductors and other material combinations such as Si/Ge or Si/Be Te/Se are considered.

Potential advantages of these Si/Ge QD solar cells are:
1) Higher light absorption in particular in the infra-red spectral region,
2) Compatibility with standard silicon solar cell production (in contrast to III/V semiconductors),
3) Increase of the photo current at higher temperatures,
4) Improved radiation hardness compared with conventional solar cells.



Quantum Dot Solar Cell



Unlike conventional materials in which one photon generates just one electron, quantum dots have the potential to convert high-energy photons into multiple electrons.

Quantum dots work the same way, but they produce three electrons for every photon of sunlight that hits the dots.

Electrons moves from the valance band into the conduction band The dots also catch more spectrums of the sunlight waves, thus increasing conversion efficiency to as high as 65 percent.

Another area in which quantum dots could be used is by making so-called a hot carrier cells.

Typically the extra energy supplied by a photon is lost as heat, but with a hot carrier cells the extra energy from the photons result in higher-energy electrons which in turn leads to a higher voltage

Reduction of the Cost of Solar Cells by Nanotechnology

Nanotechnology might be able to increase the efficiency of solar cells, but the most promising application of nanotechnology is the reduction of manufacturing cost.

Chemists at the University of California, Berkeley, have discovered a way to make cheap plastic solar cells that could be painted on almost any surface.

Picture of a solar cell, which utilizes nanorods to convert light into electricity

The new plastic solar cells utilize tiny nanorods dispersed within in a polymer. The nanorods behave as wires because when they absorb light of a specific wave-length they generate electrons.

These electrons flow through the nanorods until they reach the aluminum electrode where they are combined to form a current and are used as electricity.

This type of cell is cheaper to manufacture than conventional ones for two main reasons. First, these plastic cells are not made from silicon, which can be very expensive.

Second, manufacturing of these cells does not require expensive equipment such as clean rooms or vacuum chambers like conventional silicon based solar cells.

Instead,these plastic cells can be manufactured in a beaker.

Another potential feature of these solar cells is that the nanorods could be ‘tuned’ to absorb various wave-lengths of light.

This could significantly increase the efficiency of the solar cell because more of the incident light could be utilized