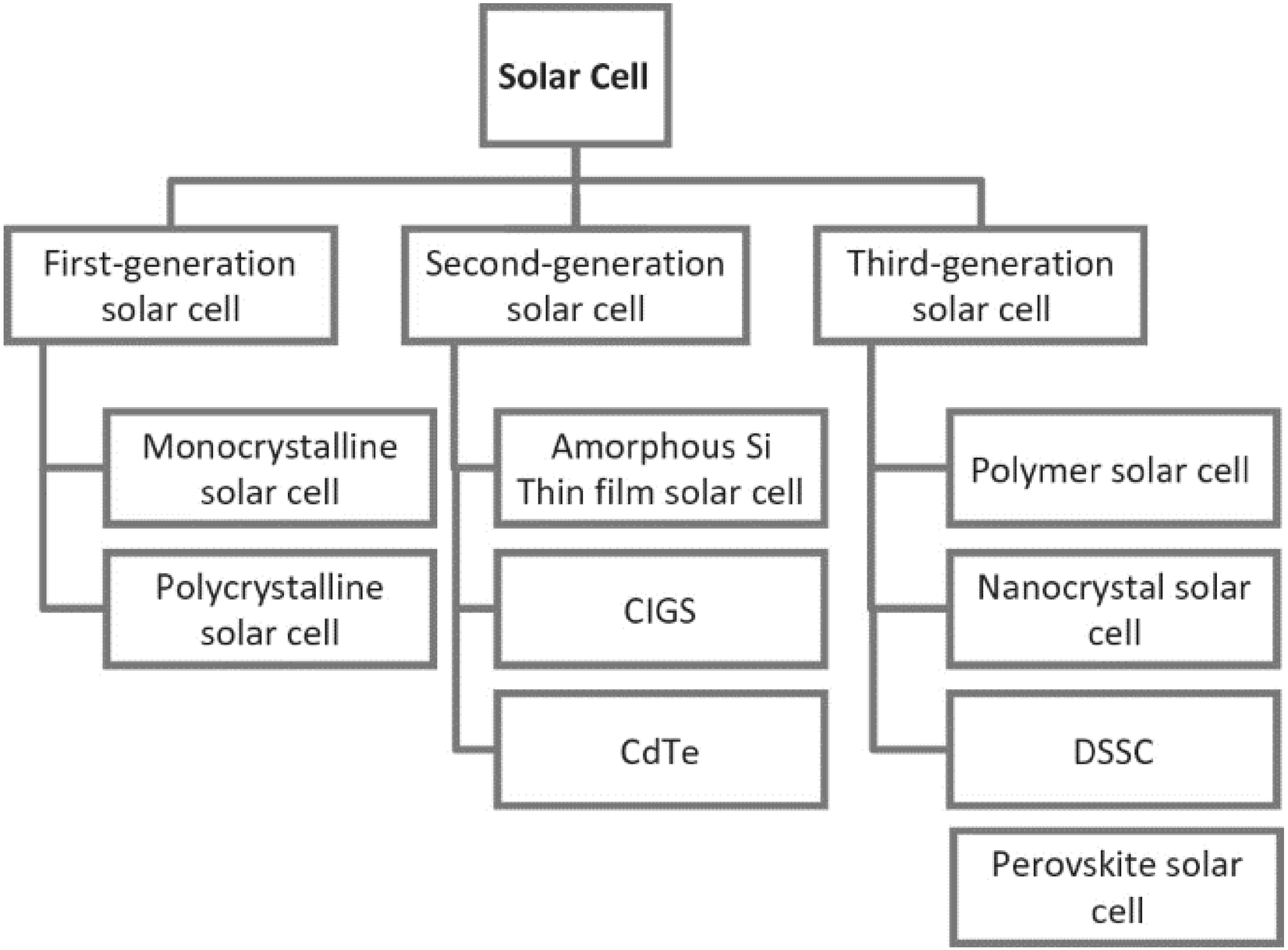
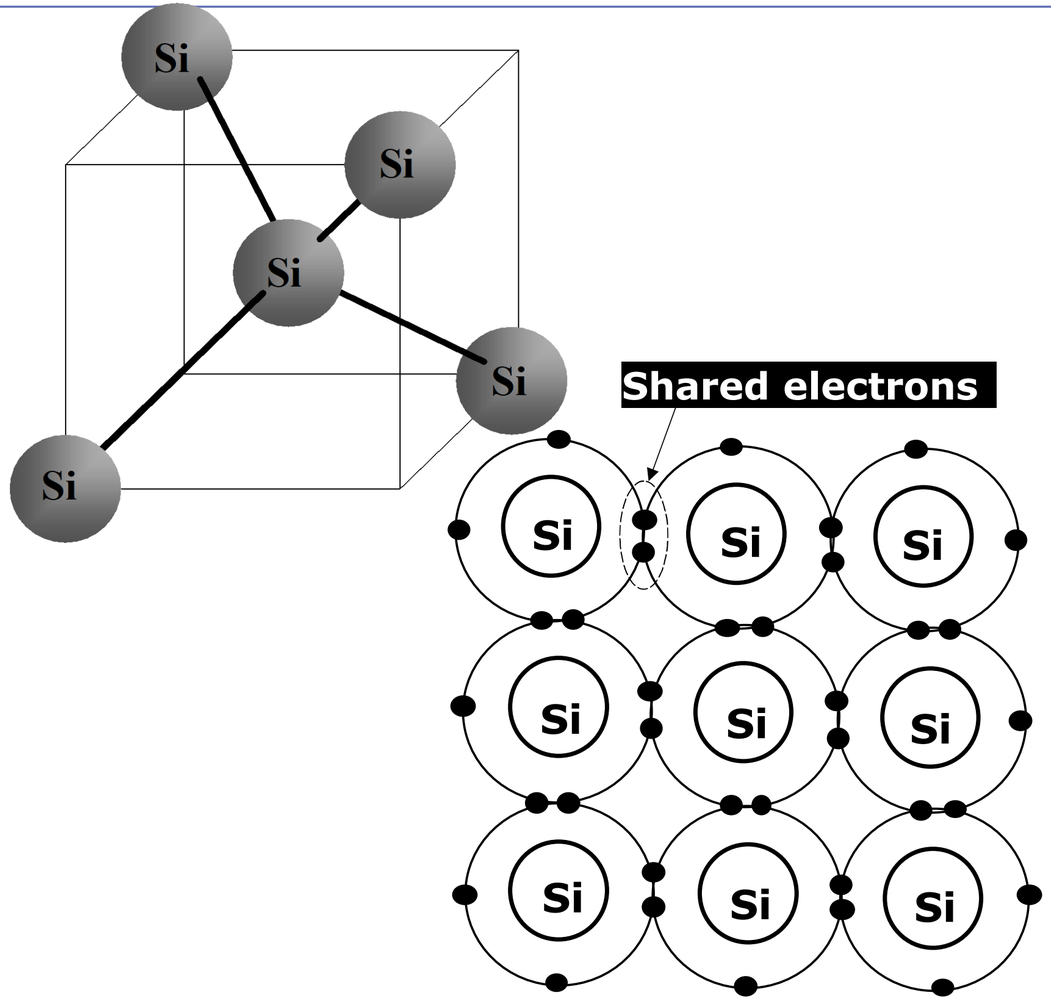
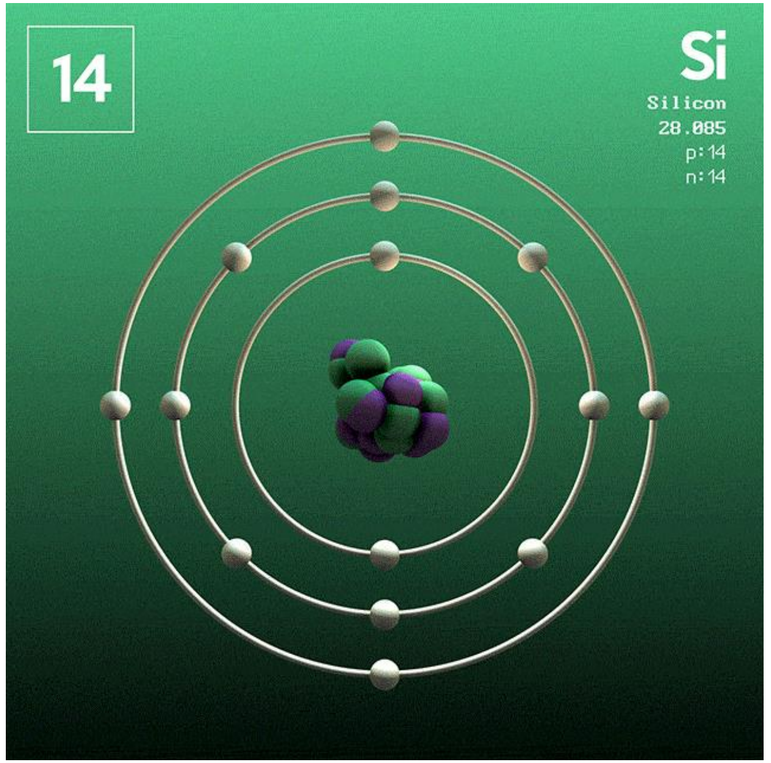
Classification of solar cells



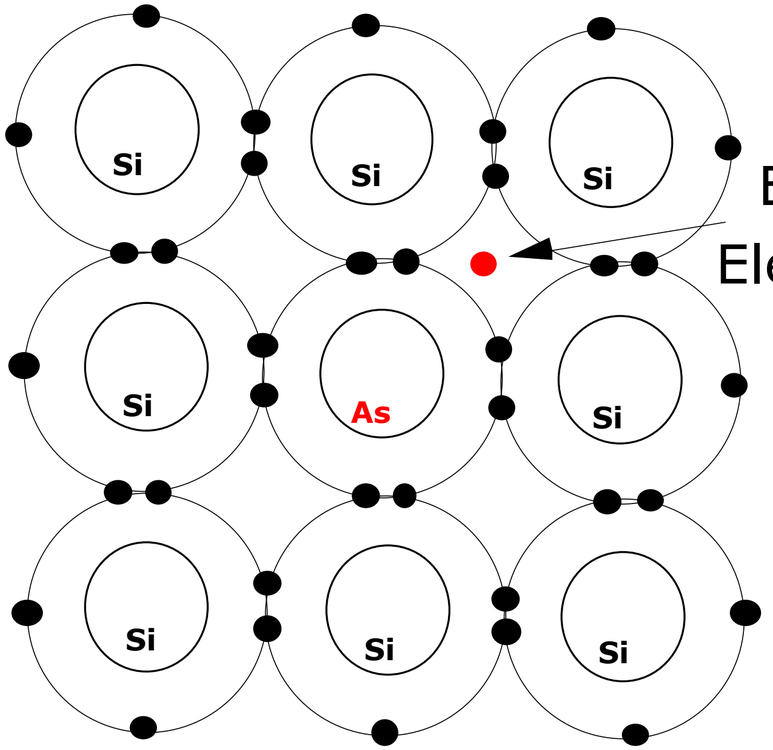
Silicon

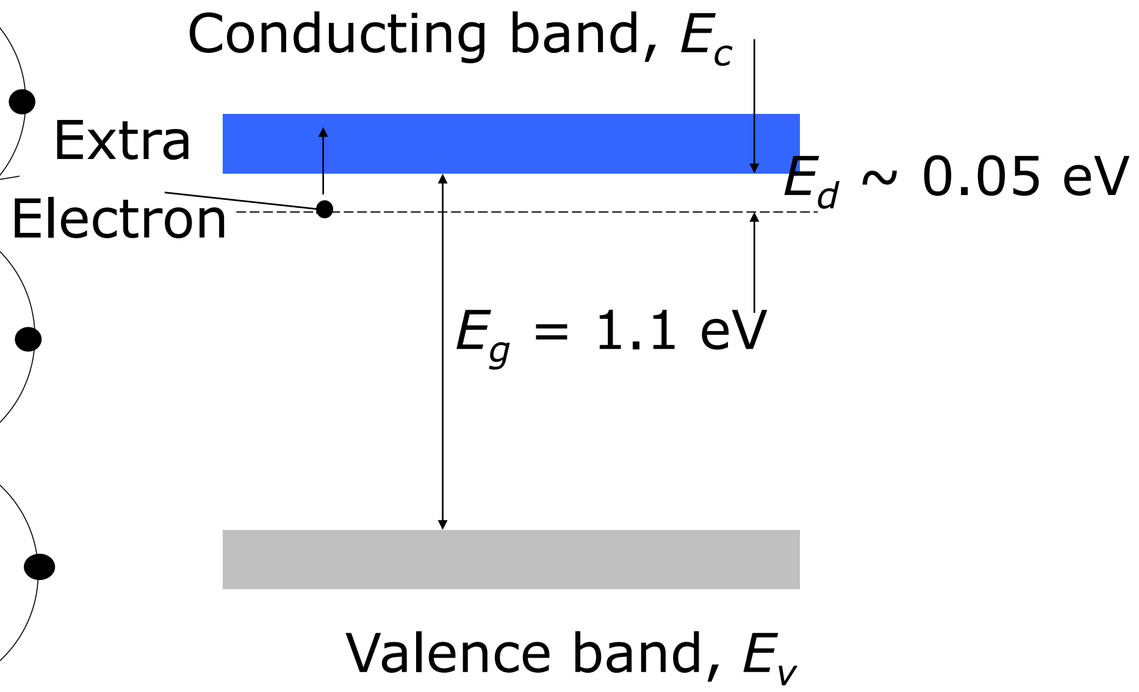




- **Silicon is group IV element – with 4 electrons in their valence shell.**
- **When silicon atoms are brought together, each atom forms covalent bond with 4 silicon atoms in a tetrahedron geometry.**

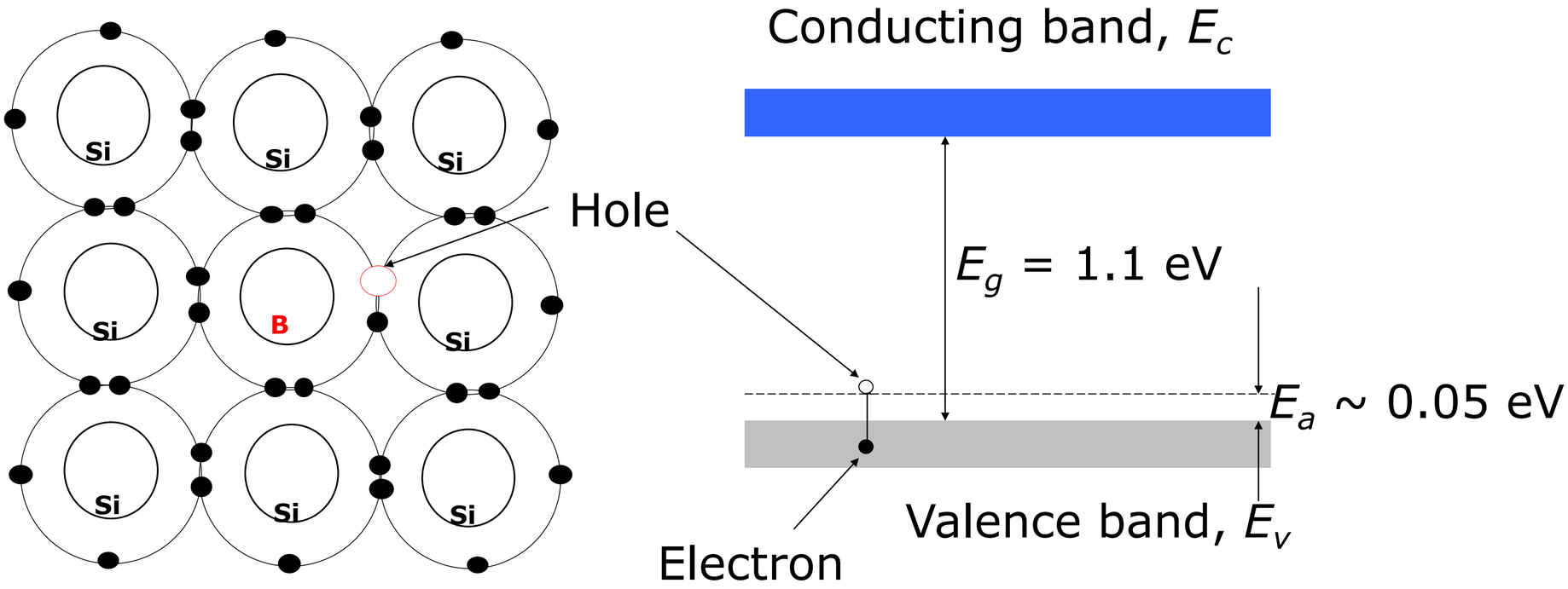
n-type Doping





- **Doping silicon lattice with group V elements can creates extra electrons in the conduction band — negative charge carriers (n-type), As- donor.**
- **Doping concentration #/cm^3 (10^{16}/cm^3 ~ 1/million).**

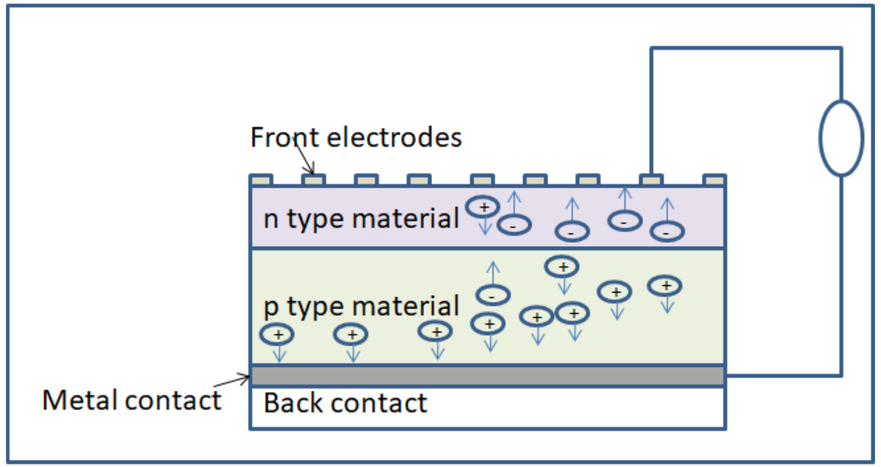
p-type doping

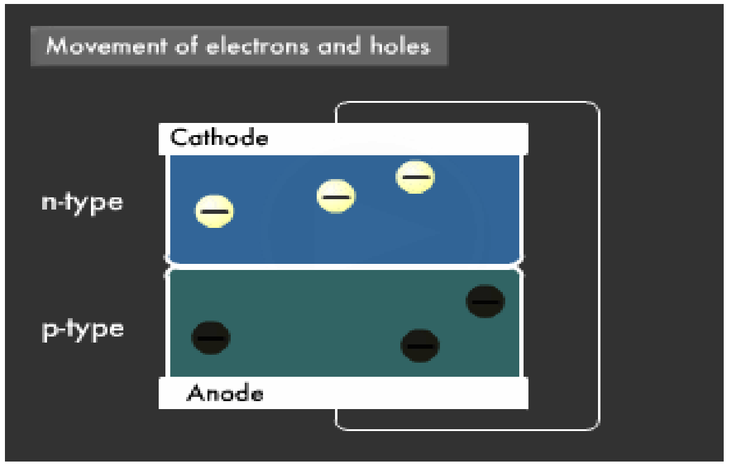


➢ Doping silicon with group III elements can creates empty holes in the conduction band — **positive charge carriers (p-type), B- (acceptor).**

Construction of amorphous silicon solar cells

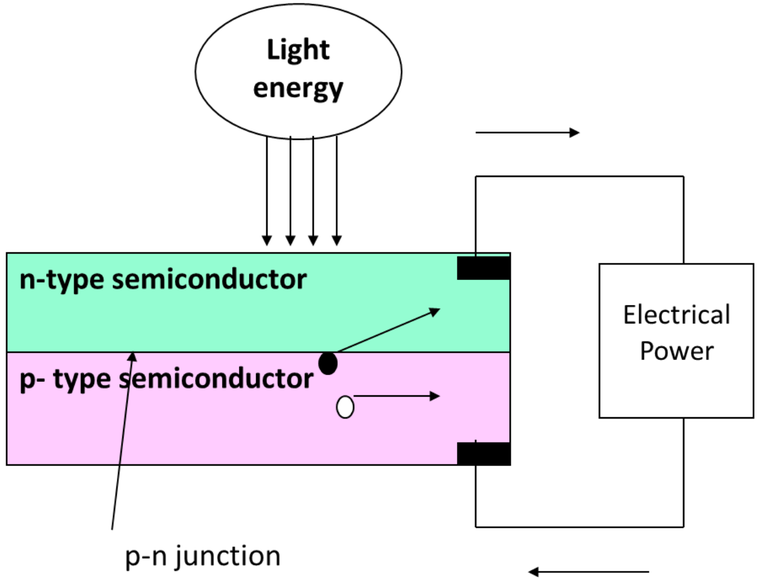
- A typical silicon solar cell consists of n-type material (Phosphorus doped silicon) and a p-type (Boron doped silicon) material made of silicon.
- In the fabrication of device these n-type and p-type materials are joined to form a p-n junction.
- On top of n type connecting front electrodes are placed.
- The metal back contact is attached to p-type layer.
- An antireflective coating is filled in between the front electrodes to avoid the reflection of sunlight.
- Finally p-type and n-type layers are joined externally to the circuit.
- The complete solar cells are sealed to avoid the environmental contact.





Working of silicon solar cells

- When sunlight is incident on solar cells photon strikes on p-n junction.
- Then electron hole pair will be created at the junction by the absorption of photon.
- This electron hole pair diffuses towards respective layer based on affinity.
- The electrons diffuse towards n-type later and holes are diffused towards p-type layer.
- These layers are connected externally through a circuit, hence current will be generated.



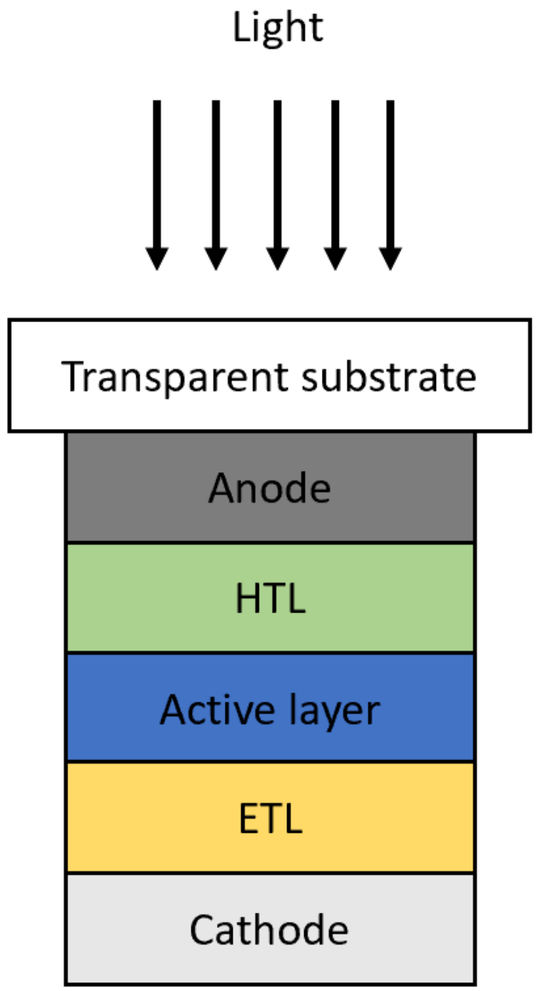
Advantages of silicon solar cells

- **Solar cell is renewable energy which can be continuously drawn from the sun.**
- **It is cost effective energy because once it installed there will be minimum maintenance charges for small usage.**
- **Solar energy is environment friendly and green energy because it doesn’t produce any greenhouse gasses and no pollutants.**
- **It doesn’t involve any combustion reaction or radioactive residue hence no pollution.**

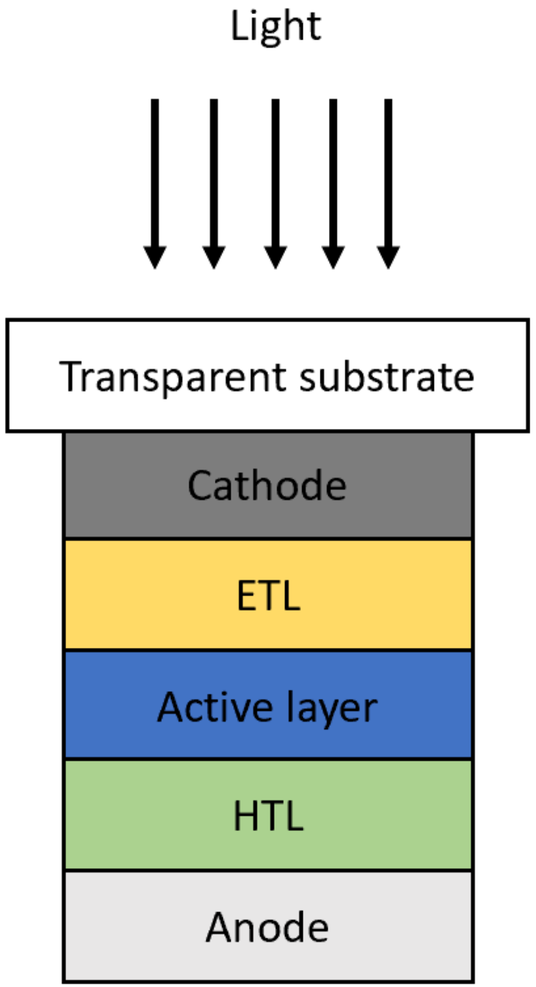
Dis-advantages of silicon solar cells

- **Space utilization: Solar cells required large area for installation.**
- **It requires high investment cost for a big power plant.**
- **During the rainy season power production is less hence grid maintenance will be difficult.**
- **Solar energy is produced only in the day time hence storage will be a big challenge.**

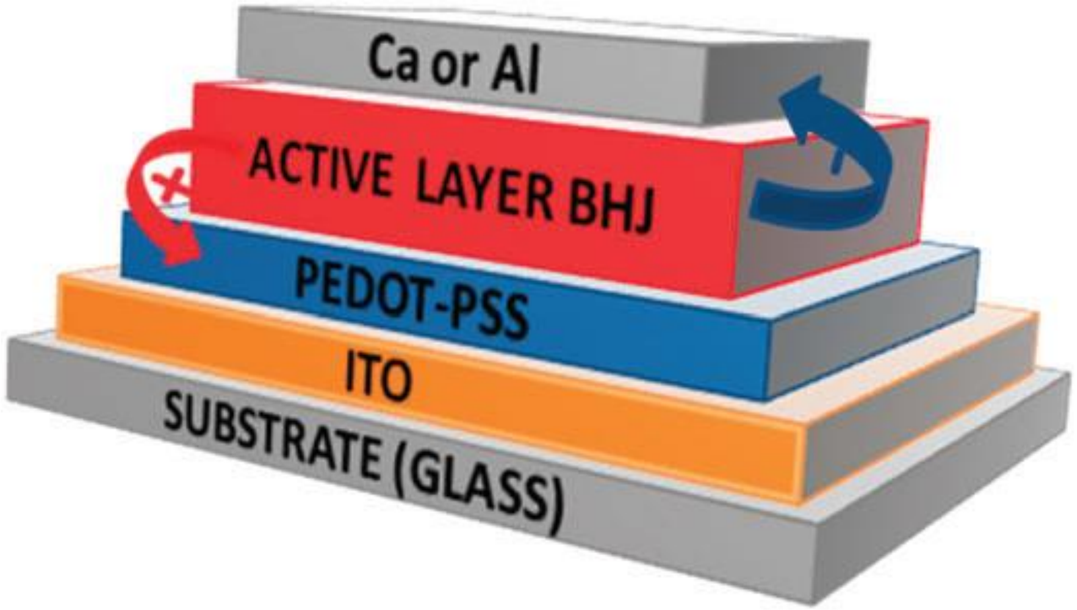
Organic photovoltaics



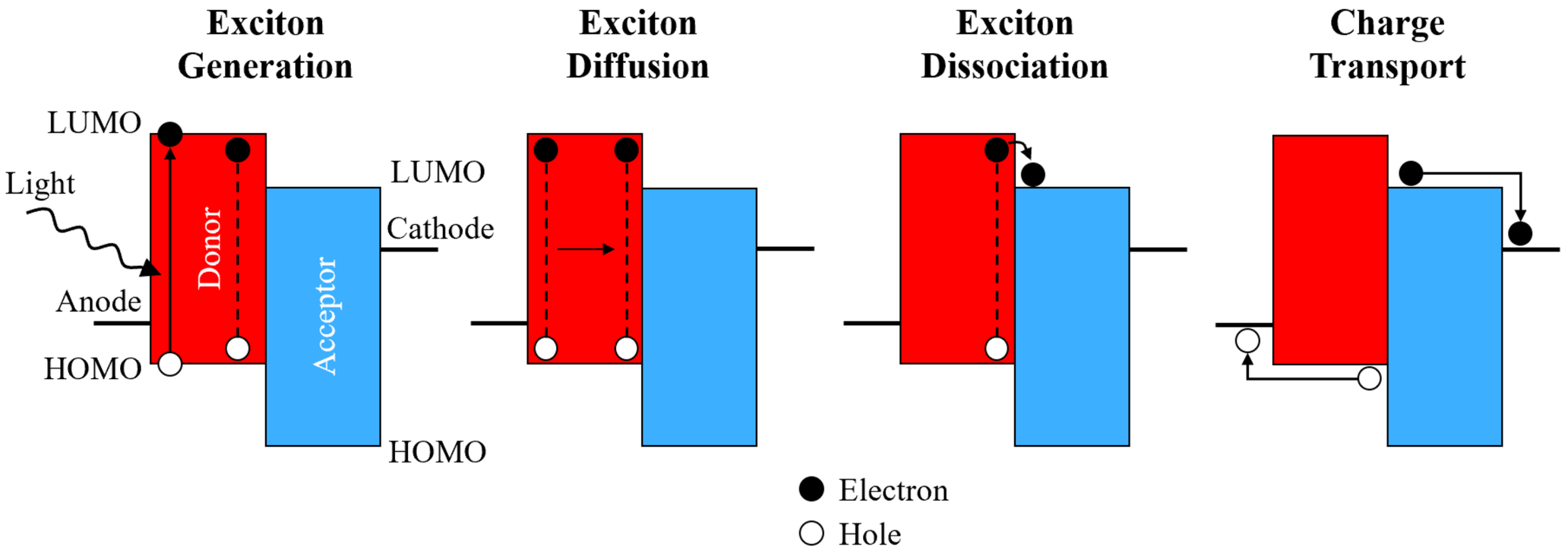
Standard design



Inverted design



Working mechanism of organic photovoltaics



Working mechanism of organic photovoltaics

Step 1. Exciton generation: Upon illumination of the active material, an electron is excited to the LUMO by absorption of a photon with energy larger than the HOMO-LUMO gap (band gap). The light absorption will generate electron-hole pairs, so-called excitons, where the electron and the hole are attracted to each other and bounded by Coulomb forces.

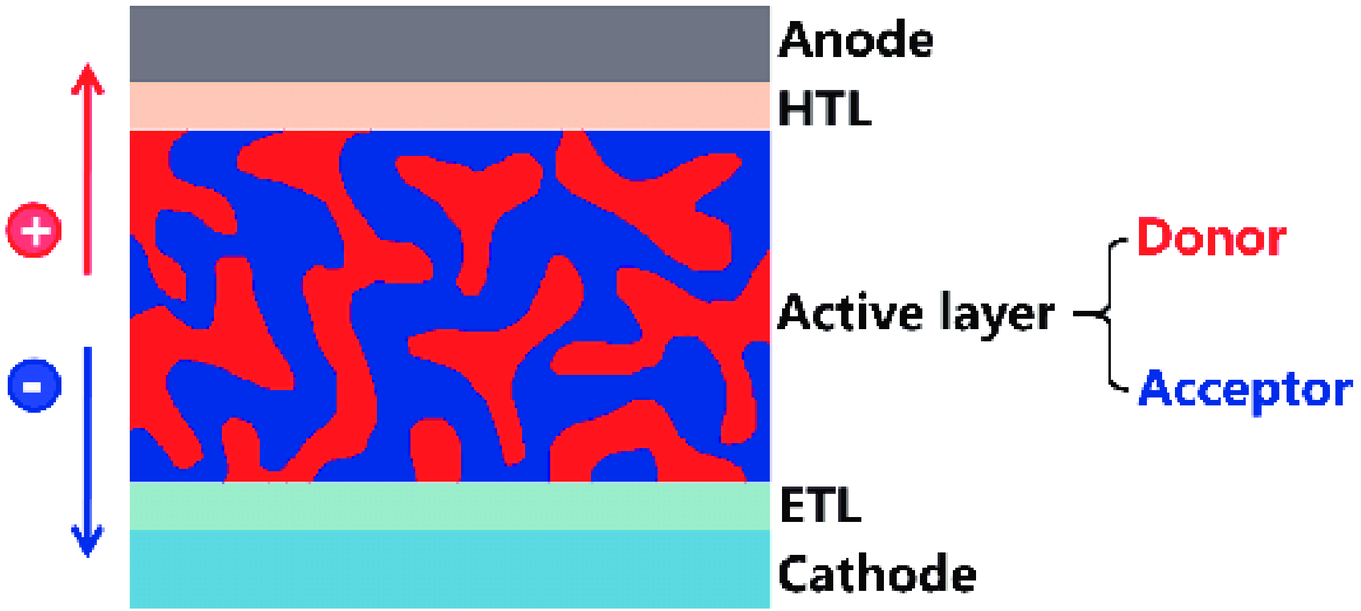
Step 2. Exciton diffusion: The generated exciton can diffuse through the material to the donor-acceptor interface. Due to the short lifetime of the exciton in organic materials, the exciton diffusion length is in order of 10 nm.

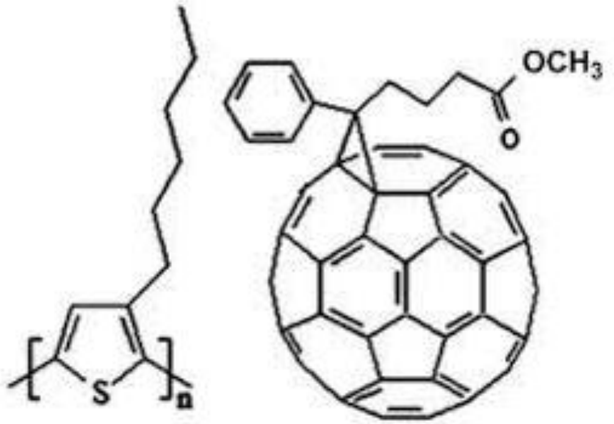
Step 3. Exciton dissociation: If the exciton reaches the donor-acceptor interface within its lifetime, it dissociates into a free electron and hole due to the local electric fields caused by an energy level offset between the two materials.

Step 4. Charge carrier transport: Free charge carriers are transported to the electrodes through the donor and acceptor material by an internal electric field caused by electrodes with different work functions. The electrons are collected at the cathode and the holes at the anode.

Organic photovoltaics

BHJ Solar Cells

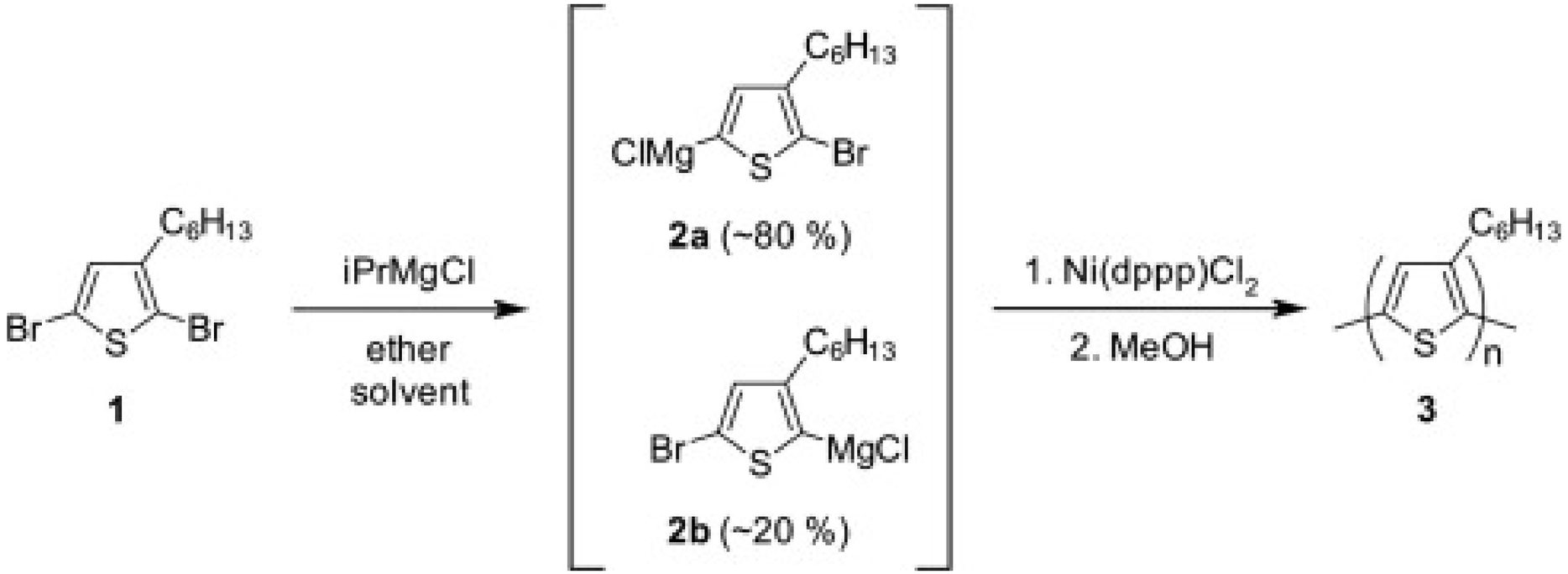




P3HT
Donor

PCBM
Acceptor

Synthesis of 3 hexyl thiophene

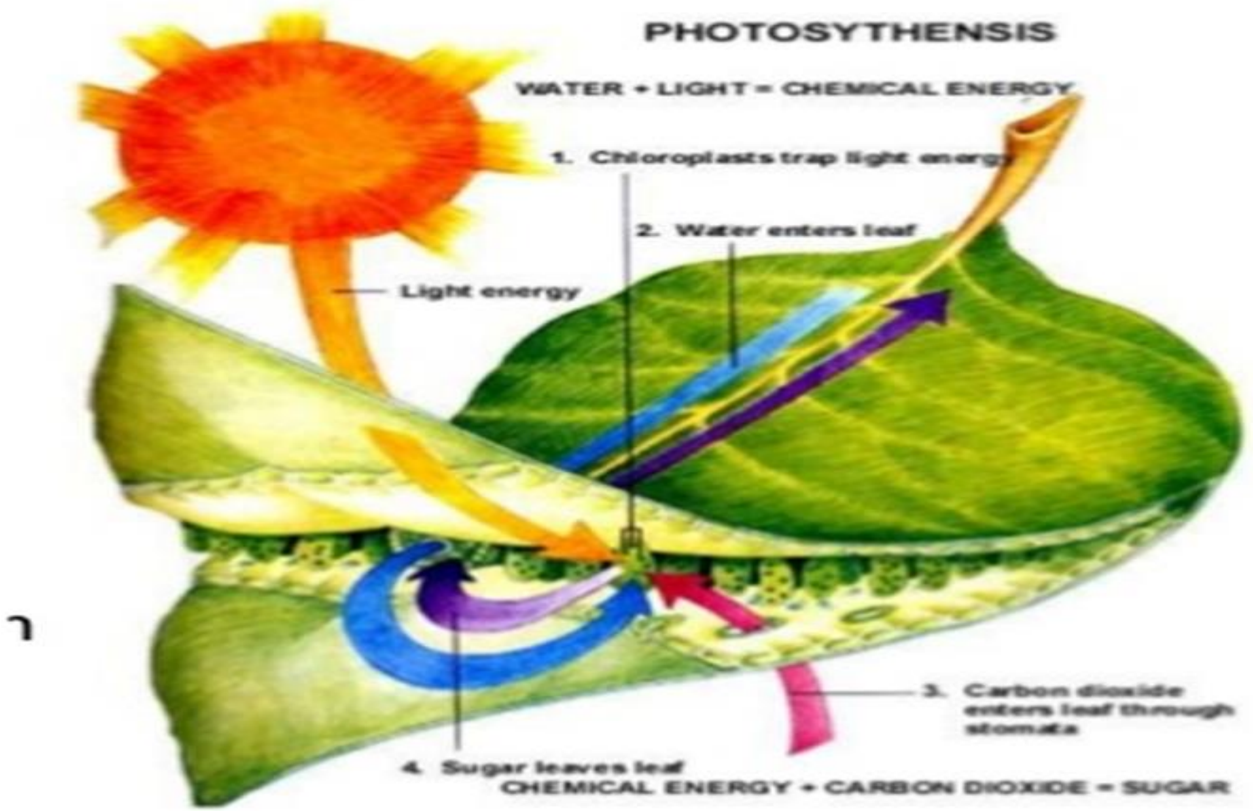


Solar cell working

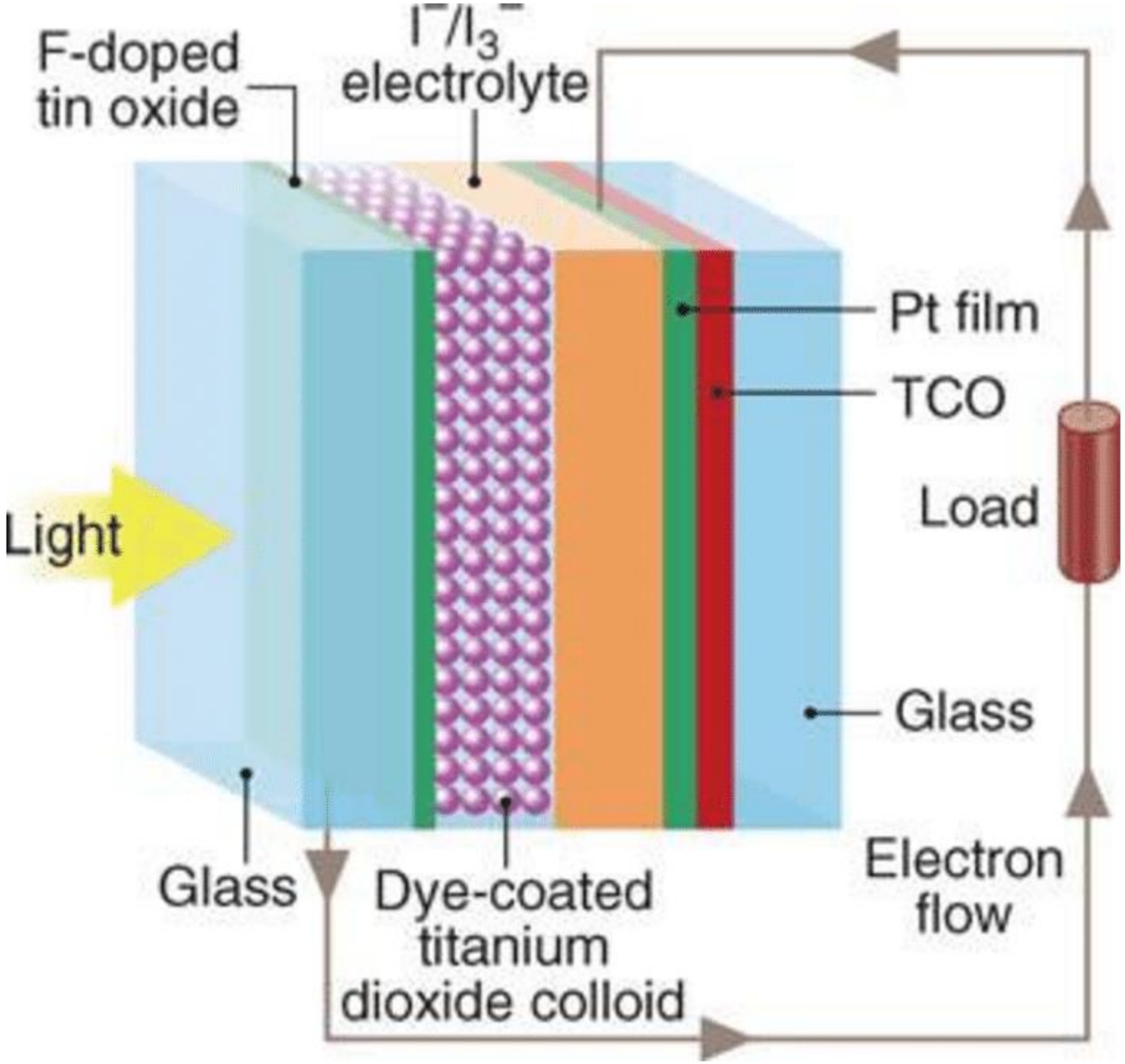
Organic Solar Cell

Dye sensitized solar cells

Dye Sensitized Solar Cell

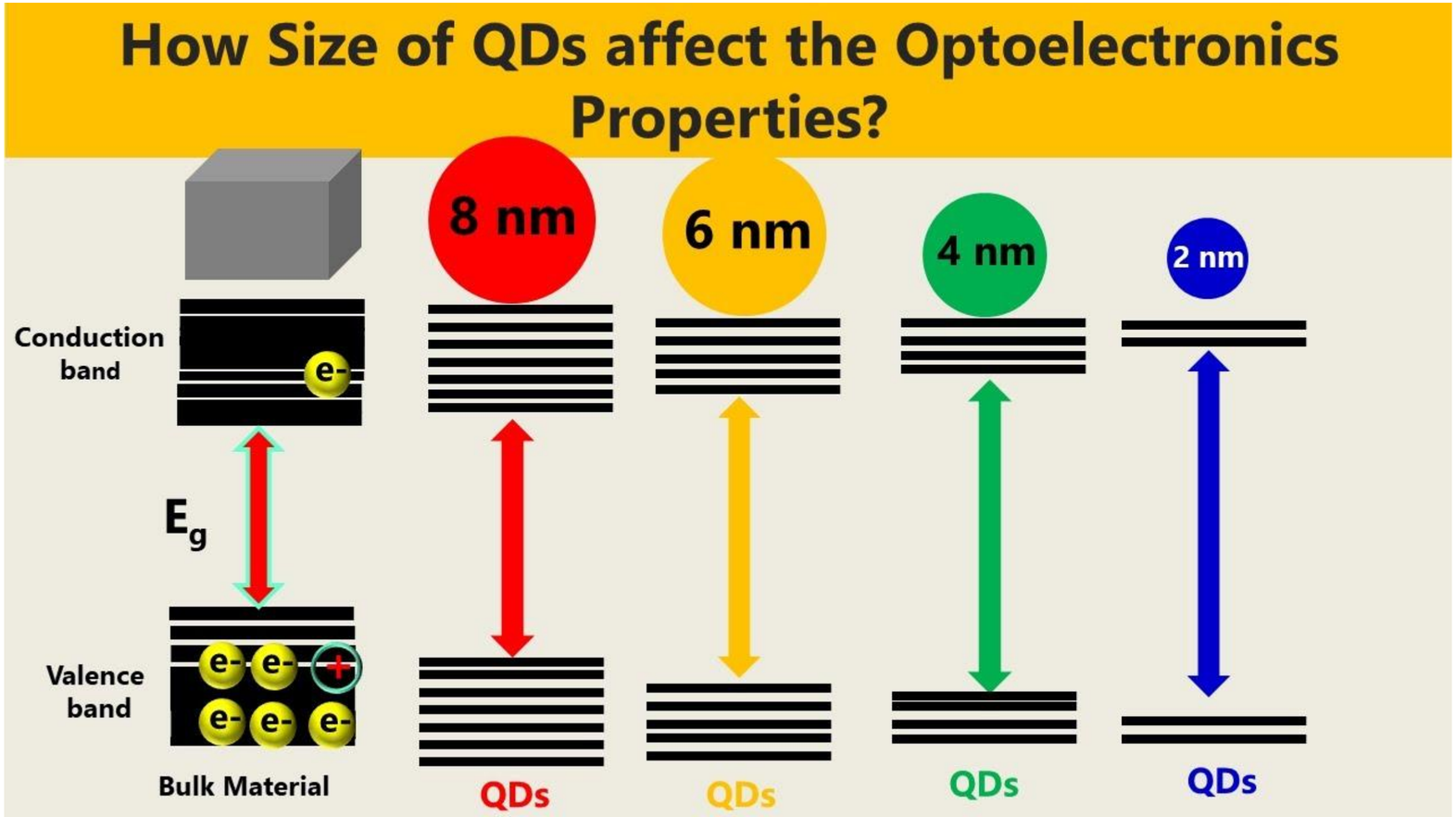


Dye sensitized solar cells

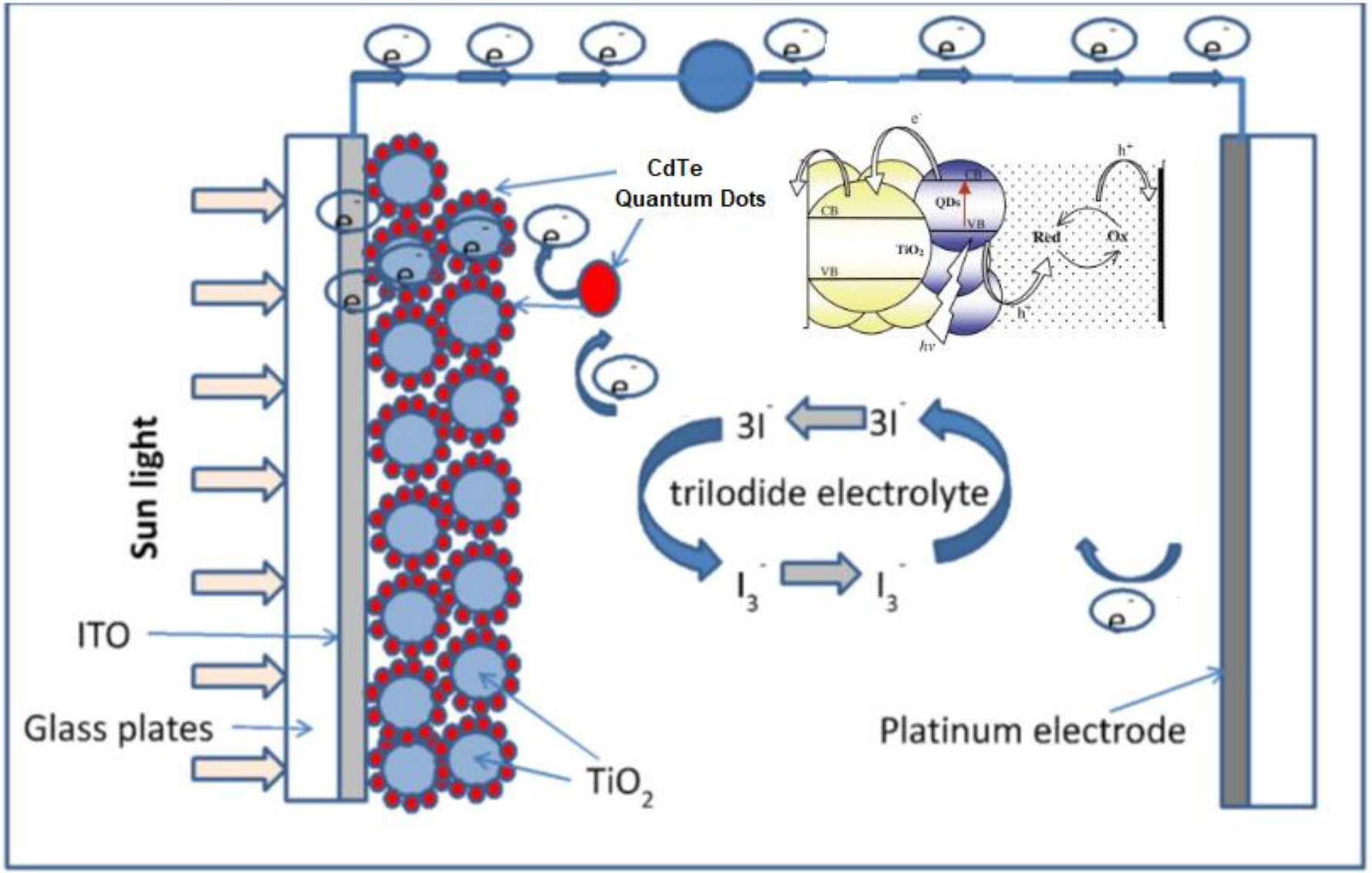


Michael Grätzel

Quantum Dot


How Size of QDs affect the Optoelectronics Properties?
8 nm
6 nm
4 nm
2 nm
Conduction band
e-
E_g
Valence band
e-
e-
e-
e-
e-
Bulk Material
QDs
QDs
QDs
QDs

Quantum Dot sensitized solar cells



Fabrication of the device

- **It consists of two electrodes cathode and anode generally cathode is made of graphite or platinum.**
- **Anode is made of transparent conducting oxide such as Indium tin oxide. Anode is coated with a layer of nano porous materials (TiO_2 of ZnO).**
- **Further these nano porous materials are coated with light absorbing organic/inorganic dye molecules/quantum dots.**
- **The nano-porous materials acts as photo-sensitizer also it provides road way for electrons.**
- **A triiodide electrolyte system is employed in between the electrodes, which helps in electron transfer process.**

Mechanism of working

- When light strikes the solar cell it passes through ITO layer and it reaches the dye molecule/ quantum dot.
- Once the photon hits the quantum dot, it undergoes excitation with the liberation of electron, which travels through the network TiO_2 nanoparticles and finally it reaches to cathode.
- The cell is completely filled with Tri iodide electrolyte.
- The electron from the cathode directly reduces the triiodide molecule to iodide molecules.
- Further this iodide molecule reaches the quantum dot oxidizes to form triiodide again with the liberation of electrons, which can be easily absorbed by dye molecules.
- And similar cycle continues whenever sunlight falls on the solar cells.

Advantages and disadvantages of Dye Sensitized Solar Cells

Advantages

- Ability to Work at Wider Angles and in Low Light
- Long Life
- Good Price/Performance Ratio
- Low Cost
- Mechanical Robustness
- Ability to Operate at Lower Internal Temperatures

Disadvantages

- DSSC design is the use of the liquid electrolyte
- which has temperature stability problems
- costly ruthenium (dye), platinum(catalyst)
- the electrolyte solution contains volatile organic compounds (or VOC's),

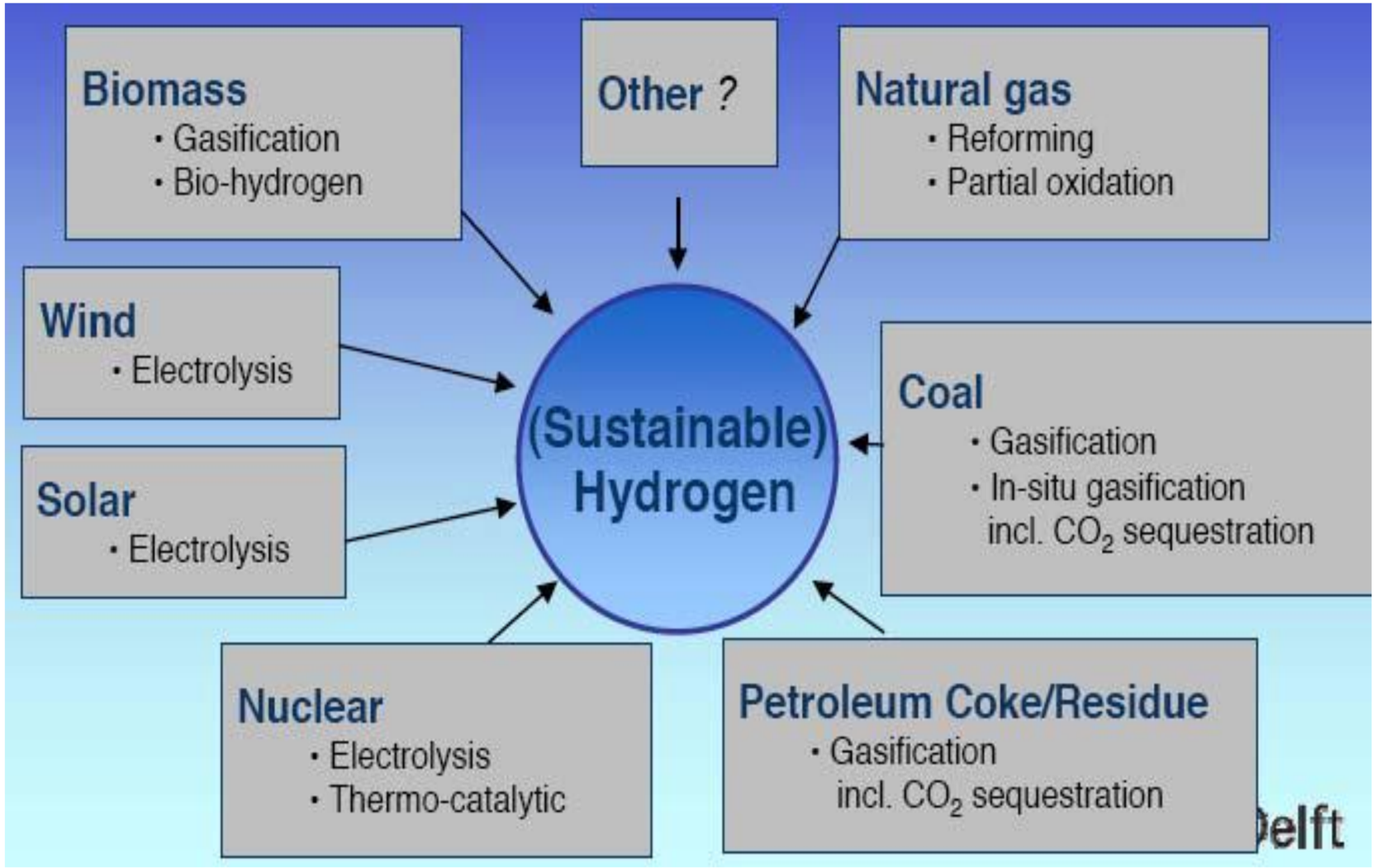
Hydrogen energy

Why hydrogen ?

- Clean – no greenhouse gases
- Energy security – can be produced from abundant sources
- Economic growth
- Efficient – fuel cells ~75% efficiency
- Portable: Car tanks, micro fuel cells…

Honda FCX Clarity

Hydrogen production



What is Photocatalytic water splitting?

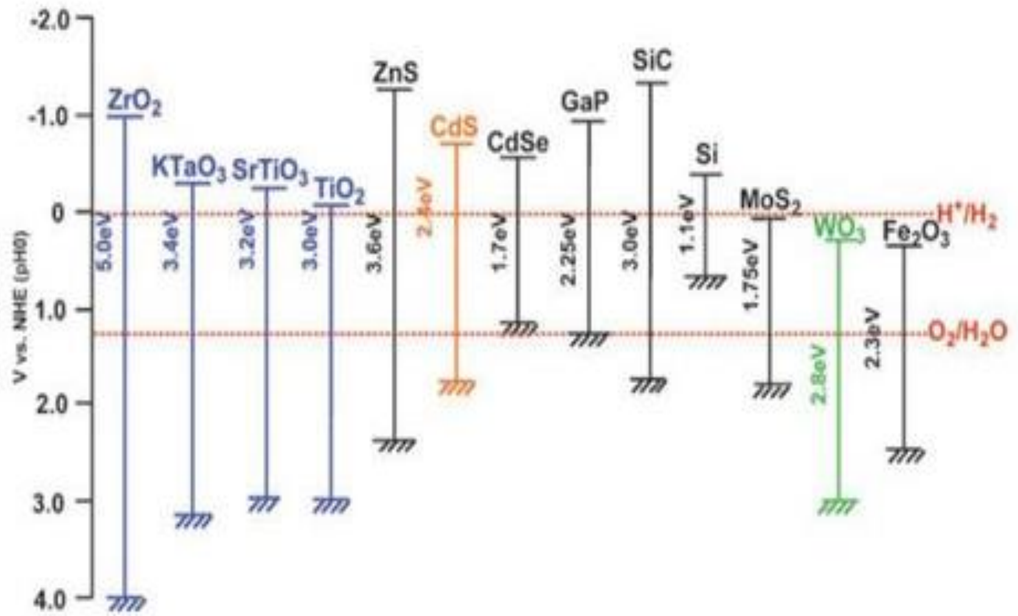
- Water splitting: $H_2O \xrightarrow{h\upsilon} H_2 + \frac{1}{2}O_2$
  - H_2: clean fuel——no pollution or green-house effect gas.
  - "O_2": water/air purification——degrade and mineralize organics into CO_2 and harmless inorganic anions.
  - The principle may be used to make primary battery.
- Photo: convert solar energy into chemical energy
  - Renewable
  - Environment friendly
  - Economic

Photo catalysts

For electrochemical decomposition of water, a potential difference more than 1.23V is needed.

This is equivalent to a photon of $\lambda \sim 1000$ nm (infrared light).

Requirements for photocatalysts



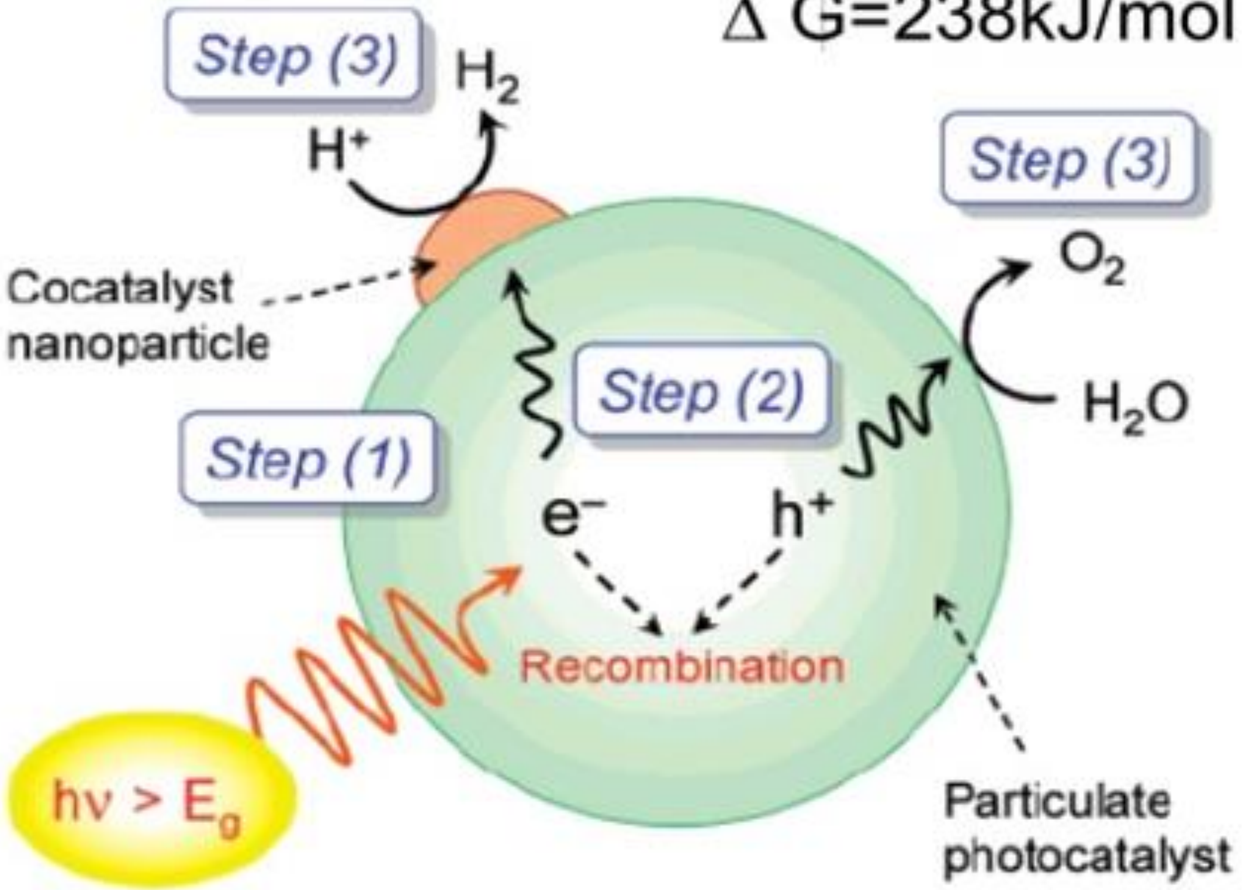
Difficulty to overcome

- Recombination of $e^- - h^+$ pair
- Fast drawback reaction
- Inability to utilize visible light
- Catalyst decay

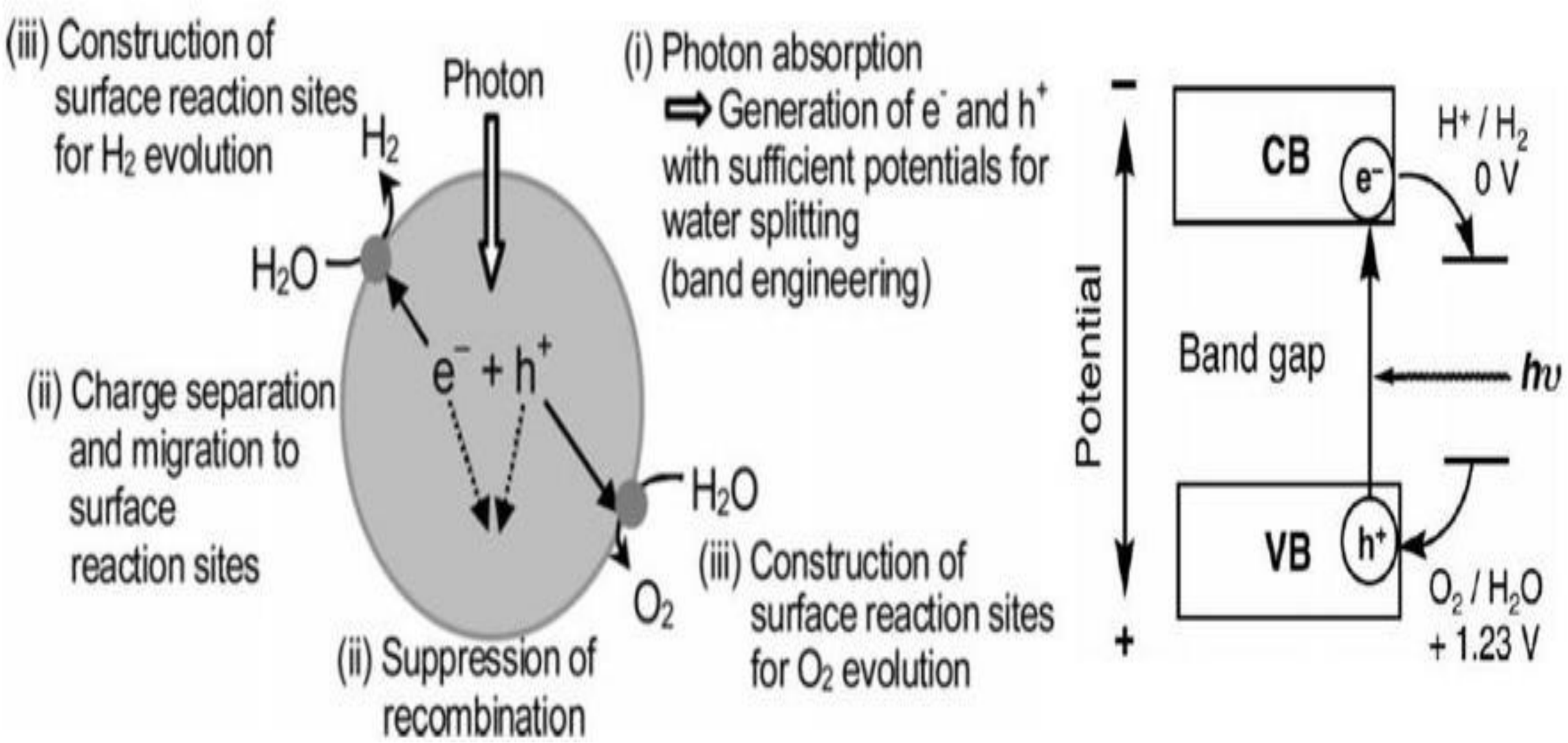
Mechanism of water splitting

$H_2O \rightarrow 2H_2 + O_2$ $\Delta V = 1.23V$, $\Delta G = 238 kJ/mol$

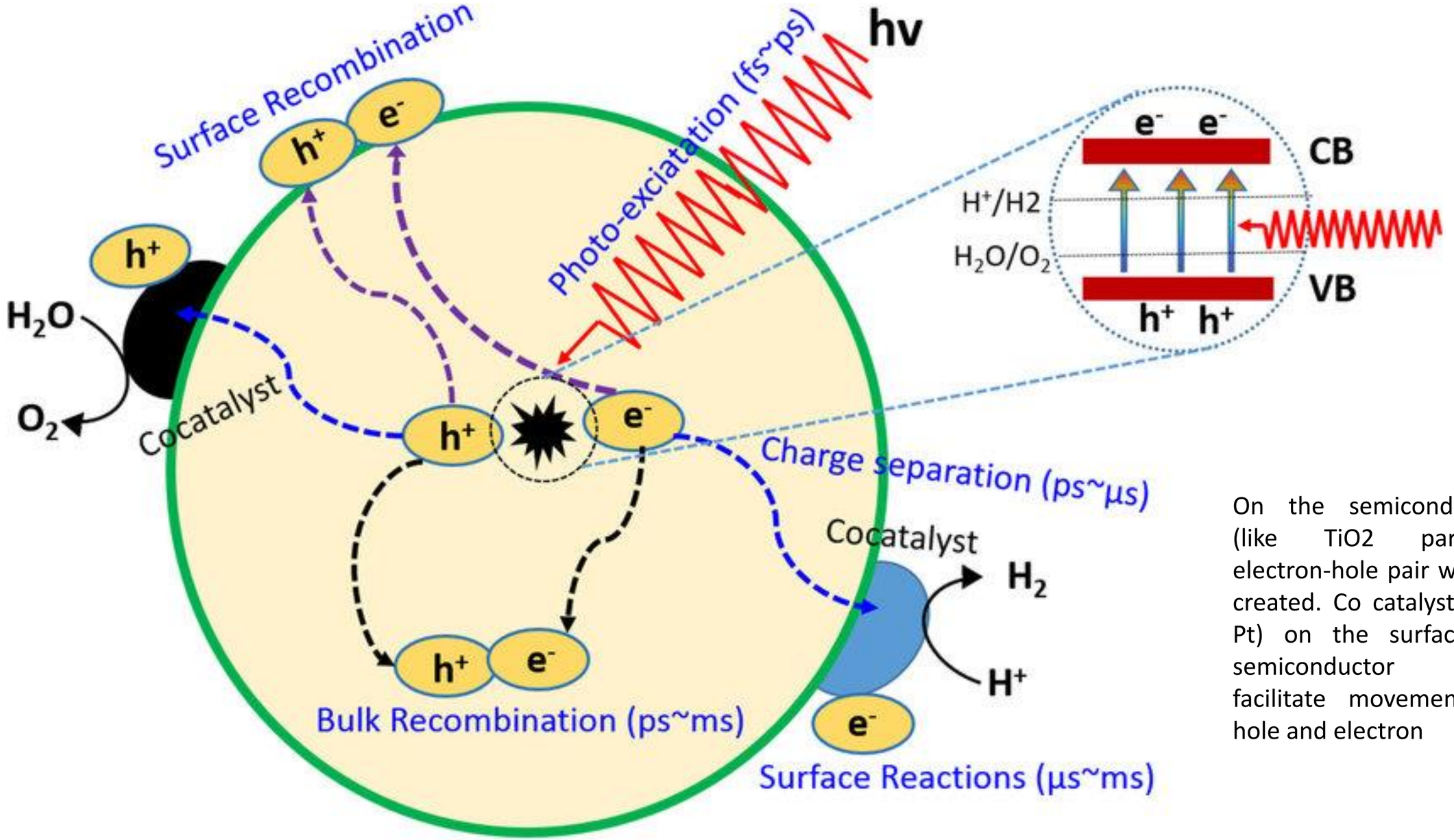
- Step 1: Photon with energy above 1.23eV ($\lambda <\sim 1000$ nm) is absorbed.
- Step 2: Photoexcited electrons and holes separate and migrate to surface.
- Step 3: Adsorbed species (water) is reduced and oxidized by the electrons and holes.



Photocatalytic water splitting: Mechanism

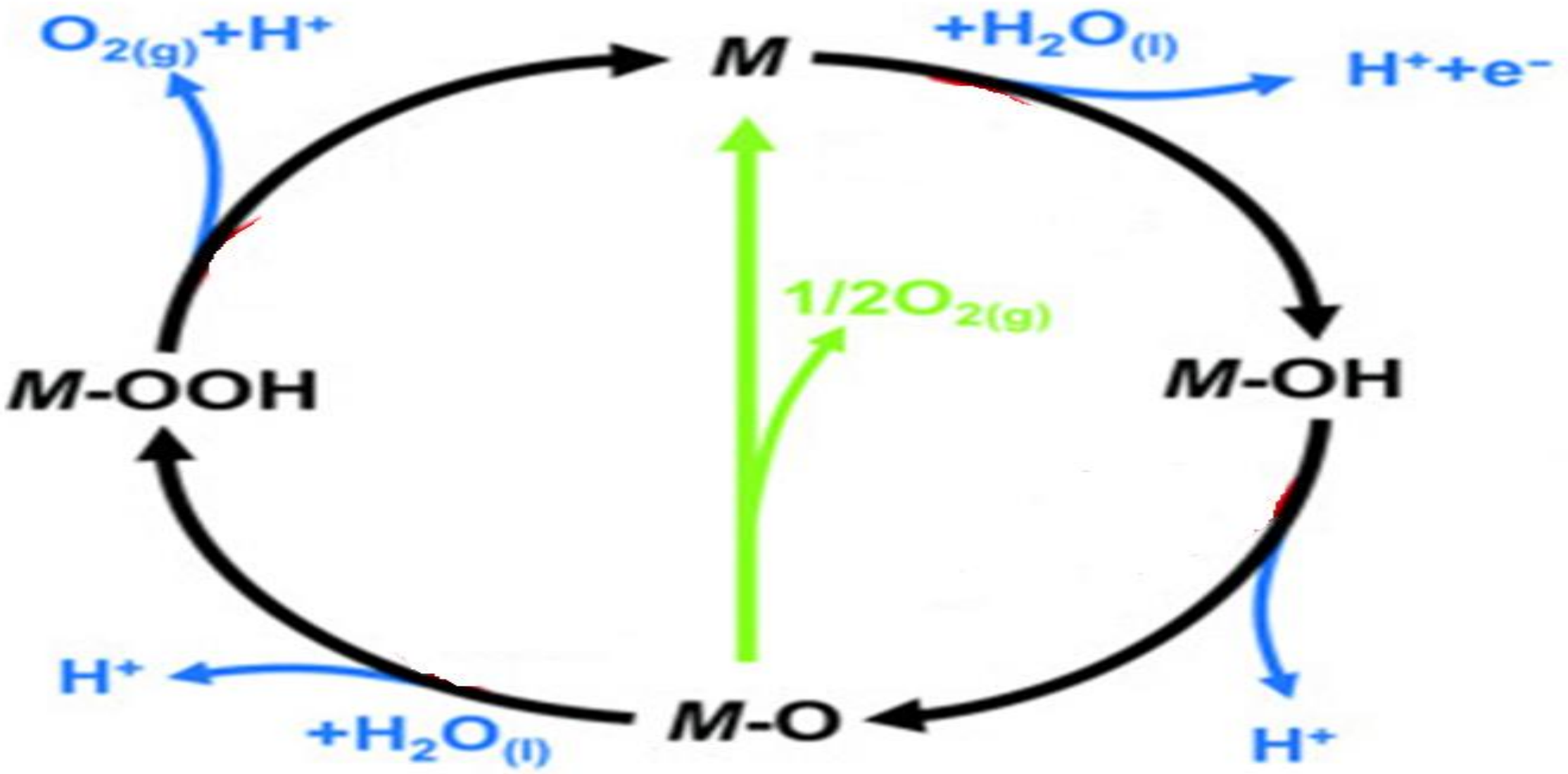


Mechanism of water splitting

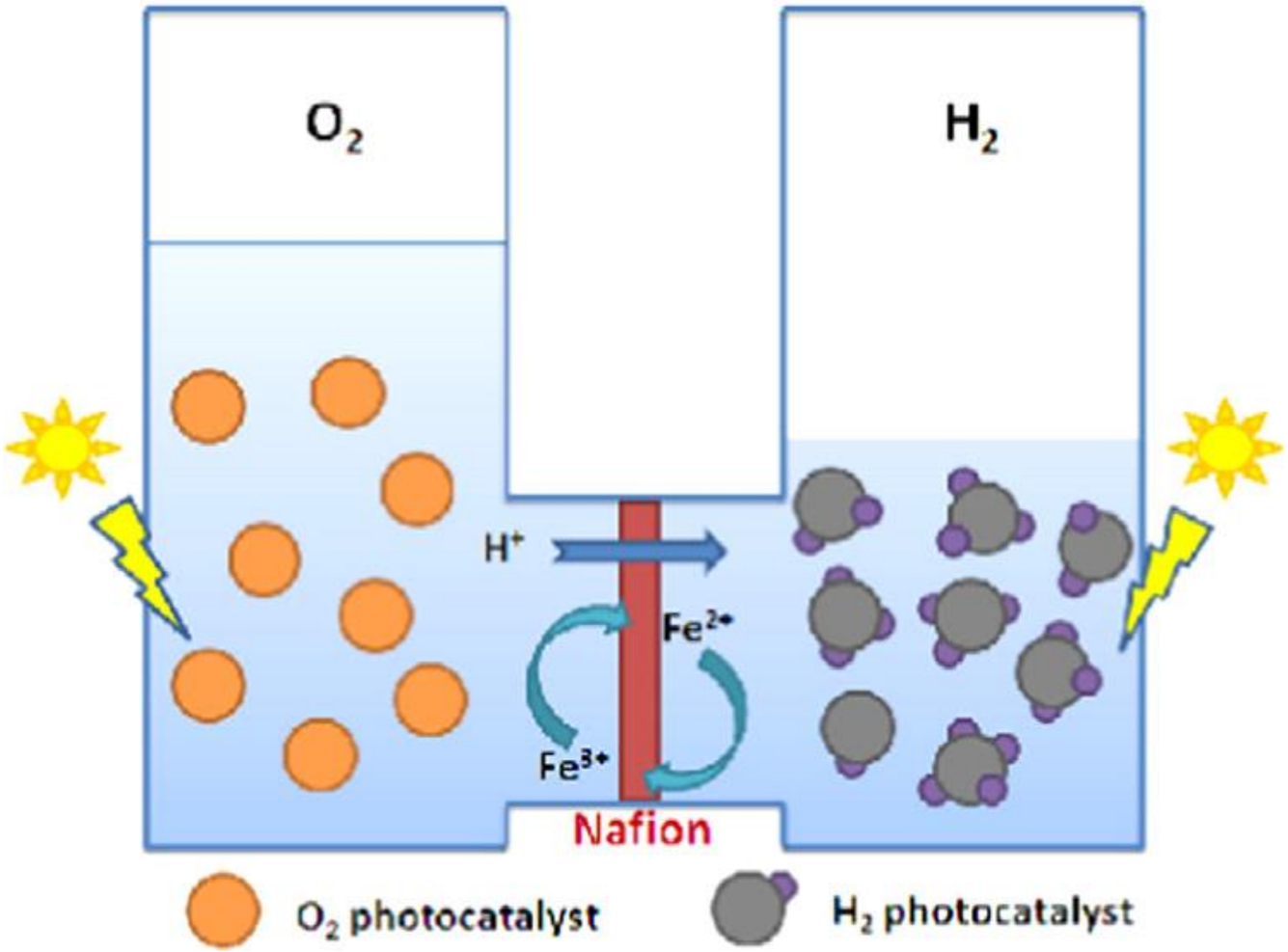


On the semiconductor (like TiO2 particle) electron-hole pair will be created. Co catalyst (like Pt) on the surface of semiconductor will facilitate movement of hole and electron

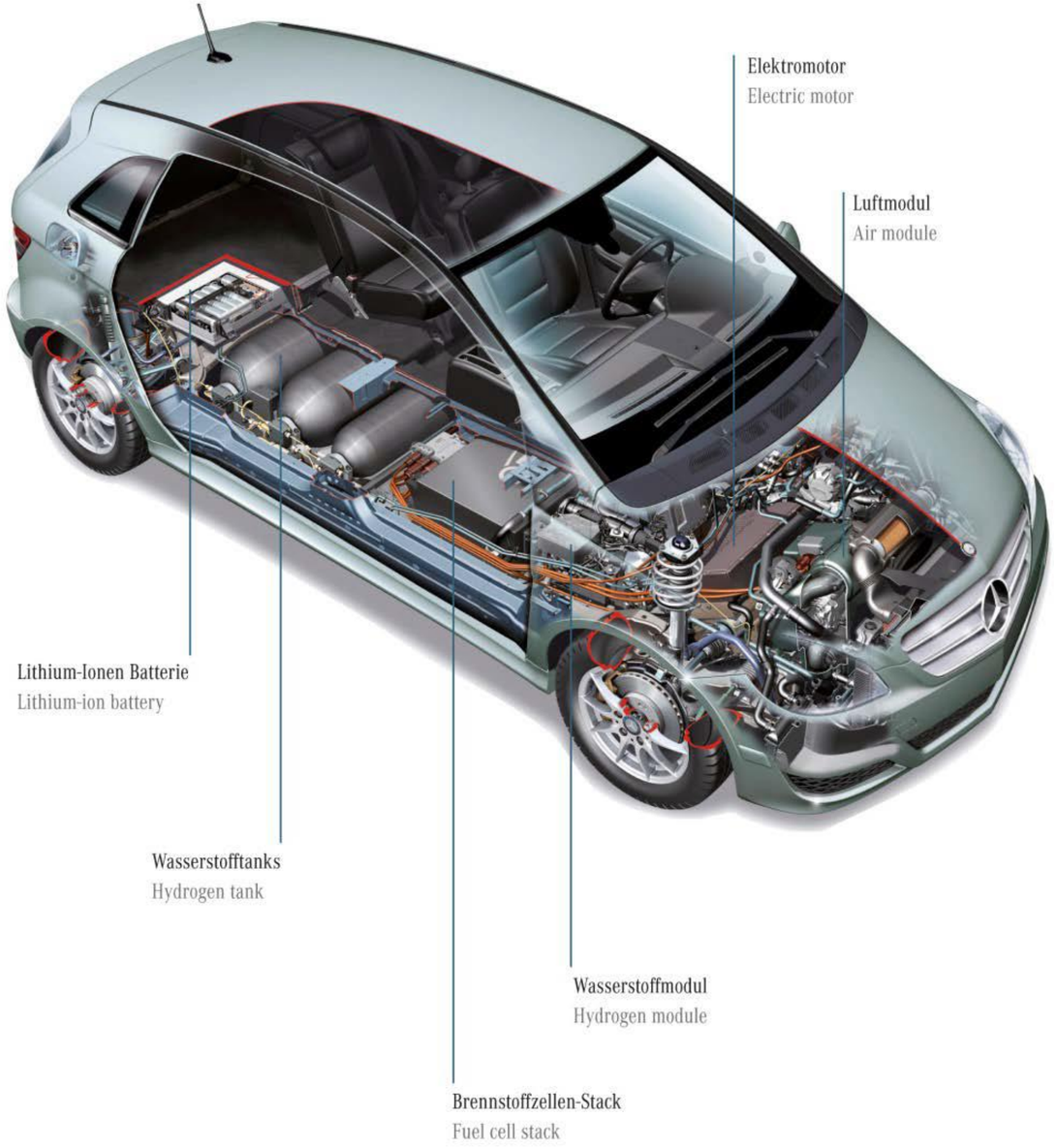
Mechanism of oxygen elimination



Photocatalytic water splitting: overview



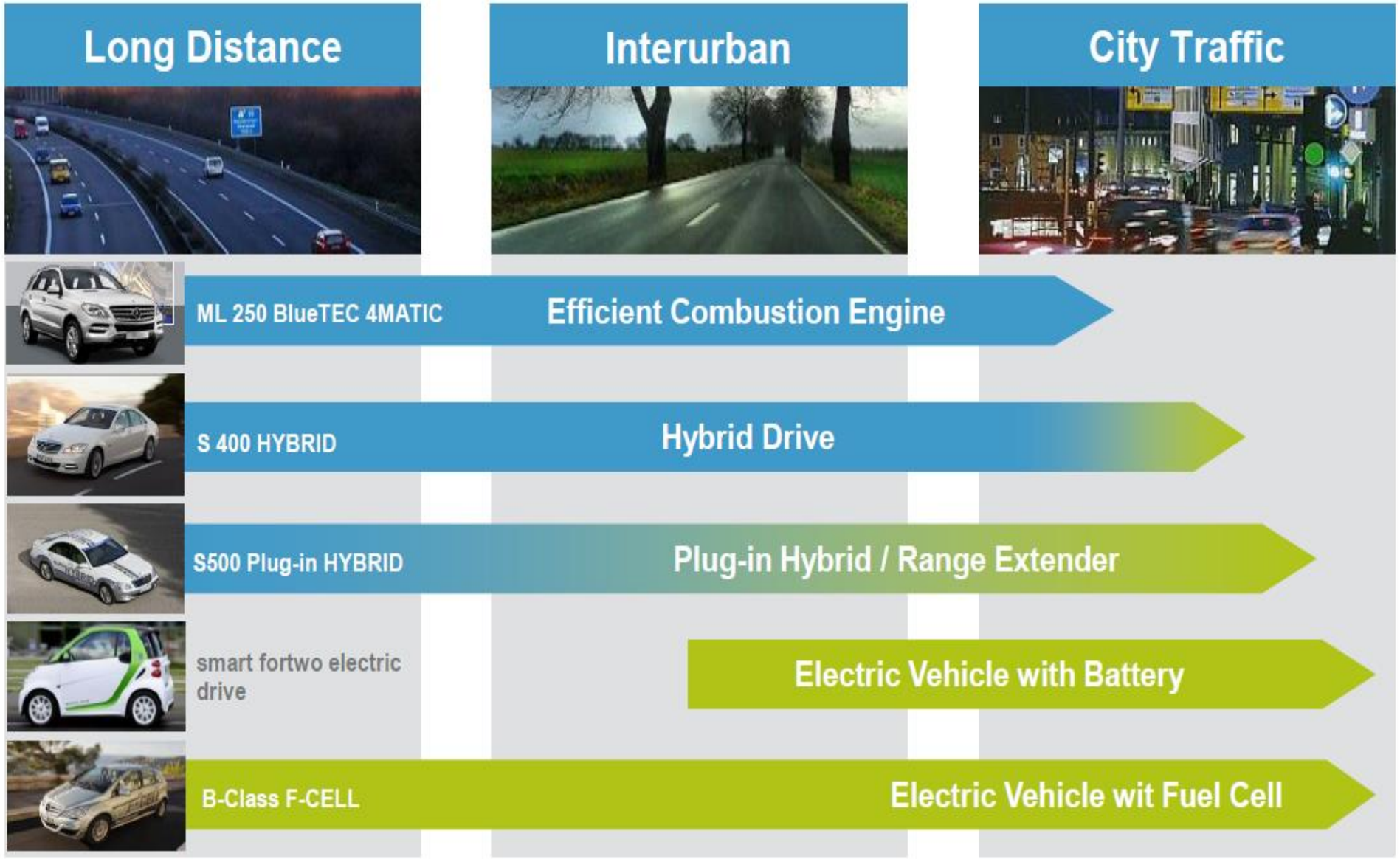
Application of hydrogen in fuel cell vehicles



Technical Data	
Vehicle	Mercedes-Benz B-Class
Fuel Cell System	PEM, 90 kW (122 hp)
Engine	Output (Cont./ Peak) 70kW / 100kW (136 hp) Max. Torque: 290 Nm
Fuel	Compressed hydrogen (70 MPa)
Range	380 km (NEDC)
Top Speed	170 km/h
Li-Ion Battery	Output (Cont./ Peak): 24 kW / 30 kW (40 hp) Capacity: 6.8 Ah, 1.4 kWh

Application of hydrogen in fuel cell vehicles

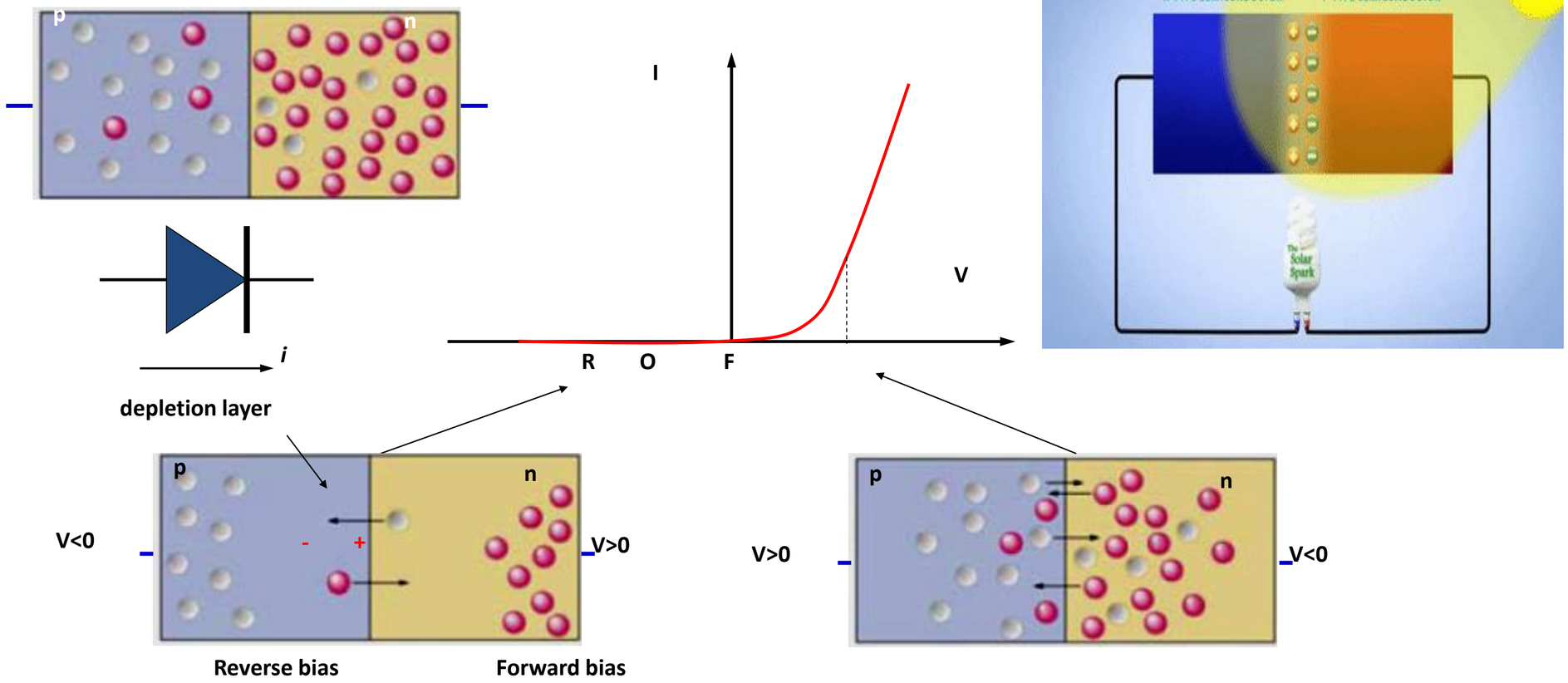
Role of hydrogen in fuel cell vehicles



Advantages
(air quality, energy savings and health benefit)

Thank you

p-n Junction (p-n diode)



- A p-n junction is a junction formed by combining p-type and n-type semiconductors together in very close contact.
- In p-n junction, the current is only allowed to flow along one direction from p-type to n-type materials.