Solar Photovoltaic (PV) Cells

A supplement topic to:

Micro-optical Sensors
- A MEMS for electric power generation

Science of Silicon PV Cells

- Scientific base for solar PV electric power generation is solid-state physics of semiconductors

- Silicon is a popular candidate material for solar PV cells because:
  - It is a semiconductor material.
  - Technology is well developed to make silicon to be positive (+ve) or negative (-ve) charge-carriers – essential elements for an electric cell or battery
  - Silicon is abundant in supply and relatively inexpensive in production

- Micro- and nano-technologies have enhanced the opto-electricity conversion efficiency of silicon solar PV cells

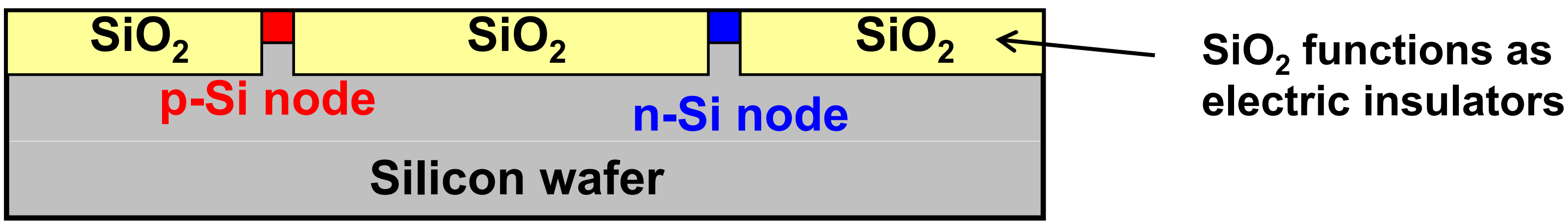
Working Principle of Silicon Solar PV Cells

Photovoltaic material of device converts:

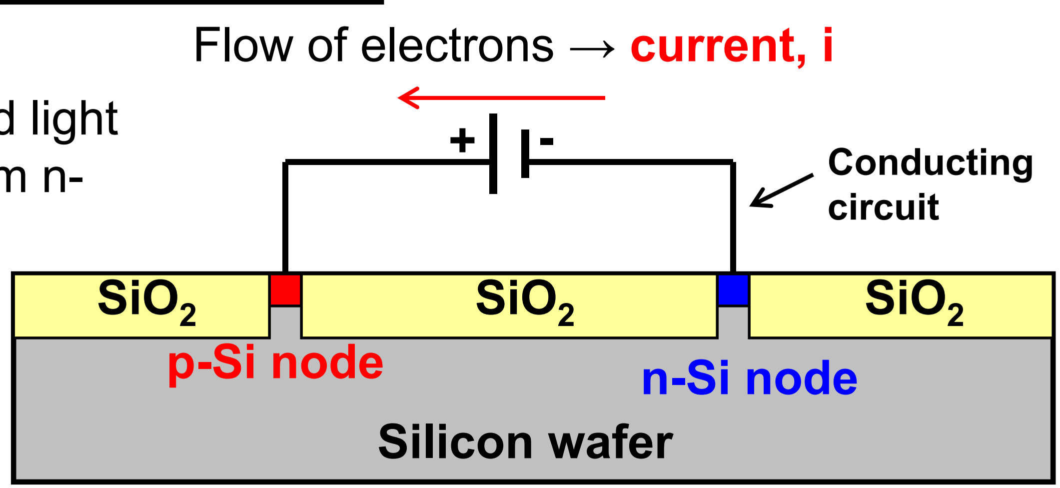
Light (photon) Energy → **Electric Energy**

Silicon solar photovoltaic cells = a device made of semiconductor materials that produce electricity under light

- A **p-n junction** is created in silicon by a **doping process**.



- The **photons** from the exposed light prompted electrons flowing from n-junction to the p-junction → **Electric current flow**.

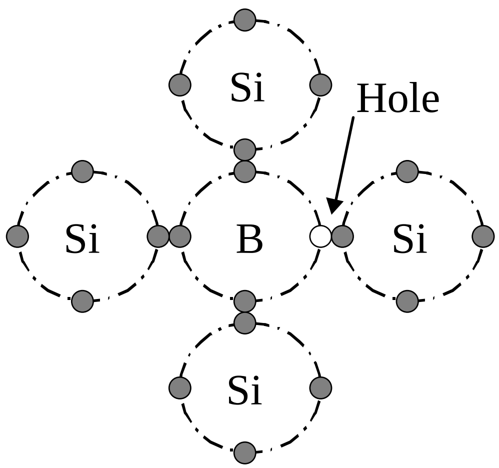


Doping of Semiconductors

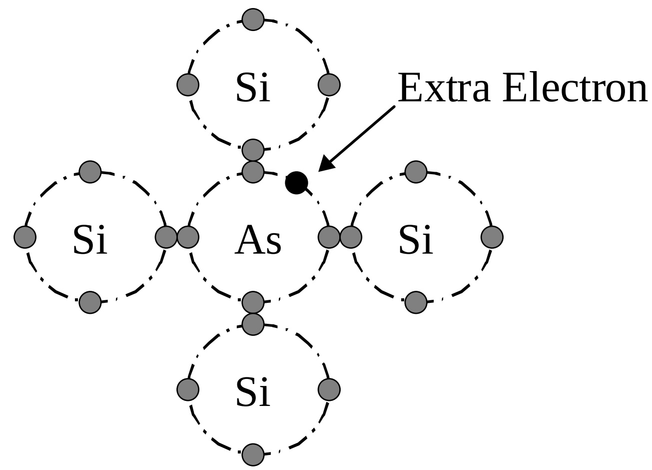
- **Doping for common semiconductor, e.g. silicon (Si) involves <u>adding</u> atoms with different number of electrons to create unbalanced number of electrons in the base material (e.g. Si)**

- **The base material, after doping, with excessive electrons will carry –ve charge.**
- **The base material, after doping, with deficit in electron will carry +ve charge.**

- **Doping of silicon can be achieved by "ion implantation" or "diffusion" of Boron (B) atom for +ve charge or of Arsenide (As) or Phosphorus (P) for –ve charge.**



P-type doping
("holes" for electrons)



N-type doping
(with extra electrons)

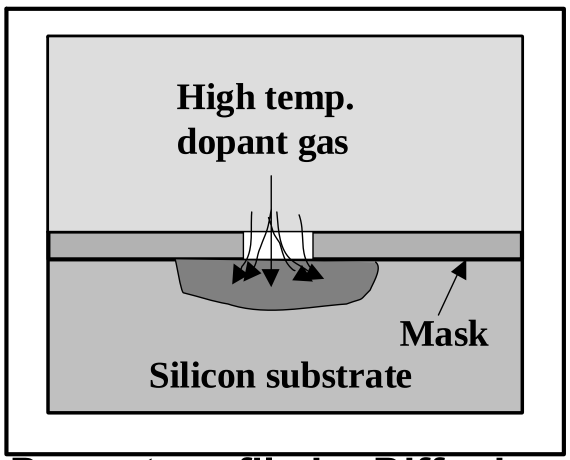
Doping by Ion Implantation and Diffusion

- Doping of Si can be done by either ion implantation at room temperature, or diffusion at high temperature.

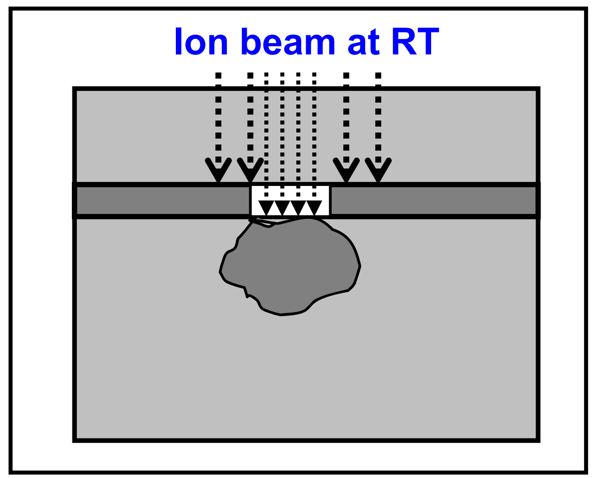
- Ion implantation require energy to ionize the dopant. It is a faster doping process.

- Diffusion is a chemical process. It is a slower process but at lower cost and easy to control.

- The profile of the spread of dopant in silicon by diffusion is different from that by ion implantation:



Dopant profile by Diffusion



Dopant profile by ion implantation

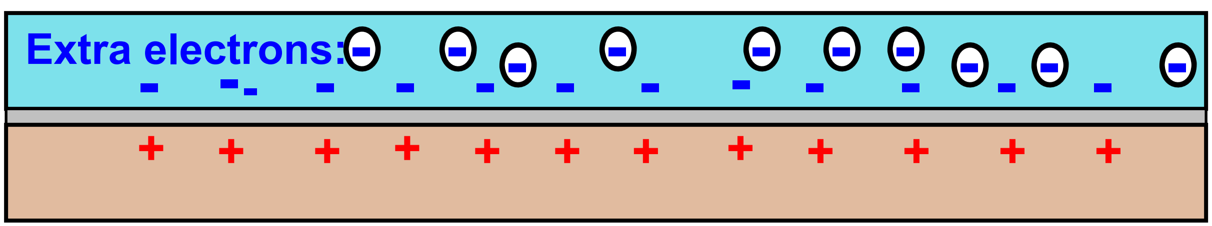
Silicon Solar Photovoltaic – solar battery cell

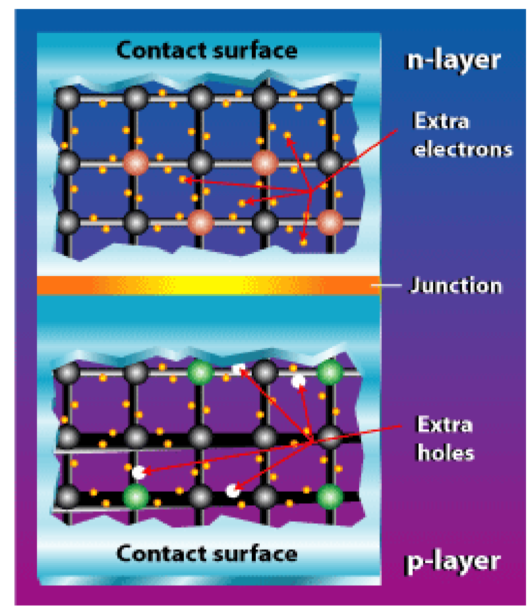
n-silicon (excessive electrons)

Junction (weak dielectric)

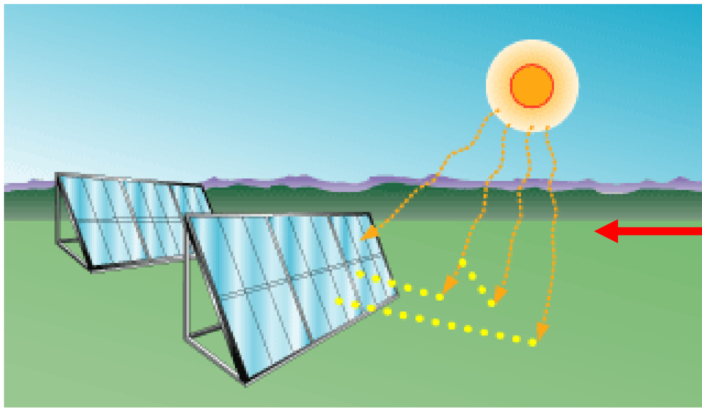
p-silicon (atoms with “holes” by unbalanced electrons)

Electric field with +ve and -ve electrodes (like a battery):



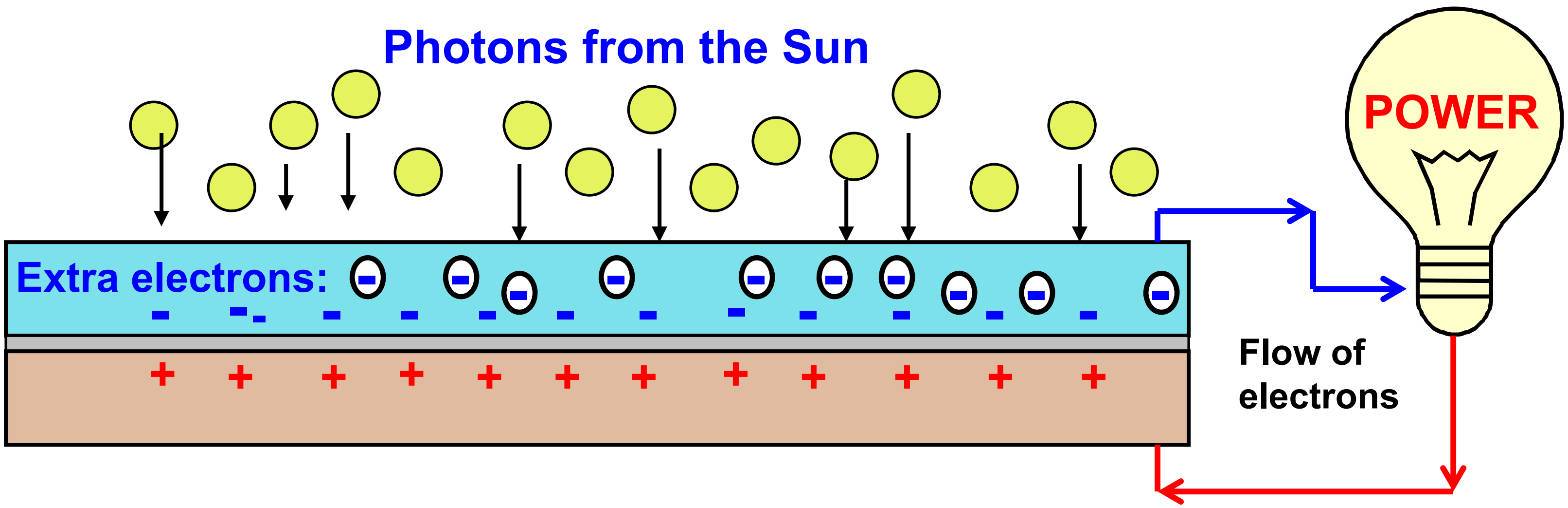


Silicon Solar Photovoltaic – Cont'd



Bombardment of photons from solar rays energize electrons → Junction.

Break the junction into the p-layer → Electricity

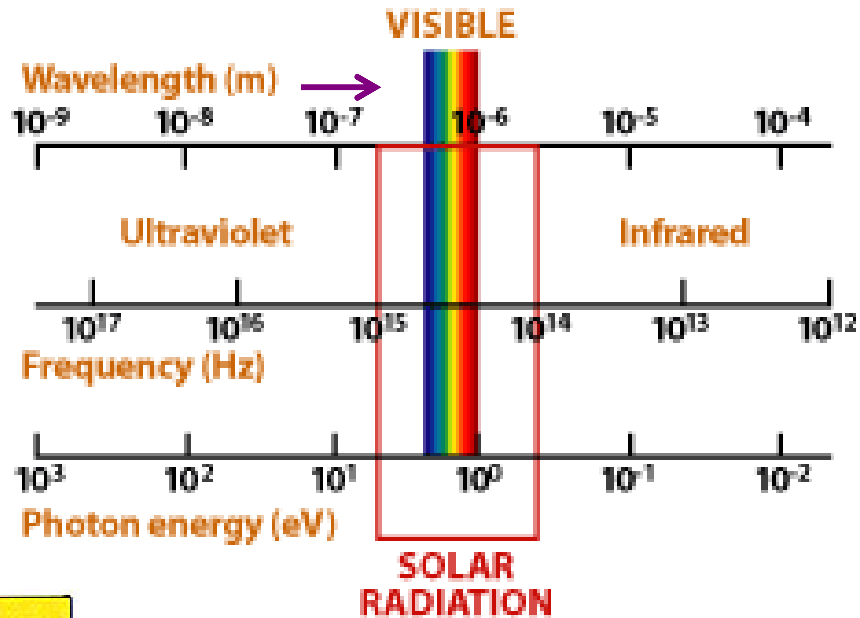


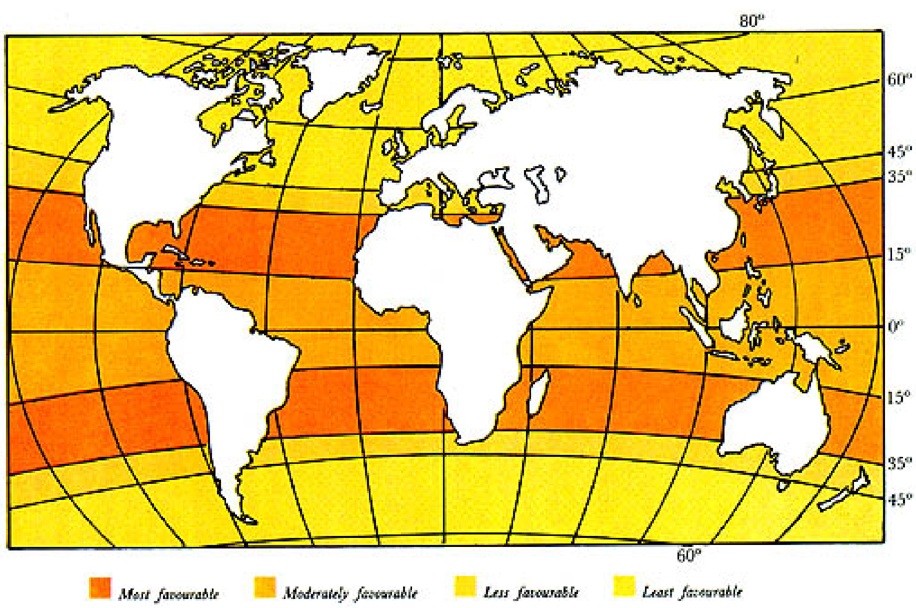
Solar Radiation Energy

Spectrum of sun light

Density on Earth surface:
1.4 kW/m^2

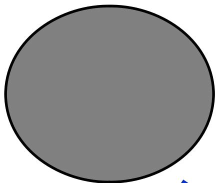
- **Solar energy is associated with photons in the rays.**



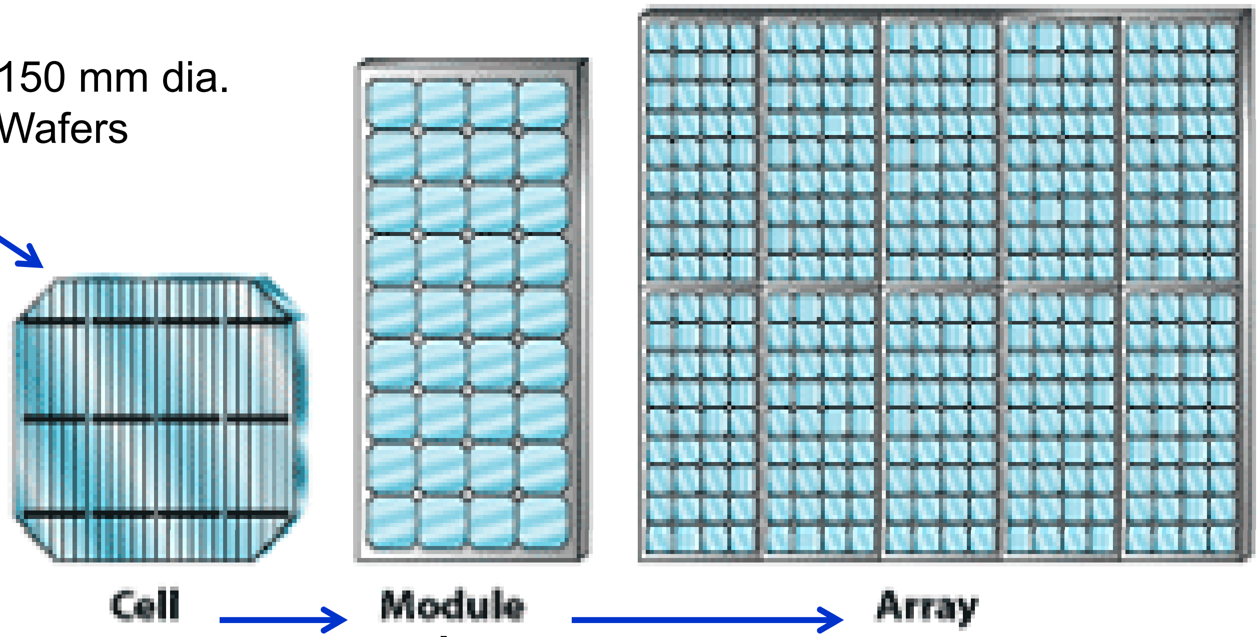


Global distribution of solar energy

Silicon Solar PV Product –
Silicon Solar PV Panels



150 mm dia.
Wafers



For power generation

150 cm^2
12.25 cm x 12.25 cm

SunPower Corp. Model SPR-215-BLK modules:
798 mm wide x 1559 mm long x 46 mm thick (with 72 cells)
Weight: 15 kg
Output: 40 v, 5.4 A (216 W)
Conversion efficiency: 17.3% (21.5% for all-black-contact cells)

Common Solar Cell Materials

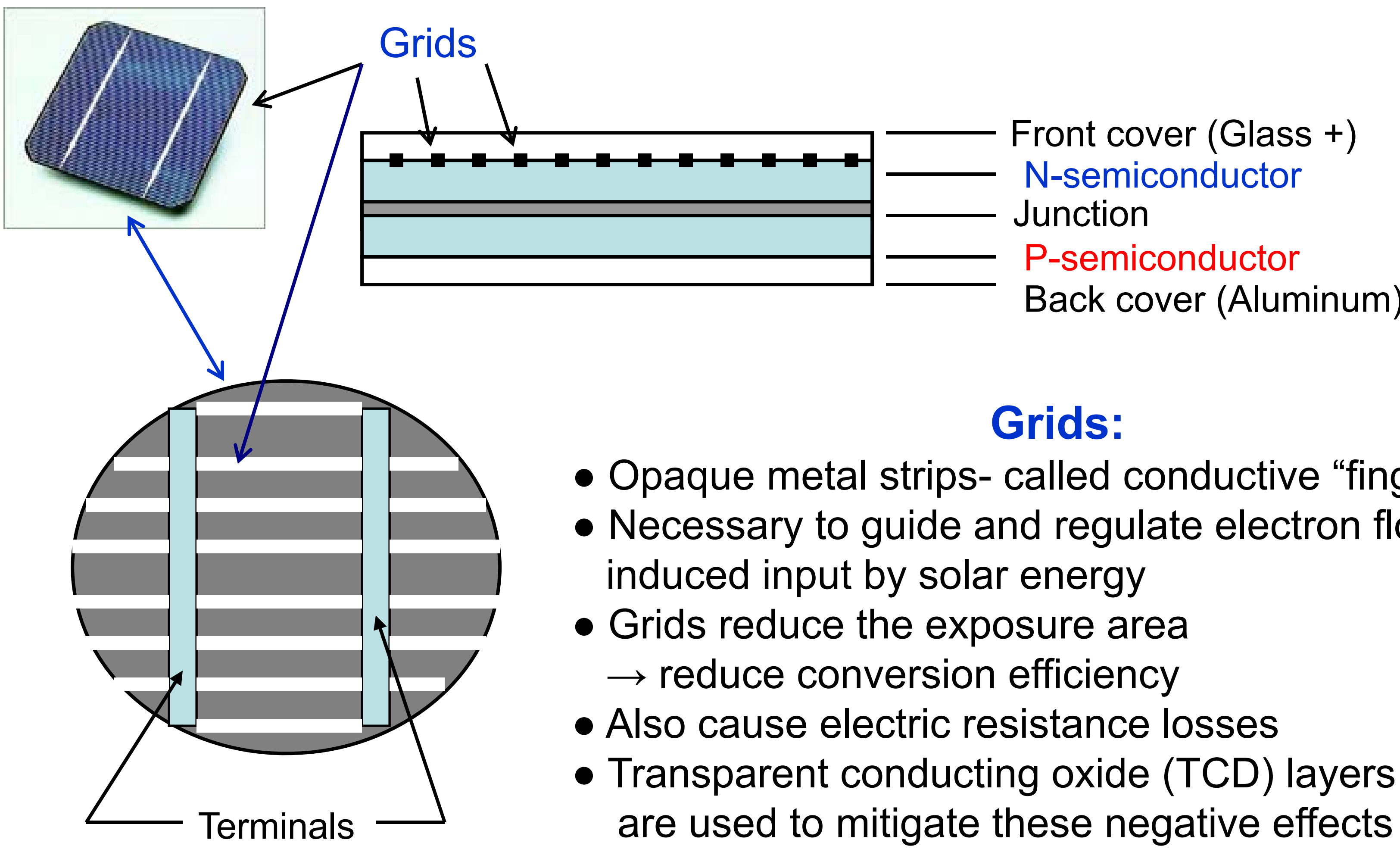
Single Crystalline	Polycrystalline (Thin films)
Silicon (Si): Single crystalline Polycrystalline silicon Amorphous silicon (non-crystalline Si for higher light absorption) **Gallium arsenide** (GaAs)	**Cadmium telluride** (CdTe) **Copper indium diselenide** (CIS)

Approximate Achievable Conversion Efficiencies

Single Si	15 – 25%
Poly Si	10 – 15%
A-Si	5 - 10

GaAs	25 – 30%
CdTe	7%
CIS	10

Conducting Grids – a necessary evil



Grids:

- Opaque metal strips- called conductive "fingers"
- Necessary to guide and regulate electron flows induced input by solar energy
- Grids reduce the exposure area
  → reduce conversion efficiency
- Also cause electric resistance losses
- Transparent conducting oxide (TCD) layers are used to mitigate these negative effects
- DRIE and plasma etching are often used to create these grids

Types of Solar PV Cells

A. Flat plate systems:

- On rigid flat surface
- Usually from single wafers from 300 to 250 to 200 μm tk
- Area: 170 cm^2 approx.
- Output power: 1 - 2 W approx.
- Output Voltage: 0.5 v approx.

B. Concentrator systems:

- With optical components, e.g. lenses to direct and concentrate sunlight on the PV cells of small areas
- Involving tracking mechanisms for directing the sunlight
- Can increase power flux of sunlight hundreds of times
- Heat dissipation required