

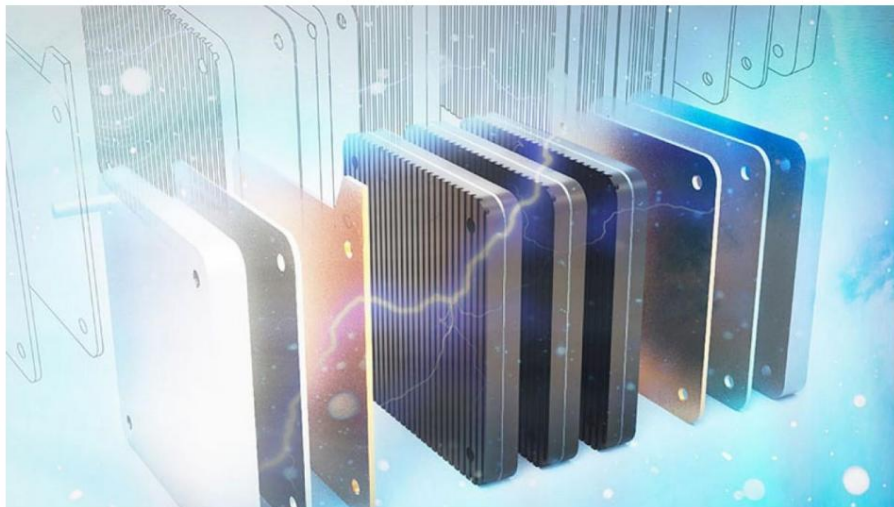
## Chapter 07 Semiconductors for micro-generation of photoelectric hydrogen L2 ER-EE

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### 1. Introduction to Semiconductors

Semiconductors play a crucial role in photoelectric hydrogen microgeneration by facilitating the absorption of solar photons and optimizing energy conversion. Specific materials such as those used in hybrid photocatalytic systems, or those coupled with organisms such as microalgae, are used. The process involves the photolysis of water or the transfer of electrons to produce hydrogen. These photoelectrochemical systems promise a clean energy source, but extensive research on semiconductor materials is still needed to improve efficiency.

Semiconductors are materials whose electrical conductivity lies between that of conductors (such as metals) and insulators (such as glass). They play a vital role in modern electronics and photovoltaic technologies.



#### 1.2 Properties of Semiconductors

- **Electrical Conductivity** : Depends on temperature, purity and presence of impurities (doping).
- **Energy Bandgap** : Semiconductors have a bandgap that determines their ability to conduct electricity. Materials with a bandgap of about 1 to 2 eV are often used in solar cells.

#### 1.3 Types of Semiconductors

- **Intrinsic Semiconductors** : Pure materials that have no added impurities. Their conductivity is low at room temperature.
- **Extrinsic Semiconductors** : Materials doped with impurities to improve their conductivity. They are divided into:

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- **Type N** : Doped with donor elements (e.g. phosphorus), adding electrons.
- **Type P** : Doped with acceptor elements (e.g. boron), creating "holes" (lack of



of electrons).

### **1.4 Applications of Semiconductors**

- **Electronics** : Used in transistors, diodes, and integrated circuits.
- **Photovoltaic** : Essential for the manufacture of solar cells, converting light in electricity.
- **Electrolysis** : Used in electrolysis systems for the generation of hydrogen from water.

### **1.5 Importance in Micro-generation of Hydrogen**

Semiconductors are crucial for improving the efficiency of hydrogen micro-generation systems by optimizing the conversion of solar energy into electricity, which is then used for water electrolysis.

## **2. Principles of Photovoltaics**

Photovoltaic panels convert sunlight into electricity using the photoelectric effect. The photovoltaic cells that make up the panels absorb photons from the sun. This absorption excites electrons, creating a direct current (DC) electricity. An inverter then converts this DC electricity into alternating current (AC) that can be used to power electrical devices. The process relies on the ability of materials, particularly silicon, to generate an electric current when exposed to light.

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### 2.1 Photovoltaic Effect

The photovoltaic effect is the process by which light is converted into electricity in a semiconductor material. Here are the key steps:

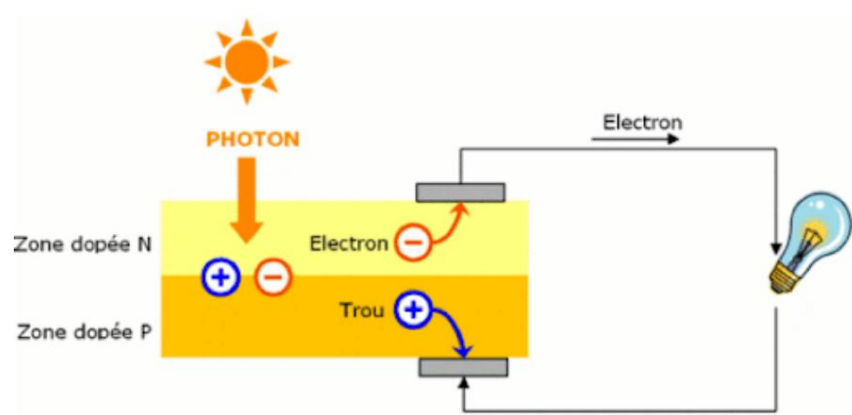
1. **Light Absorption** : The photons of the incident light are absorbed by the semiconductor, which excites the electrons in the material.
2. **Generation of electron-hole pairs** : The absorbed energy allows an electron to move from the valence band to the conduction band, thus creating an electron-hole pair.
3. **Charge Separation** : The internal electric fields in the solar cell (usually created by the PN junction) push electrons towards the anode and holes towards the cathode, thus separating the charges.
4. **Current Flow** : When electrons flow through an external circuit to reach the anode, an electric current is generated.

### 2.2 Solar Cells

Solar cells are devices that use the photovoltaic effect to convert light into electricity. The main types include:

- **Monocrystalline Cells** : Made from a single silicon crystal, offering high efficiency (15-22%).
- **Polycrystalline Cells** : Composed of several silicon crystals, they are generally less expensive but slightly less efficient (13-16%).
- **Thin Film Cells** : Use materials such as cadmium telluride or organic cells, offering flexibility and lightness, but with generally lower efficiency.

lower (10-12%).



### 2.3 Solar Cell Efficiency

The efficiency of a solar cell is determined by its ability to convert incident light into electricity. Several factors influence this efficiency:

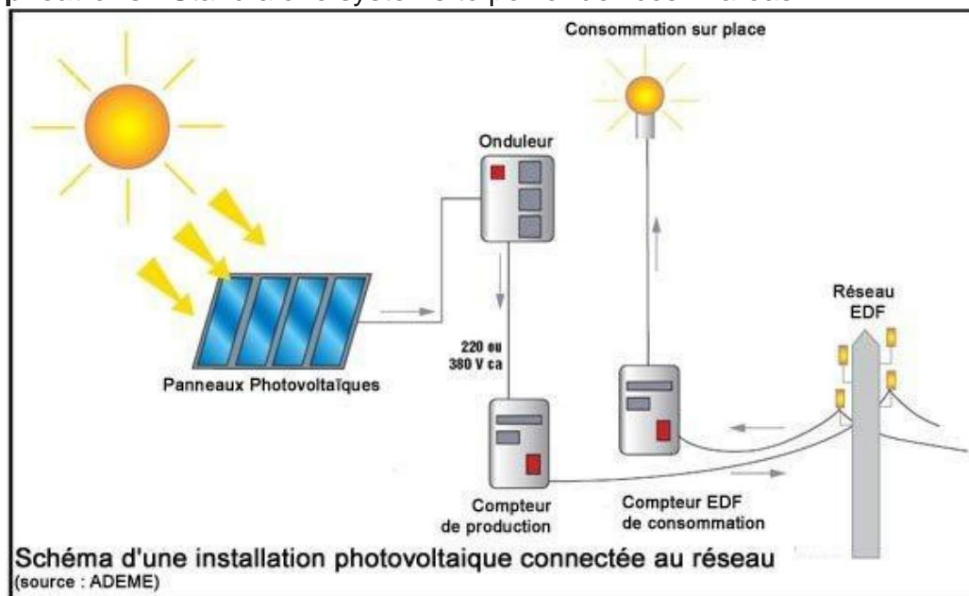
- **Material Quality** : The purity and structure of the semiconductor.

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- **Lighting Conditions** : Intensity and angle of incident light.
- **Temperature** : Higher temperature may reduce efficiency.

### 2.4 Applications of Photovoltaic Systems

- **Residential Systems** : Installation of solar panels on roofs for production of electricity.
- **Large-Scale Systems** : Solar farms that generate electricity for the grid.
- **Off-Grid Applications** : Stand-alone systems to power devices in areas



distant.

### 2.5 Role in Hydrogen Generation

Photovoltaic systems can power electrolyzers to produce hydrogen from water. Using electricity generated by solar cells, efficient electrolysis can be achieved, contributing to renewable and sustainable energy solutions.

## 3. Hydrogen Generation

Hydrogen production involves several methods. Steam reforming of fossil fuels is currently the most widely used and economical method, accounting for 96% of production. Hydrogen can also be generated from water or hydrocarbons, and even through hydrolysis in the presence of metals. Hydrogen is an energy carrier, which requires a complex value chain.

### 3.1 Electrolysis of Water

Water electrolysis is a process that uses electricity to split water (H<sub>2</sub>O) into hydrogen (H<sub>2</sub>) and oxygen (O<sub>2</sub>). Here are the key steps:

#### 1. Electrolysis Process :

- **Anode** : At the anode, water is oxidized, producing oxygen and protons (H<sup>+</sup>).  

$$2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$$
- **Cathode** : At the cathode, protons are reduced to form hydrogen.  

$$4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2$$
- **Overall Reaction** :  $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$

#### 2. Electrolysis Conditions :

- **Electrical Energy** : The electricity used can come from renewable sources, like solar panels.
- **Electrolytes** : Electrolytes, such as potassium hydroxide (KOH) or sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), are often added to improve conductivity.

### 3.2 Role of Semiconductors

Semiconductors play a crucial role in the electrolysis of water:

- **Electrodes** : Semiconductor materials can be used as electrodes in electrolyzers to improve the efficiency of the electrochemical reaction.
- **Catalysts** : Some semiconductors also function as catalysts, reducing the activation energy required for electrolysis reactions.

### 3.3 Types of Electrolyzers

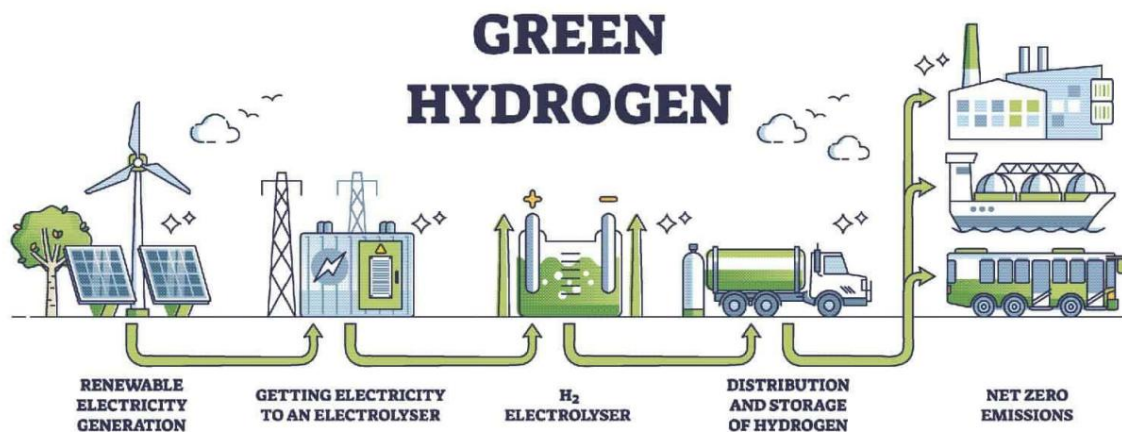
- **Alkaline Electrolyzers** : Use a potassium hydroxide solution as the electrolyte. They are robust and have a long service life.
- **Proton Exchange Membrane (PEM) Electrolyzers** : Use a membrane to separate the produced gases. They are more compact and reactive, but generally cost more.
- **High Temperature Electrolyzers** : Use heat to increase the efficiency of electrolysis, often in combination with renewable energy sources.

### 3.4 Applications of Hydrogen

Hydrogen produced by electrolysis has several applications:

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- **Fuel** : Used in hydrogen fuel cells to generate electricity in hydrogen vehicles.
- **Industry** : Used in petroleum refining, ammonia production and others chemical processes.
- **Energy Storage** : Hydrogen can be stored and used as a means of storing excess energy generated by photovoltaic systems.



### 3.5 Advantages and Challenges

- **Advantage** :
- **Renewable Energy** : Hydrogen can be produced sustainably from water and renewable electricity.
- **Zero Emissions** : The combustion of hydrogen produces only water as a by-product.
- **Challenges** :
- **Production Cost** : The cost of electrolysis and associated equipment can be high.
- **Infrastructure** : The development of an infrastructure for storage and hydrogen distribution is still ongoing.

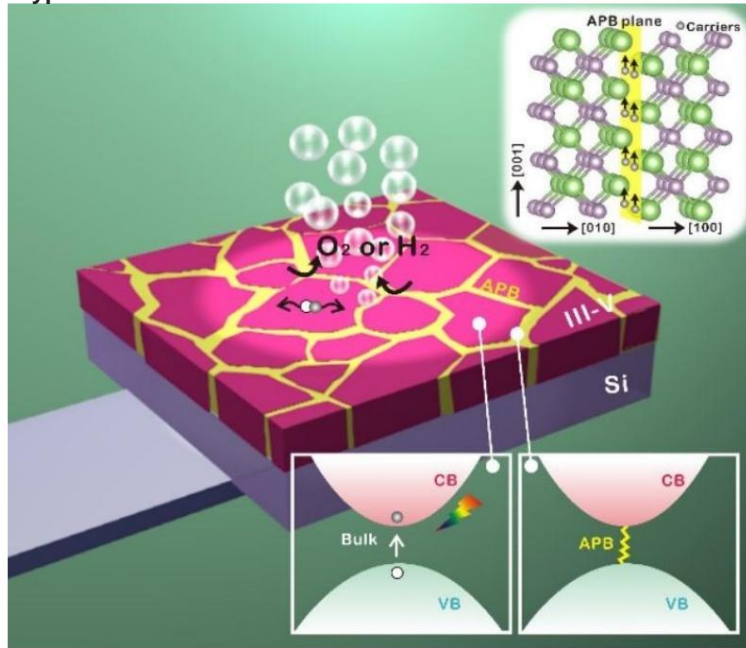
## 3. Semiconductor Materials for Hydrogen Photoelectric

Semiconductor materials are crucial for hydrogen production photoelectric, a process using solar energy to split water. Semiconductors such as  $\text{CuCr}_2\text{O}_4$  and  $\text{ZnCr}_2\text{O}_4$  are used for photocatalytic and catalytic hydrogen production. III-V semiconductors, including phosphide and

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gallium arsenide, are also being explored as alternatives to  $\text{TiO}_2$ . Research is focused on improving the efficiency and sustainability of these materials for cleaner and more affordable hydrogen production.

### Types of Semiconductor Materials



#### a. Silicon (Si)

- **Properties** : Abundant, good conductor, low cost.
- **Applications** : Used in solar cells and photoelectric devices.

#### b. Cadmium Telluride (CdTe)

- **Properties** : Good light absorption, high efficiency.
- **Applications** : Used in thin film solar panels.

#### c. Gallium Arsenide (GaAs)

- **Properties** : Superior efficiency, high performance under low temperature conditions brightness.
- **Applications** : Used in high performance solar cells and optoelectronic devices.

#### d. Perovskites

- **Properties** : High efficiency, low manufacturing cost.



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- **Applications** : In development for applications in solar cells and photoelectric devices.

### 2. Hydrogen Production Mechanisms

#### a. Photolysis of Water

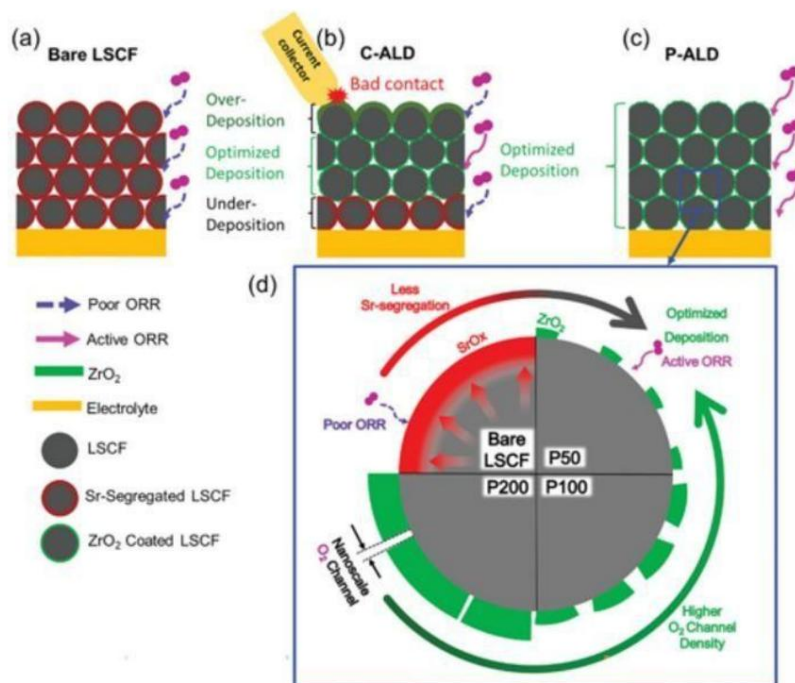
- **Description** : Using light to split water into hydrogen and oxygen.
- **Materials** : Semiconductors are used as catalysts to facilitate this reaction.

#### b. Photocatalysis

- **Description** : Use of light to accelerate a chemical reaction.
- **Materials** : Semiconductors such as  $\text{TiO}_2$  are often used to catalyze the reaction.

### 3. Challenges and Perspectives

- **Efficiency** : Improve the efficiency of semiconductor materials to maximize hydrogen production.
- **Sustainability** : Developing more durable materials to withstand the conditions environmental.
- **Cost** : Reduce production costs to make technologies accessible.





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### Conclusion

Semiconductor materials are essential for the development of photoelectric hydrogen technologies. Continued innovation in this field could transform our approach to renewable energy and hydrogen production.

## 4. Applications and Technologies

Semiconductor materials are at the heart of several innovative technologies for producing hydrogen from renewable energy sources. Here's an overview of the main applications and associated technologies.

### 1. Applications

#### a. Solar Panels

- **Description** : Use of semiconductors to convert sunlight into electricity.
- **Impact** : The electricity generated can be used to power electrolyzers, thus producing hydrogen.

#### b. Electrolyzers

- **Description** : Devices that use electricity (often generated by solar panels) to split water into hydrogen and oxygen.
- **Technologies** :
- **Alkaline electrolysis** : Uses alkaline solutions to improve efficiency.
- **Proton Exchange Membrane (PEM) Electrolysis** : Provides high efficiency and fast response to power supply fluctuations.

#### c. Hydrogen Storage Systems



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- **Description** : Use of the produced hydrogen as an energy vector for storage at long term.
- **Technologies** :
- **Metal hydrides** : Storage of hydrogen in solid form.
- **High pressure cylinders** : Storage of hydrogen in gaseous form.

### 2. Emerging Technologies

#### a. Photocatalysis

- **Description** : Use of semiconductor materials to catalyze the reaction of decomposition of water under light irradiation.
- **Materials** :  $\text{TiO}_2$ , CdS, and other perovskites.

#### b. Coupled Photovoltaics and Electrolysis

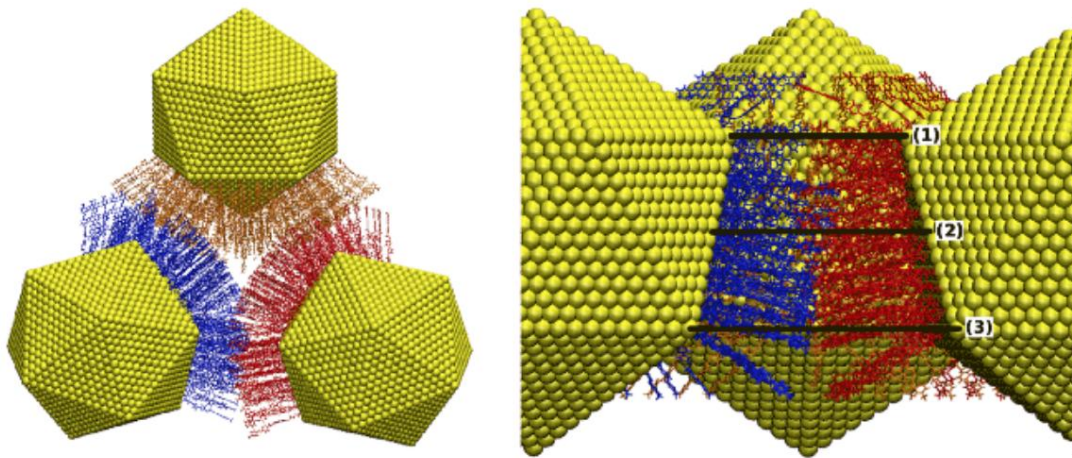


- **Description** : Integration of solar panels with electrolyzers for direct conversion of solar energy into hydrogen.
- **Benefits** : Increases overall system efficiency.

#### c. Nanostructure-Based Materials

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- **Description** : Use of nanomaterials to improve photoelectric properties and catalytic.
- **Examples** : Carbon nanotubes, metal nanoparticles, etc.

### 3. Future Prospects

- **Improved Efficiency** : Continuous research to develop more efficient materials efficient and sustainable.
- **Systemic Integration** : Development of integrated systems that combine production energy, storage and use.
- **Cost Reduction** : Innovations aimed at reducing manufacturing and installation costs technologies.

## Conclusion

Semiconductor materials are essential in the development of technologies for producing hydrogen from renewable energy sources. Their ability to efficiently convert light into chemical energy paves the way for sustainable and innovative solutions to meet global energy needs.

As research advances, we are seeing significant advances in material efficiency, system durability, and reduced production costs.

Integrating these technologies into larger energy systems, such as solar panels coupled with electrolyzers, demonstrates immense potential to transform our approach to energy.

By investing in the research and development of these technologies, we can not only improve hydrogen production, but also contribute to the fight against climate change by reducing our dependence on fossil fuels. The future of

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Photoelectric hydrogen is promising, and it represents a crucial step towards a sustainable and resilient energy transition.

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