SOLAR ENERGY

Approximately 120,000 TW of solar energy strikes the earth's surface, capturing only a fraction could supply all of our energy needs.
What is Photovoltaics?

Photovoltaics is a high-technology approach to converting sunlight directly into electrical energy. The electricity is direct current and can be used that way, converted to alternating for use.
Sunlight is composed of photons.

- Photons have energy corresponding to the different wavelengths of the solar spectrum.
- Energy of the photon is transferred to an electron in an atom of the cell.
- Electron escapes, a 'hole' is formed, it becomes part of the current in an electrical circuit.
- The built-in electric field of a PV cell provides the voltage needed to drive the current through an external load.

How a Photovoltaic cell works
Fabrication of Solar Cell Material

- Sensitive to the color of the sunlight.
  - Some materials are better absorbers.
  - Band gap of the semiconductor material.
Materials/Technology Used

Presently and commonly used:

- Monocrystalline Silicon,
- Polycrystalline Silicon,
- Amorphous Silicon,
- Cadmium Telluride, and
- Copper Indium Selenide/Sulfide.

Other materials:

- Multi-junction solar cells (Gallium arsenide)
- Thin-films Layers,
- Organic Dyes,
- and Organic Polymers that are Deposited on supporting Substrates.
Basic structure of a silicon based solar cell and its working mechanism.
MonoCrystalline Silicon
Polycrystalline Silicon

- Composed of a number of smaller silicon crystals or crystallites.
- Polysilicon deposition is achieved by pyrolyzing silane (SiH₄) at 580 to 650 °C. This pyrolysis process releases hydrogen.
A type of multicrystalline silicon. It is formed by drawing flat thin films from molten silicon and results in a multicrystalline structure. These cells have lower efficiencies than poly-Si, but save on production costs due to a great reduction in silicon waste.

Ribbon silicon
Thin film solar cell

Also called a thin-film photovoltaic cell (TFPV), is a solar cell that is made by depositing one or more thin layers (thin film) of photovoltaic material on a substrate.

They are categorized according to the photovoltaic material used:

- Amorphous silicon (a-Si) and thin-film silicon (TF-Si)
- Cadmium telluride (CdTe)
- Copper indium gallium selenide (CIS or CIGS)
- Dye-sensitized solar cell (DSC) and other organic solar cells.
Junction formed between two semiconductor materials of opposite

Antireflection coating

Transparent conducting coating

Light

Substrate

Ohmic contact

Bottom p-type "Absorber" layer formed by second semiconductor material

Top n-type "Window" layer formed by first semiconductor material
Thin Film Silicon

- A silicon thin-film cell mostly uses amorphous (a-Si or a-Si:H).
- Silicon deposited by chemical vapor deposition, from silane (SiH₄) gas and hydrogen gas.
- Silicon is deposited on glass, plastic or metal coated with a layer of transparent conducting oxide (TCO).
- p-i-n structure is usually used.
Cadmium telluride (CdTe) Photovoltaics

- A photovoltaic (PV) technology that is based on the use of cadmium telluride thin film.
- The first and only thin film photovoltaic technology to surpass crystalline silicon PV in cheapness for a significant portion of the PV market, namely in multi-kilowatt systems.
Cross-section of a CdTe thin film solar cell.

<table>
<thead>
<tr>
<th>Layer</th>
</tr>
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<tbody>
<tr>
<td>Glass substrate</td>
</tr>
<tr>
<td>ITO (low resistivity TCO)</td>
</tr>
<tr>
<td>SnO₂ (high resistivity TCO)</td>
</tr>
<tr>
<td>n-doped CdS (window layer)</td>
</tr>
<tr>
<td>p-doped CdTe (absorber)</td>
</tr>
<tr>
<td>Au or Ni-Al metal contact</td>
</tr>
</tbody>
</table>
Copper indium gallium selenide solar cell
Structure of a CIGS thin-film solar cell

- **Transparent front contact**
- **ZnO:Al (0.3-0.4 µm)**
- **ZnO (~0.1 µm)**
- **CdS (~0.05 µm)**

- **Cu(In,Ga)Se₂ (1.5-2.5 µm)**

- **Mo (0.3-0.4 µm)**

- **Glass substrate**
Multi-junction solar cells

Solar cells containing several p-n junctions containing in series. Cell covers more of the light spectrum, more complexity of cell design and manufacture. Sub-cells determined by the requirements for lattice-matching, current-matching, and high performance optoelectronic properties.
There are six important types of layers: pn junctions, back surface field (BSF) layers, window layers, tunnel junctions, anti-reflective coating and metallic contacts.

(a) Diagram showing the layers of a solar cell:

- GaAs (n-type)
- AR COATING
- AlInP (n-type)
- InGaP (window)
- InGaP (n-type)
- InGaP (p-type)
- AlGaInP (p-type)
- TUNNEL JUNCTION
- InGaP (n-type)
- InGaP (p-type)
- InGaAs (n-type)
- InGaAs (p-type)
- InGaAs (buffer)
- InGaP (hetero layer)
- Ge (n-type)
- Ge (p-type)
- TUNNEL JUNCTION
- InGaP (n-type)
- InGaAs (p-type)
- TOP CELL
- InGaP 1.86 eV
- MIDDLE CELL
- InGaAs 1.4 eV
- BOTTOM CELL
- Ge 0.65 eV

(b) Spectral irradiance graph:

- AM1.5 spectrum
- TOP CELL InGaP 1.86 eV
- MIDDLE CELL InGaAs 1.4 eV
- BOTTOM CELL Ge 0.65 eV

Wavelength (nm)
For example, AlGaAs/GaAs solar arrays with a total area of 70 m² were installed in the Russian space station 'Mir' launched in 1986.
Dye-sensitized solar cell

Semiconductor formed between a photosensitized anode and an electrolyte, a photoelectrochemical system. This cell, also known as the Grätzel cell, was invented by Michael Grätzel and Brian O'Regan at the École Polytechnique Fédérale de Lausanne in 1991.

The dye is complexed or chelated (attached) to the titanium dioxide.
Structure of Dye-sensitized solar cell

- A porous layer of titanium dioxide nanoparticles, covered with a molecular dye that absorbs sunlight.
- The titanium dioxide is immersed under an electrolyte solution, above which is a platinum-based catalyst.
- As in a conventional alkaline battery, an anode (the titanium dioxide) and a cathode (the platinum) are placed on either side of a liquid conductor (the electrolyte).
Pigment of fruit dye
The optical absorption coefficient of organic molecules is high.

Single layer, bilayer, and heterojunction Organic solar cells.

The main disadvantages of organic photovoltaic cells are low efficiency, low stability and low strength compared to inorganic photovoltaic cells.
Single layer organic photovoltaic cell

electrode 1
(ITO, metal)

organic electronic material
(small molecule, polymer)

electrode 2
(Al, Mg, Ca)
Bijunction layer organic cell

electrode 1
(ITO, metal)

electron donor

electron acceptor

electrode 2
(Al, Mg, Ca)
Disadvantages of single layer and bilayer solar cell

- Low quantum efficiencies (<1%) and low power conversion efficiencies (<0.1%).
- The electric field resulting from the difference between the two conductive electrodes is seldom sufficient to break up the photogenerated excitons.
- Often the electrons recombine with the holes rather than reach the electrode.
Bulk heterojunction organic solar cell
A third group are made from nanocrystals and used as quantum dots (electron-confined nanoparticles).
Quantum dots hold promise for low-cost solar cells because:

Can be made using simple, inexpensive chemical reactions

Nanocrystals can emit more electron per photon absorbed.

Tuning of nanocrystal absorption to match the solar spectrum.
In a transmission electron microscope image, indium arsenide quantum dots, 3.3 nanometers wide, are doped with silver atoms, yielding an n-type material rich in electrons.
THANK YOU