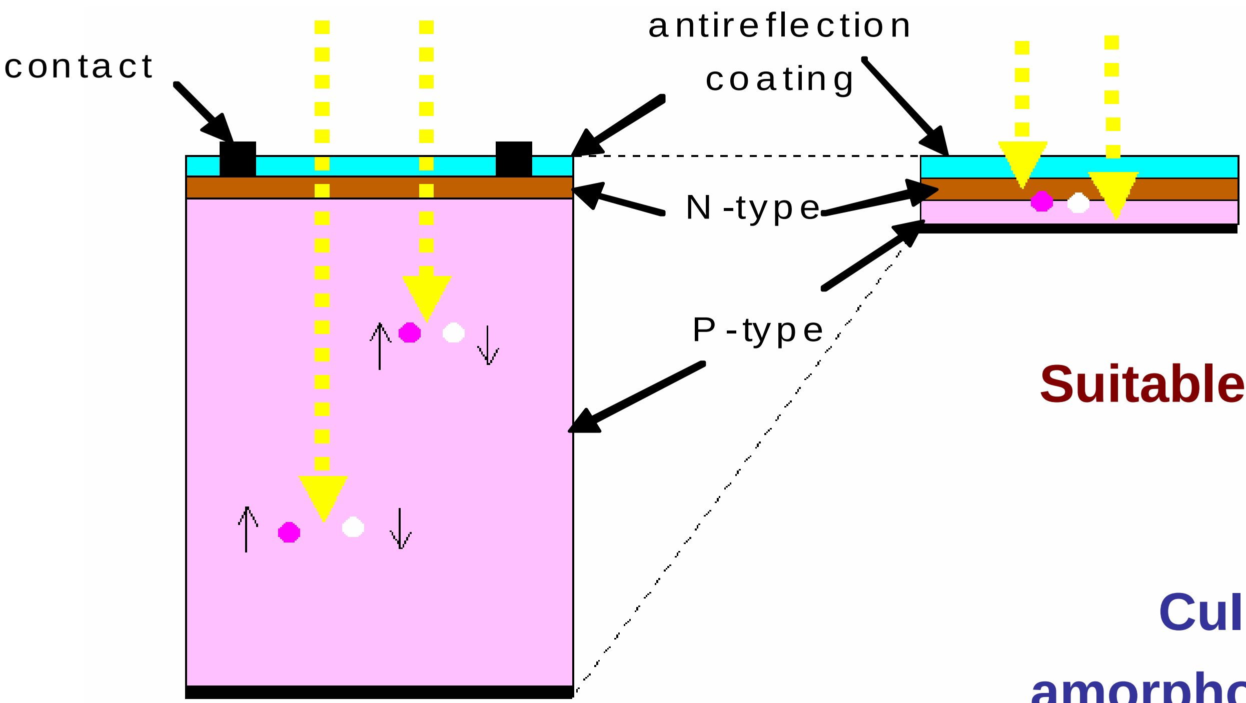
# Thin film solar cells

# Basic types of solar cells:

Crystalline silicon cells

Thin film cells




**Suitable materials**

**$CuInSe_2$**

**amorphous silicon**

**amorphous SiGe**

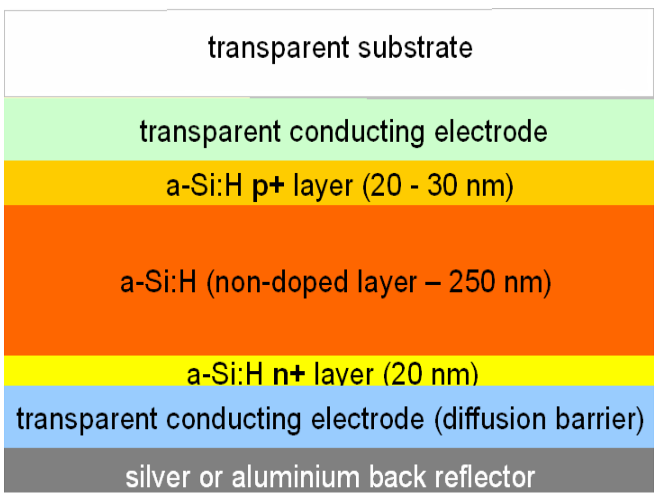
**CdTe/CdS**

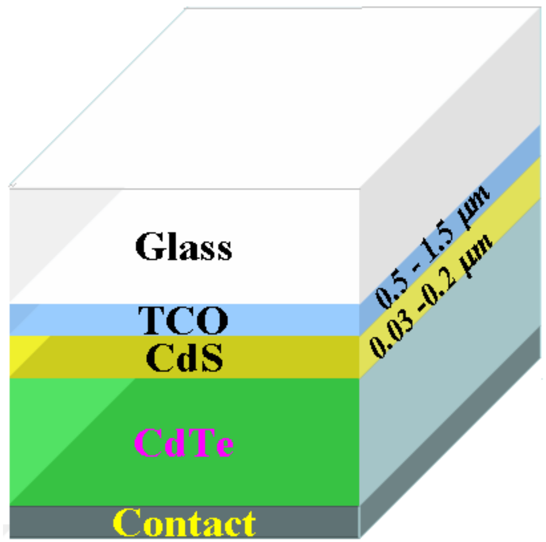
**Basic problem: cost…...**

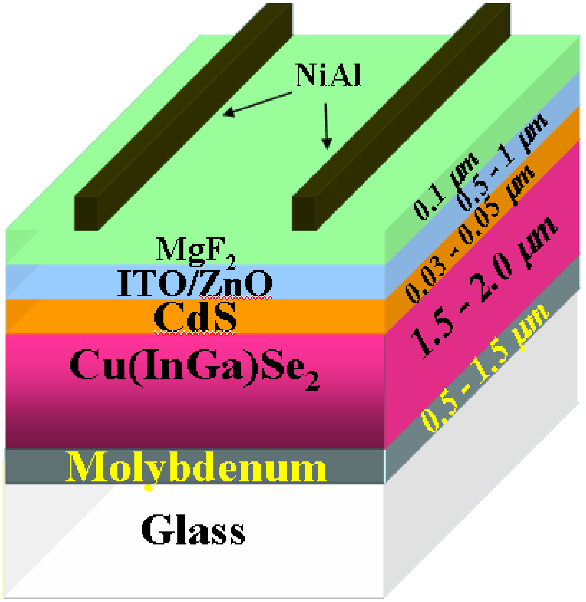
Amorphous Si

CdTe/CdS

CIS



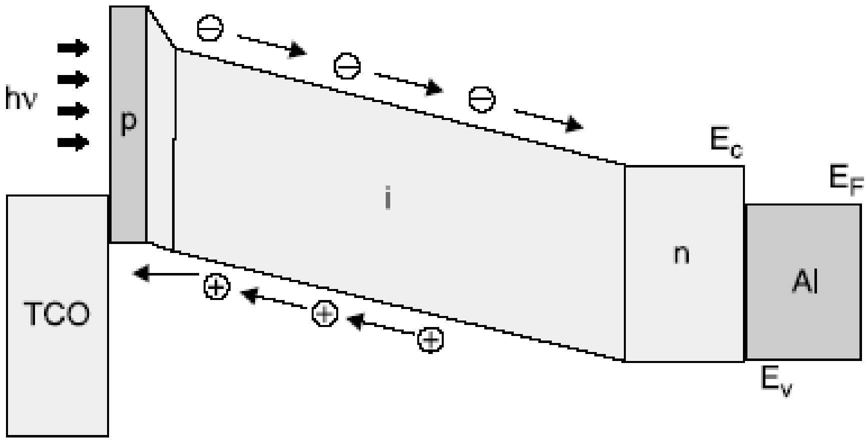




Market share (2011) :

4.7%

5.7%

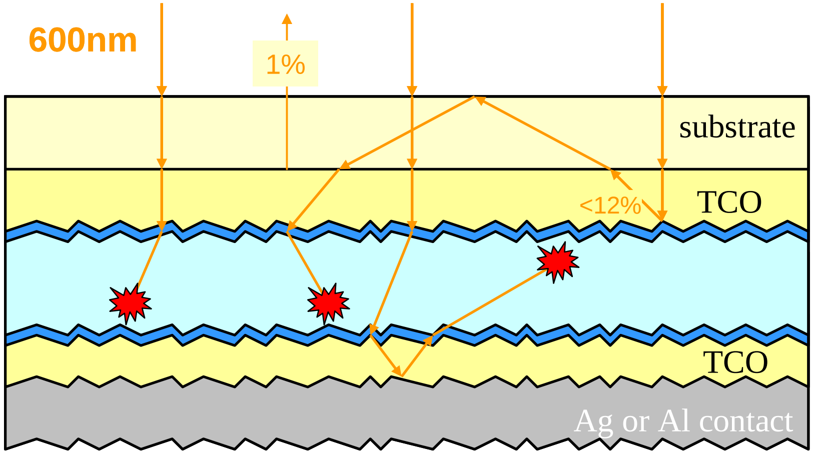
0.5%

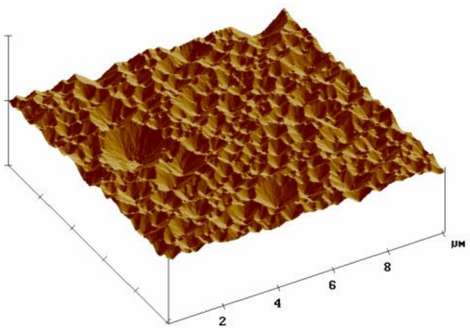



# TCO:

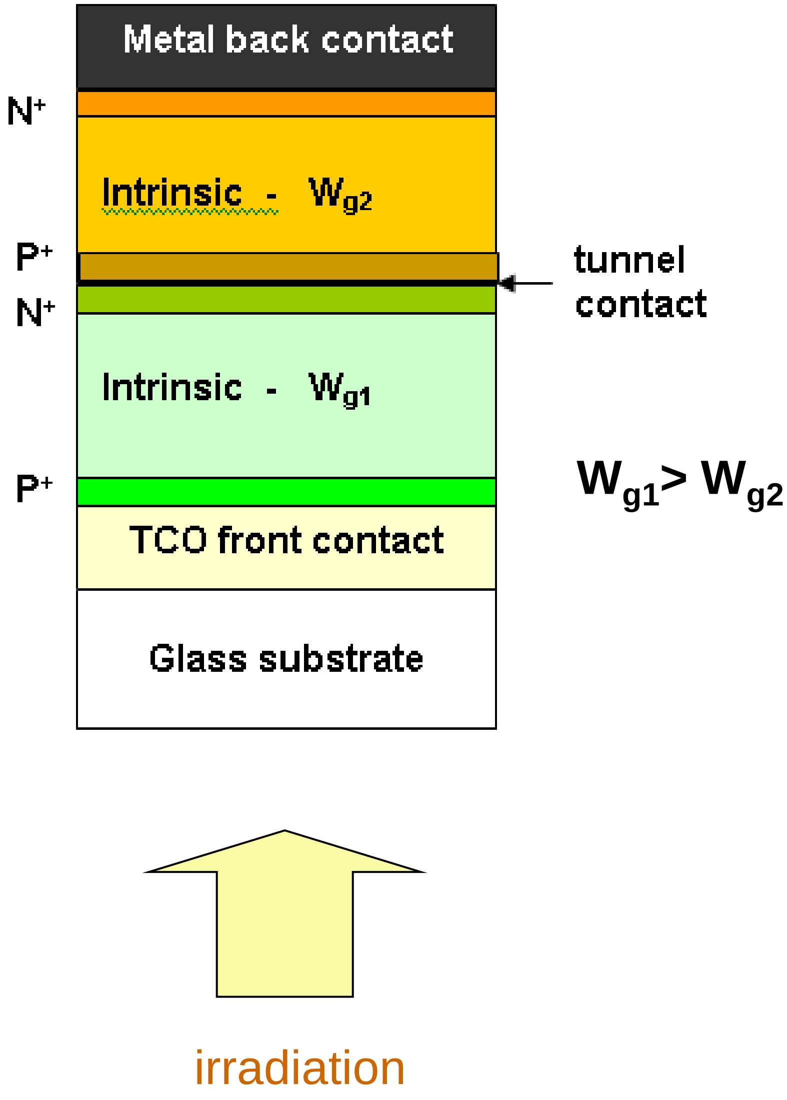
- $SnO_2$
- ITO (indium-tin oxide)
- ZnO

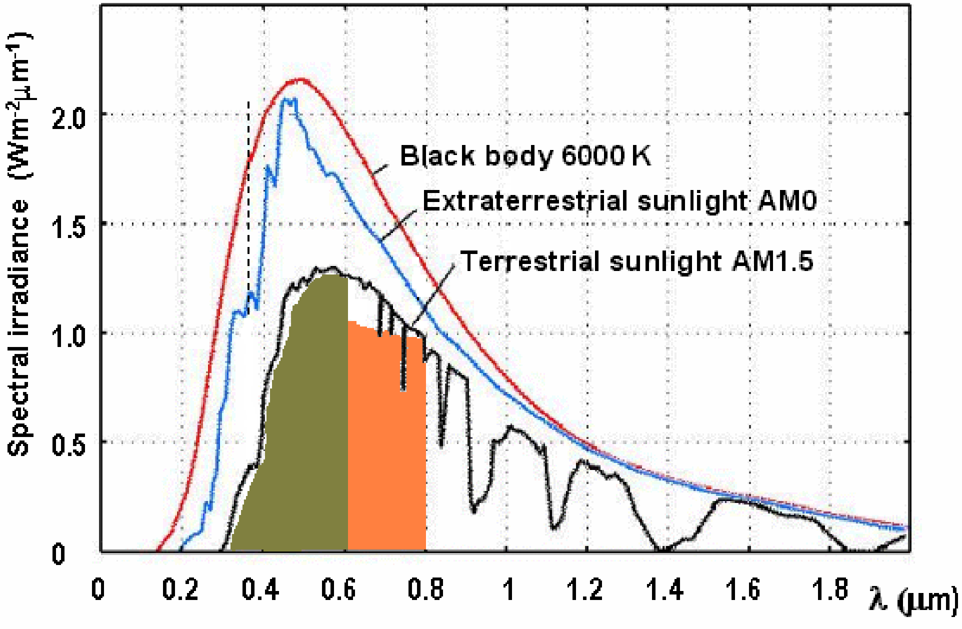
## Light trapping

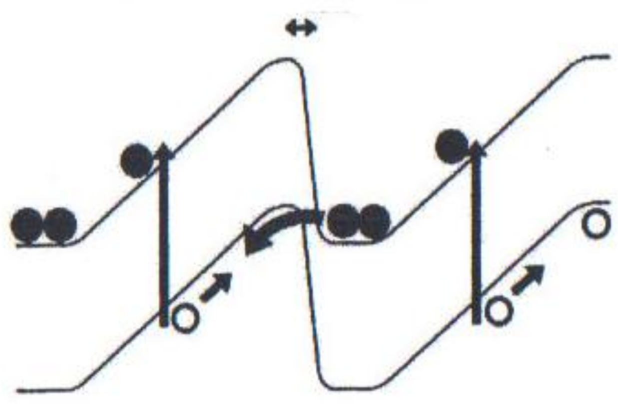


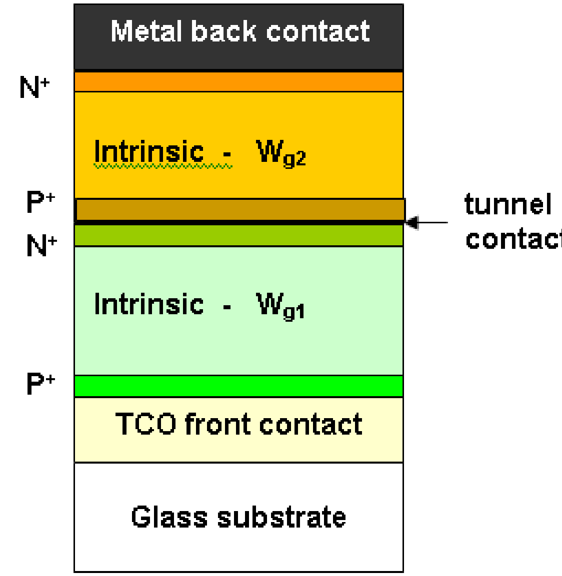
# Tandem cells

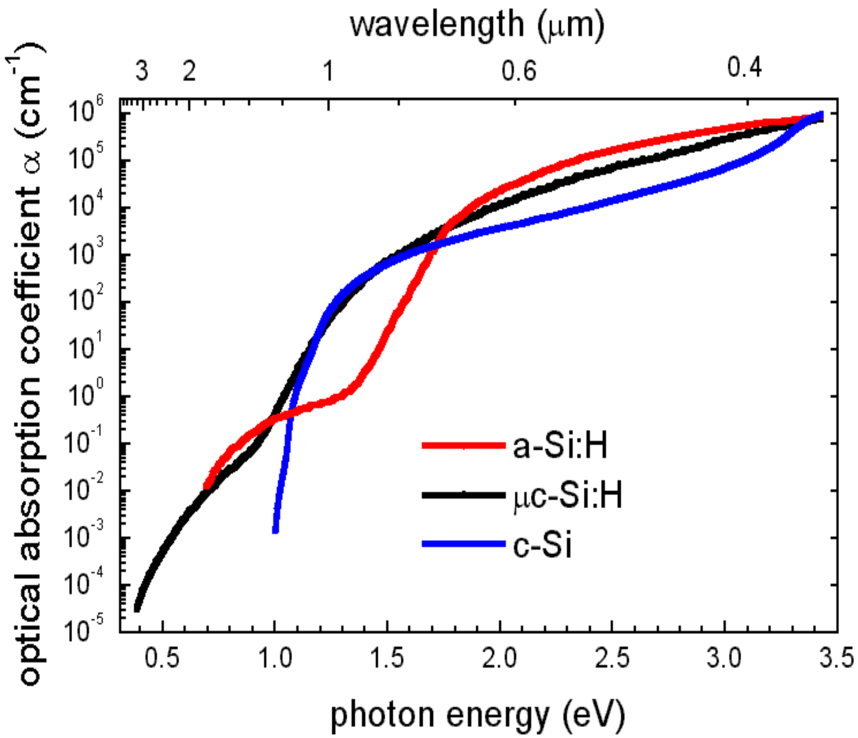


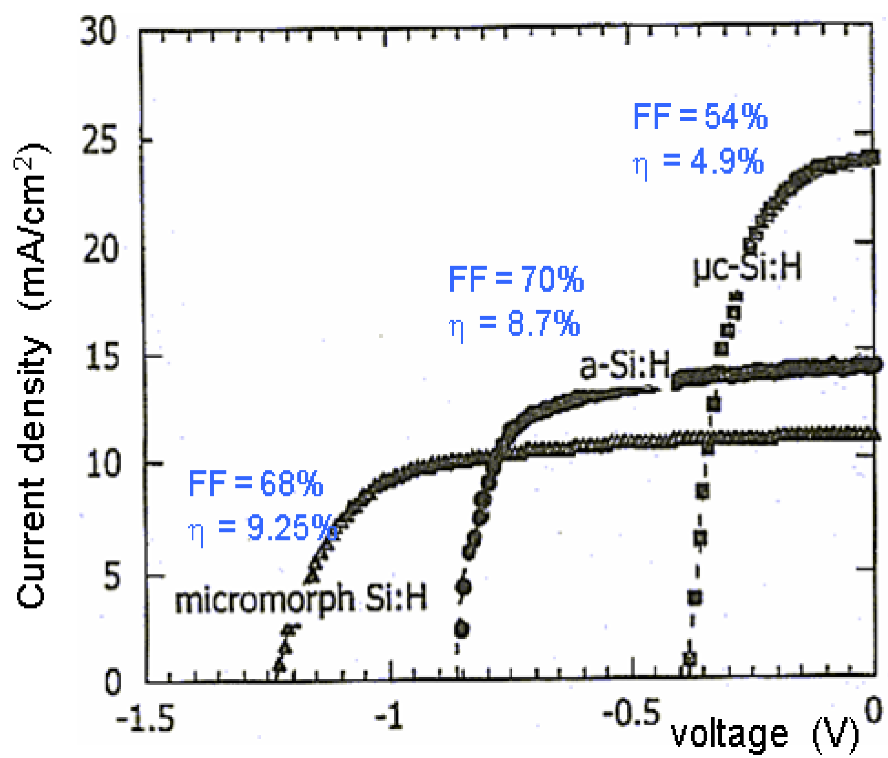



# "Micromorf" cells



# Thin film solar cell technology

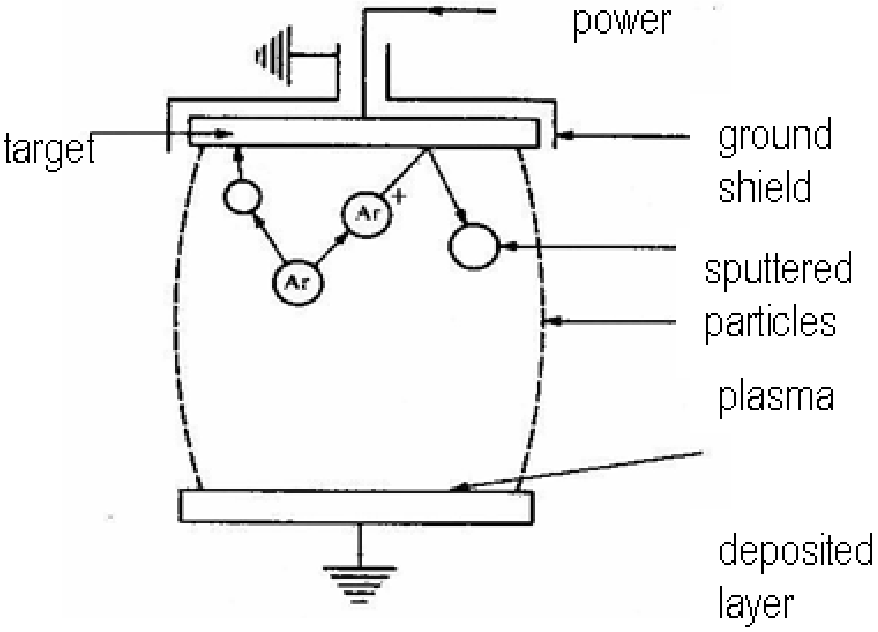
A) Vacuum deposition

*Filament evaporation*

*Electron-beam evaporation*

*Flash evaporation*

*Sputtering*



# B) CVD (Chemical vapour deposition ) technique

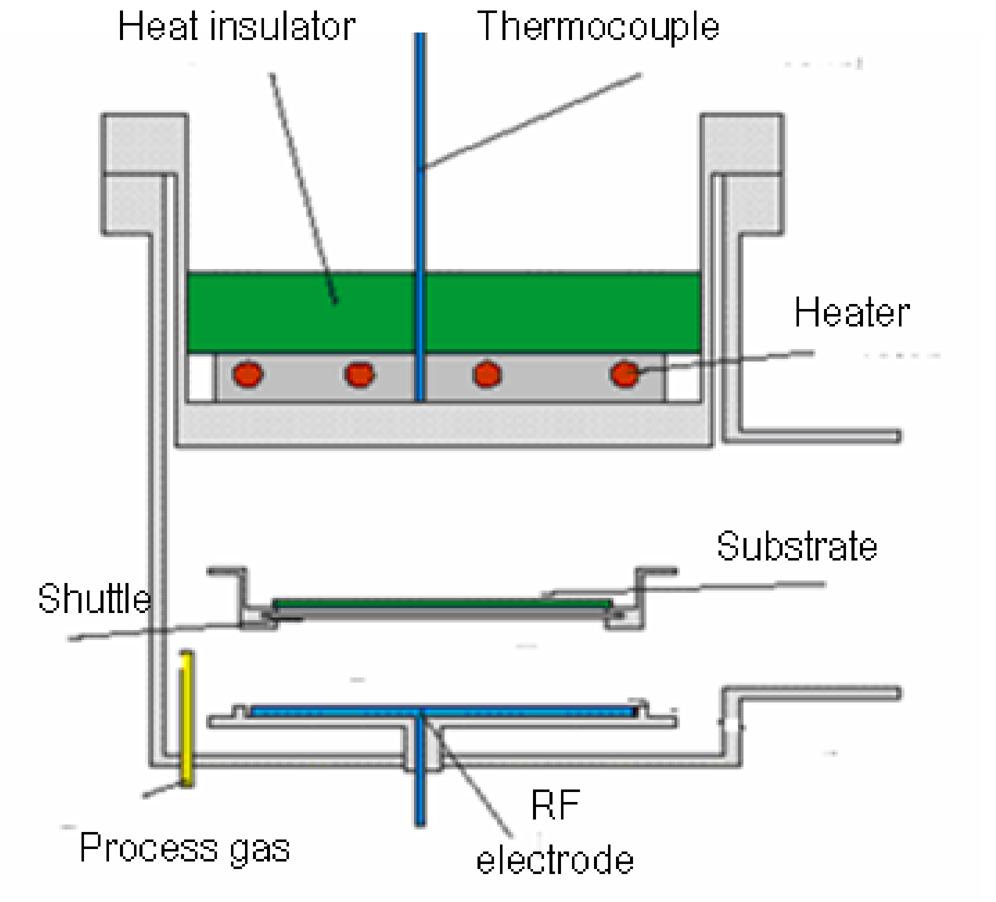
CVD technology is the formation of a stable compound on a heated substrate by the thermal reaction or decomposition of gaseous compounds

- Deposition of silicon nitride $3SiH_4 + 3NH_3 \rightarrow Si_3N_4 + 12H_2$
- Deposition of polysilicon layers $SiH_4 \rightarrow Si + 2H_2$

- Reaction chamber
- Gas control section
- Timing and sequence control
- Heat source for substrates
- Effective handling

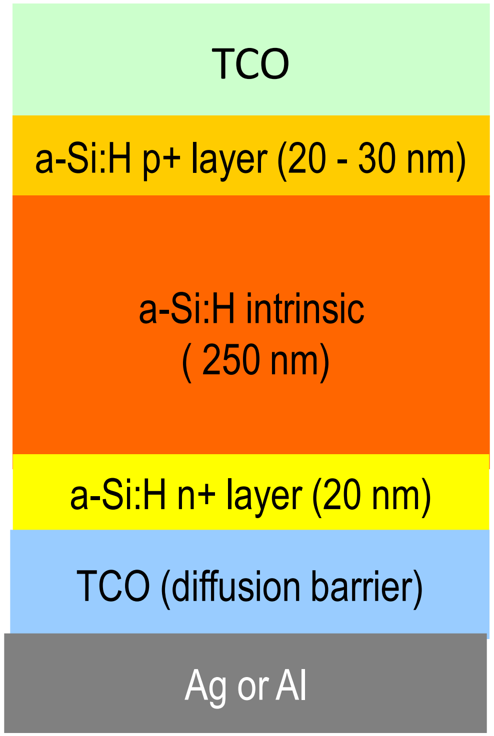
# Plasma enhanced CVD (PECVD)

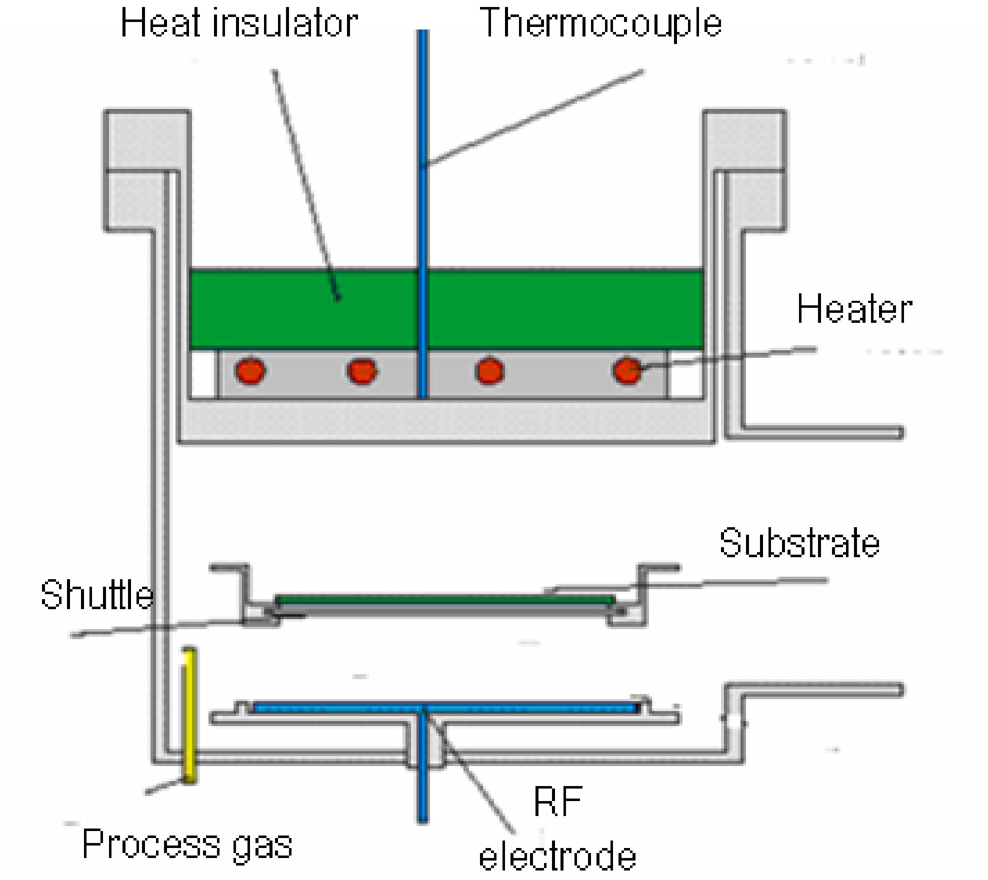
- RF electrode and substrate create the capacitor structure
- In this space the plasma and incorporated deposition of material on substrate takes place



# Amorphous (microcrystalline) silicon solar cells

transparent substrate (glass)

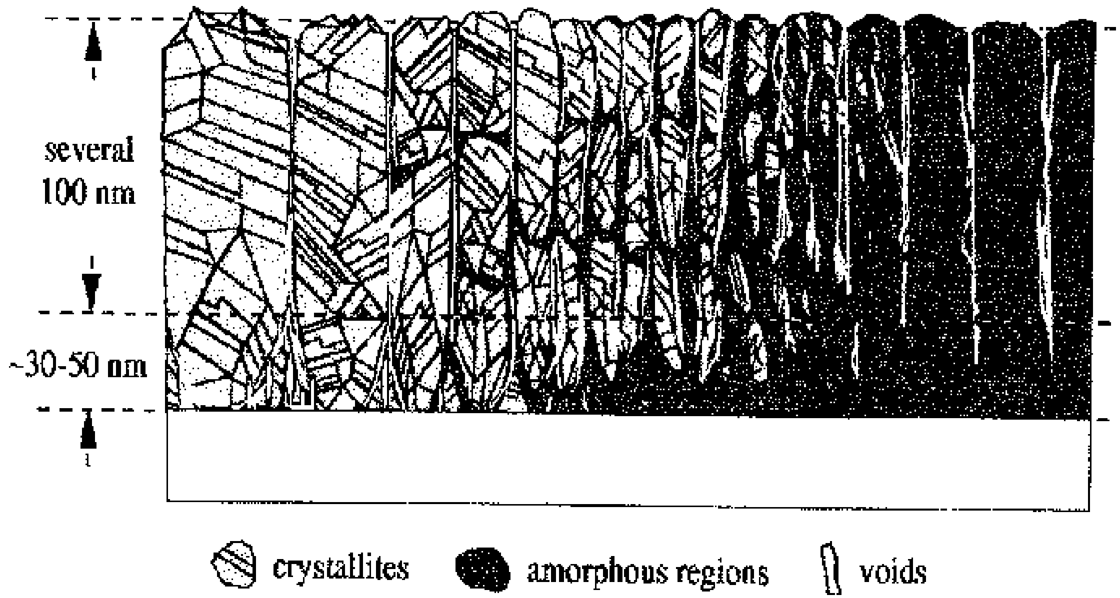



$SiH_4$, $H_2$, $B_2H_6$, $PH_3$, $GeH_4$, etc

The deposited layer structure depends on the gas composition and substrate temperature

150 – 350°C



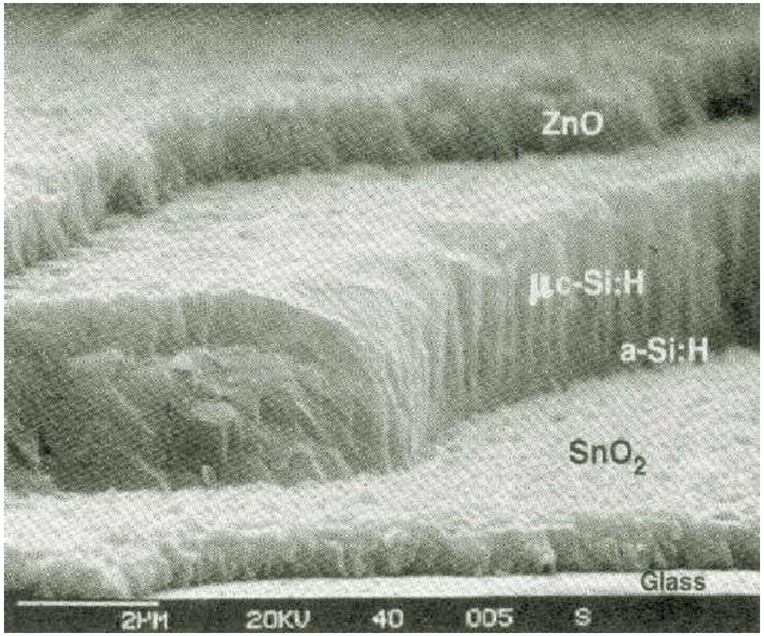

dilution ratio

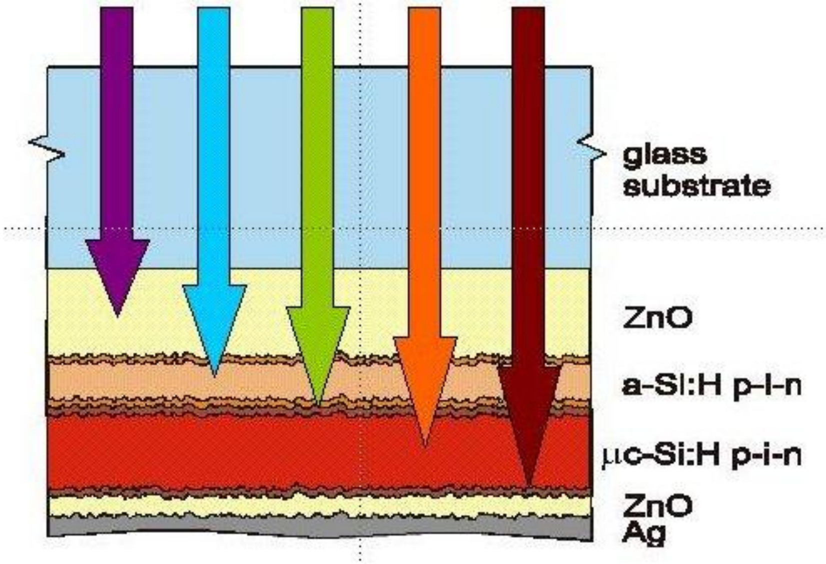
rH = ([H2] + [SiH4])/[SiH4].

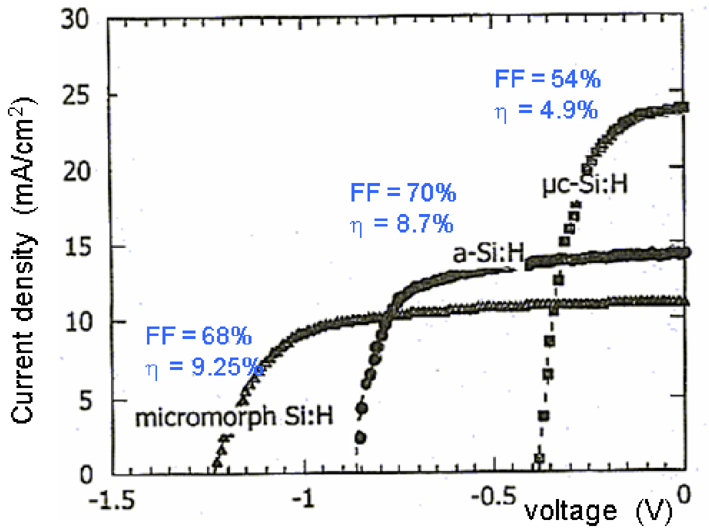
rH < 30, amorphous silicon growth

rH > 45, crystalline layers are formed

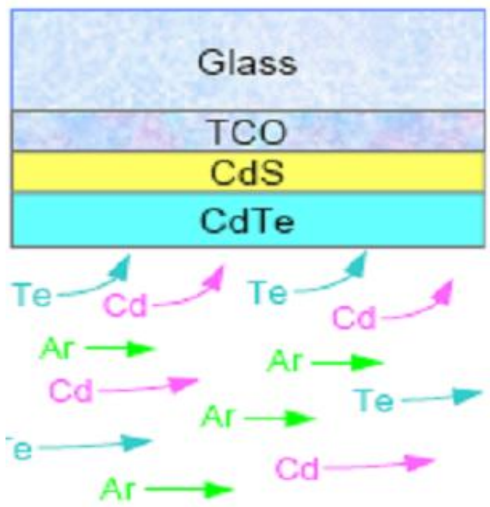
# Tandem solar cell – „micromorph"(microcrystal + amorphous)



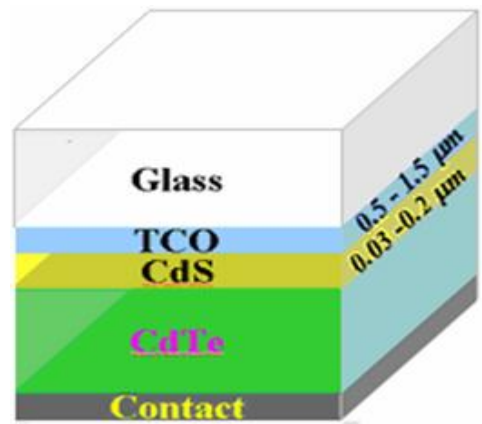



# CdTe modules




*Vapor Transport Deposition*



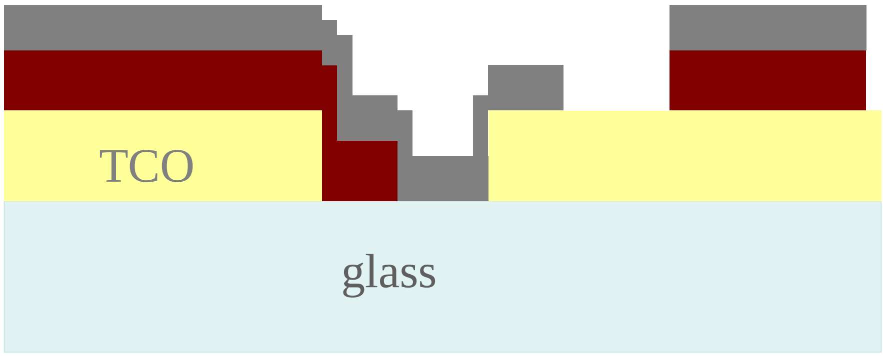

CdTe solar Cells

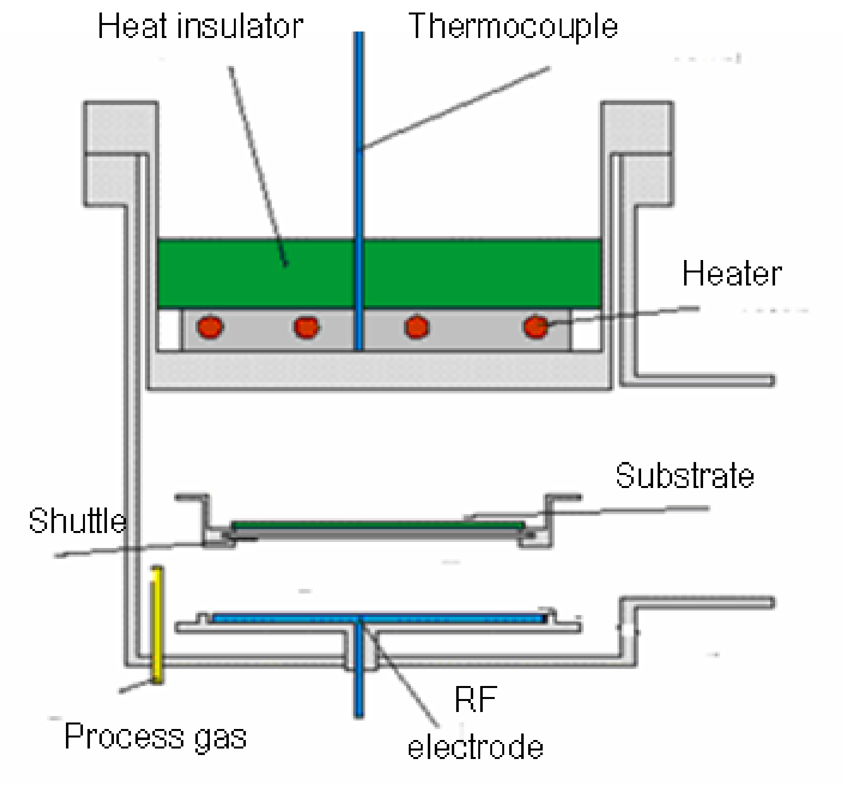
toxicity of Cd
limited supply of Te

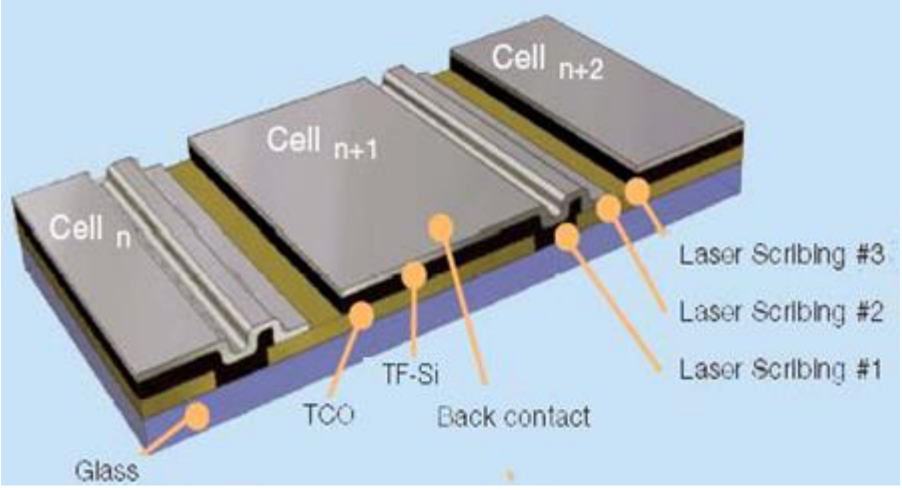
Low fabrication cost

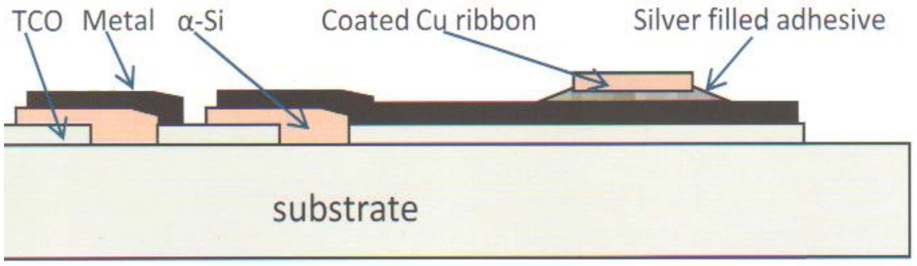
Relatively high efficiency (10%)

# Thin-film modules on glass substrates



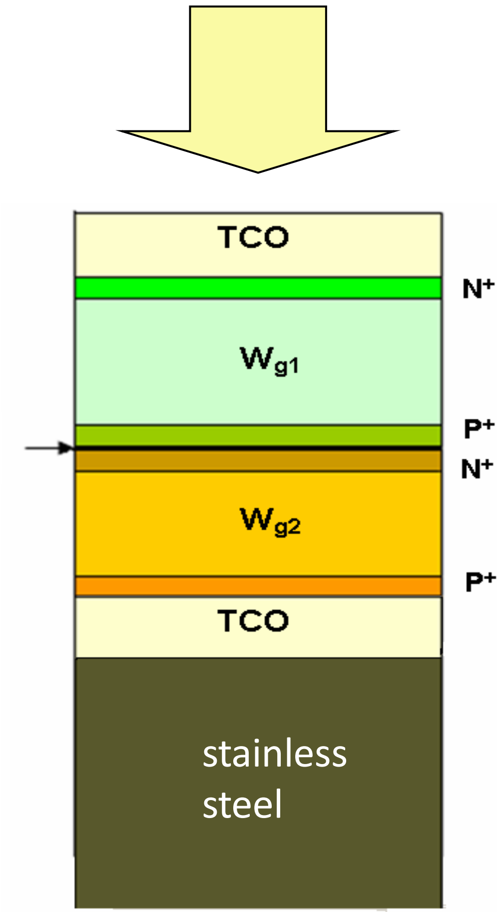



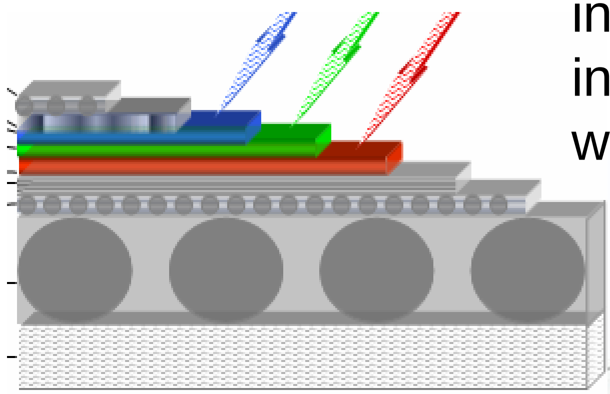

Back surface is laminated with EVA and suitable covering sheet (glass, tedlar)

# Thin-film modules on metallic substrates



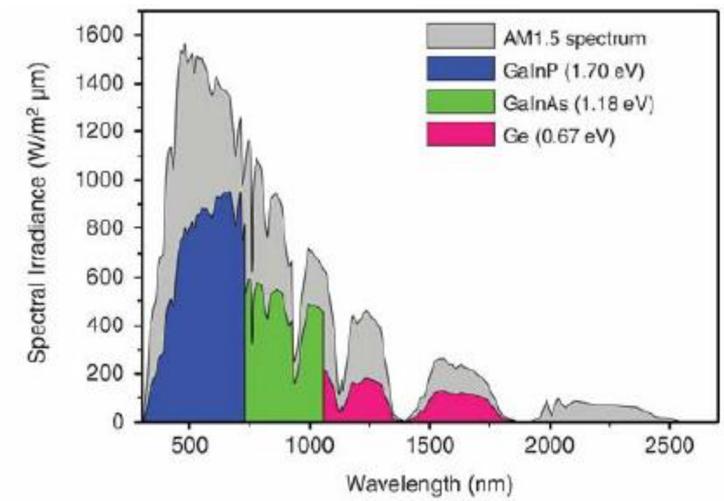

$\eta \approx 7\%$

„Roll to roll“ technology



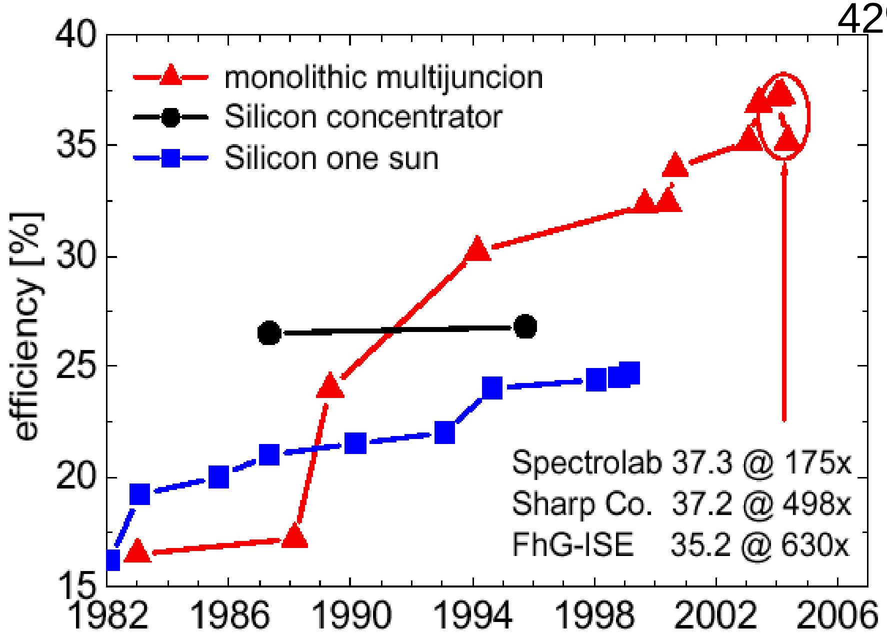
After cutting the long sheet, individual cells are connected in series and encapsulated with polymers

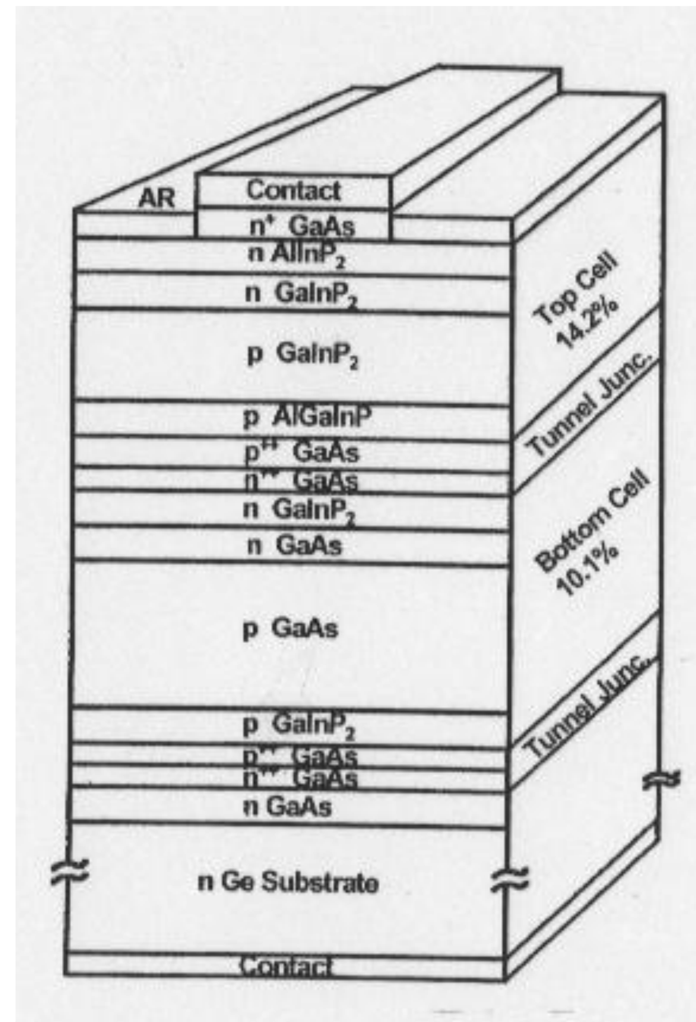
# $A^{III}B^{V}$ multijunction cells




The highest efficiency from all solar cell types □ □ 30%

42% in 2010

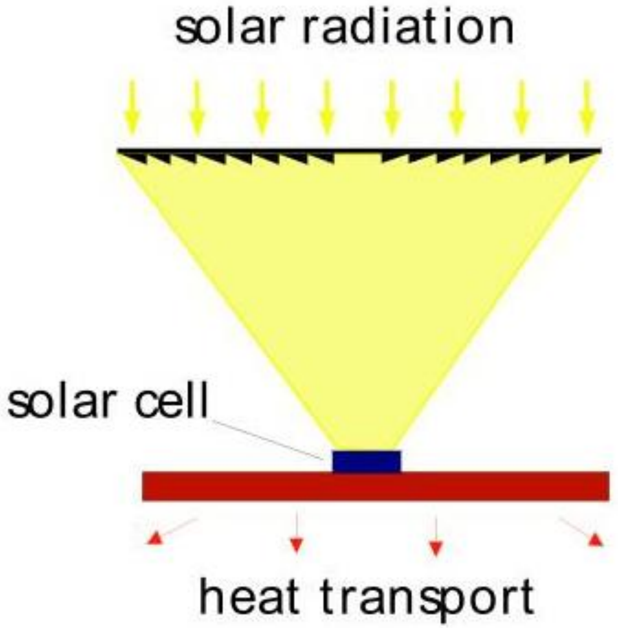


# High efficiency solar cell application

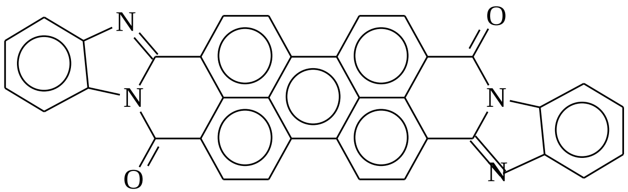
| Cell | $V_{OC}$ [mV] | $1/V_{OC}\,dV_{OC}/dT$ [%/K] |
|---|---|---|
| Ge | 200 | −0.90 |
| GaAs | 1050 | −0.19 |
| GaInP | 1350 | −0.16 |
| GaInP/GaAs | 2400 | −0.17 |
| GaInP/GaAs/Ge | 2600 | −0.23 |
| GaInP/GaAs/Ge (500 suns) | 3080 | −0.19 |

Concentrator modules

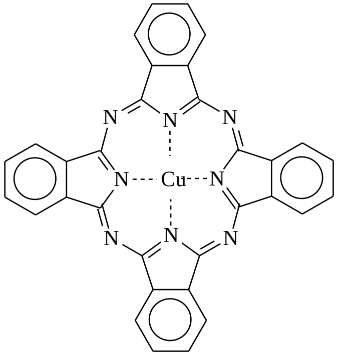



# New solar cell concepts

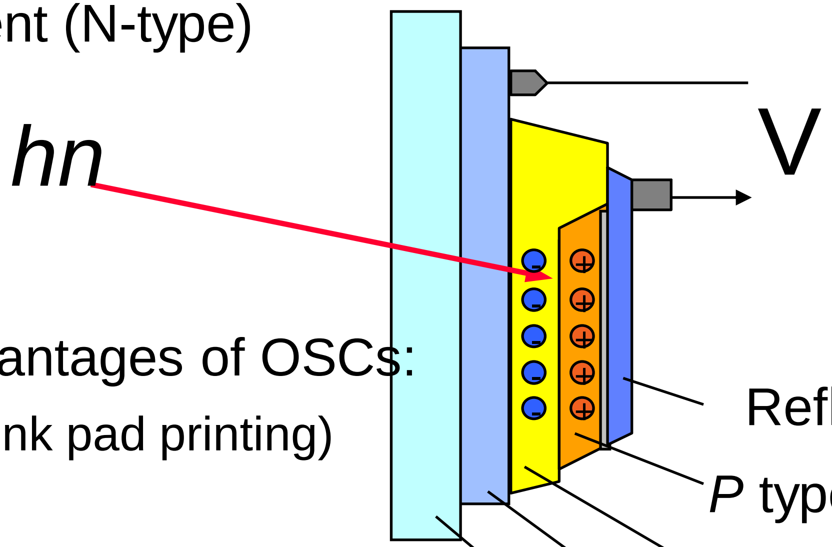
## Organic semiconductors




Perylen pigment (N-type)




Cu Phtalocyanin (P-type)




Reflecting Electrode (Al)

*P* type organic semiconductor

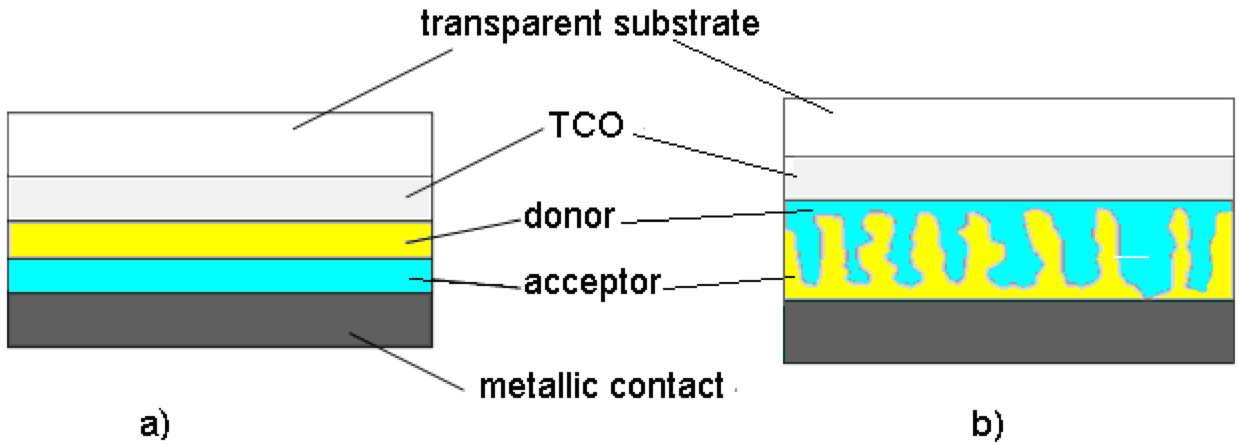
N type organic semiconductor

Transparent Conducting Oxyde

Transparent Substrate

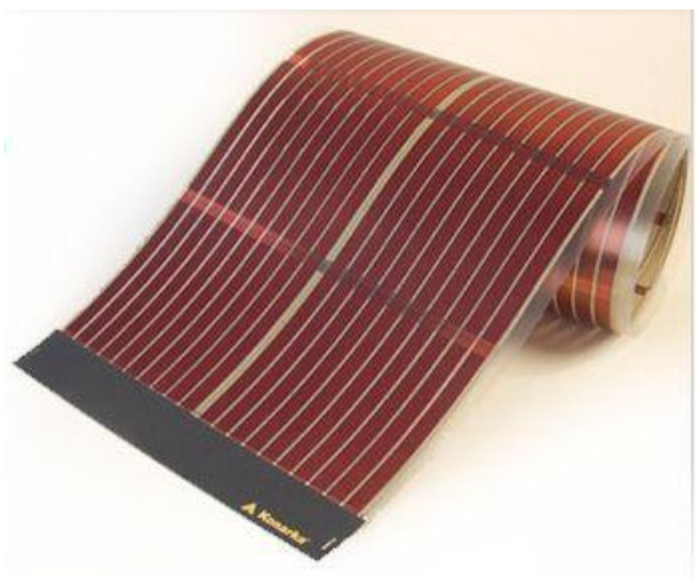
Technological advantages of OSCs:

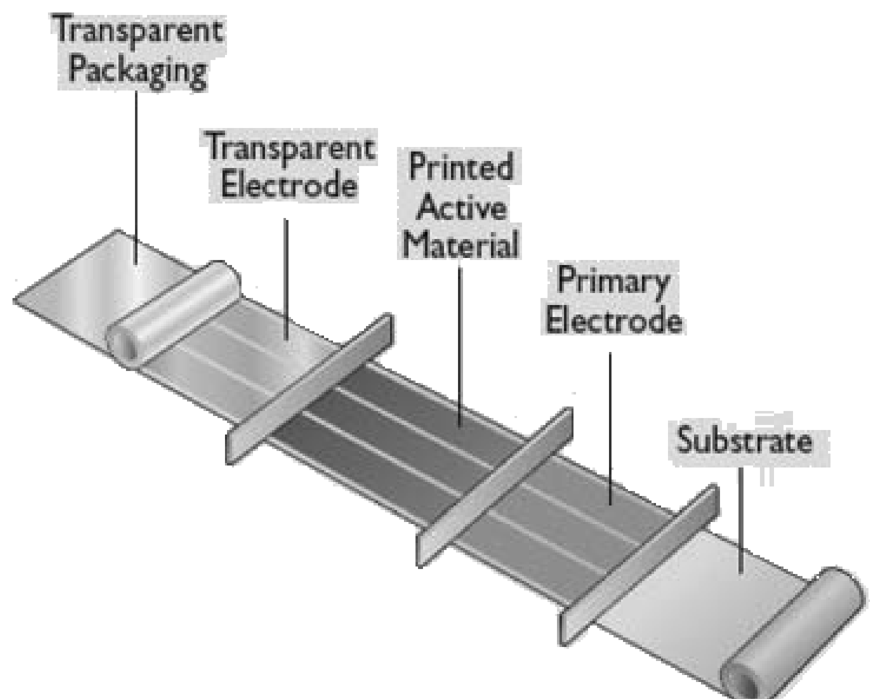
- Wet processing (Ink pad printing)
- Soft cells
- Large surfaces
- Low cost
- Molecular materials




two layer structure

bulk heterojunction cell

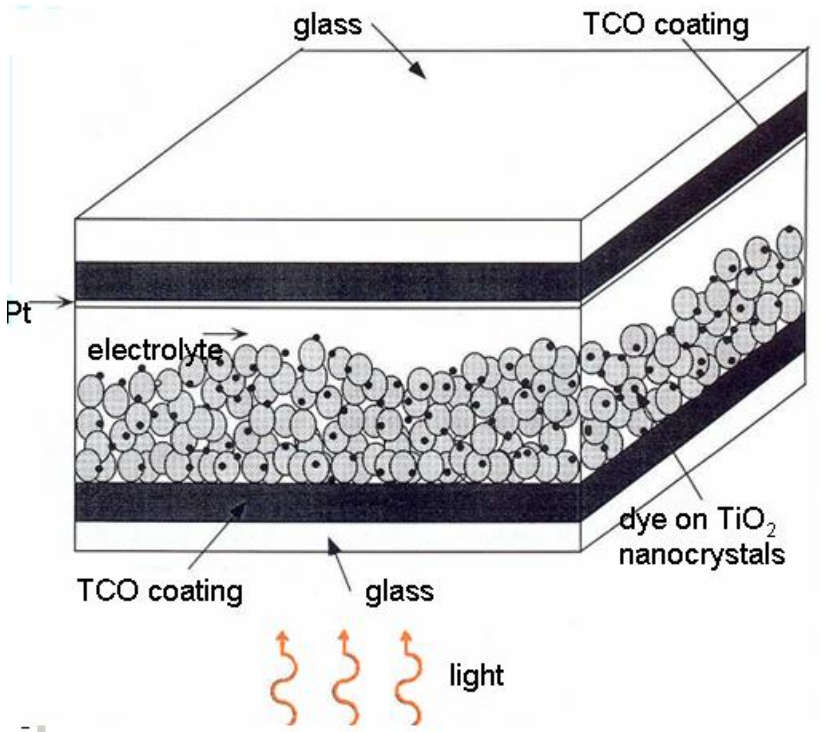




# Dye-sensitized Solar Cells (DSSC)

In development since 1992

$TiO_2$ – Iodine system




$S + h\nu \rightarrow S^*$

$S^* \rightarrow S^+ + e^-(TiO_2)$

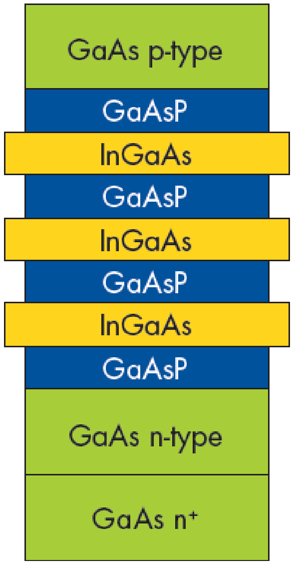
$S^+ + e^- \rightarrow S$

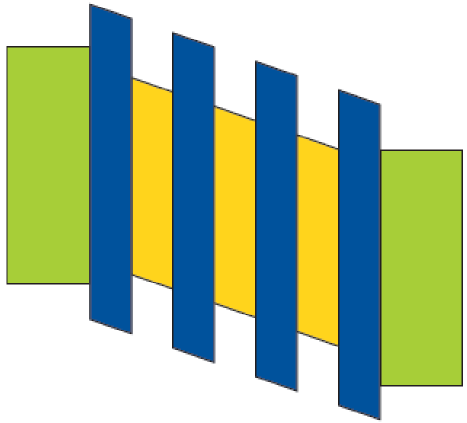
$I_3^- + 2e^- \rightarrow 3I^-$

$\eta = 8\%$

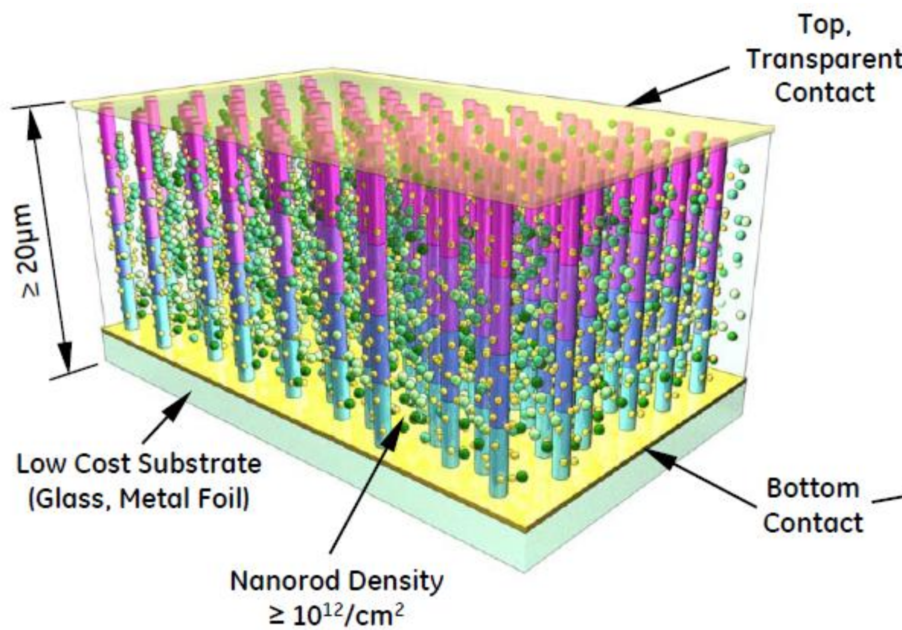
Operating temperature problems

# Quantum effect solar cells



Nanotechnologies




All these quantum effect technologies are still in the stage of research.

Some of structures may come to development and comertional phase in a few years