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INNOVATIONS IN GREEN ENERGY: NOVEL PHOTOCATALYTIC MATERIALS FOR CONVERTING SUNLIGHT AND WATER INTO CLEAN FUEL

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Анотація

У статті представлено комплексний аналіз інноваційної технології отримання чистої енергії шляхом перетворення сонячного світла та води за допомогою новітніх фотокаталітичних матеріалів. Детально розглянуто фізичні принципи штучного фотосинтезу, процеси генерації носіїв заряду та потенціал водневого палива як основи для стабілізації енергосистем.

Ключові слова: зелена енергетика, фотокаталіз, розщеплення води, водень, штучний фотосинтез, електрон-діркові пари, напівпровідники.

Abstract

The article presents a complex analysis of an innovative clean energy technology based on the conversion of sunlight and water using novel photocatalytic materials. It examines the physical principles of artificial photosynthesis, charge carrier generation processes, and the potential of hydrogen fuel as a foundation for grid stabilization.

Keywords: green energy, photocatalysis, water splitting, hydrogen, artificial photosynthesis, electron-hole pairs, semiconductors.

Introduction

The modern transition to carbon-neutral energy requires not only increasing the capacity of renewable energy sources but also solving the fundamental problem of their instability. Solar and wind generation depend on weather conditions, which creates a constant imbalance between generation and consumption. One of the most promising ways to solve this problem is the technology of direct conversion of solar energy into chemical energy – artificial photosynthesis. The use of novel physical materials allows for the efficient accumulation of the Sun's energy in the form of environmentally friendly hydrogen fuel (H_2)

Physical principles and challenges

The physical mechanism of the process is based on the solid-state band theory. When photons with energy exceeding or equal to the band gap hit a semiconductor photocatalyst, electrons are excited, and electron-hole pairs are generated. These charges migrate to the catalyst surface, where they react with water. Electrons reduce hydrogen ions to gas$(2H^+ + 2e^- \to H_2)$, while holes oxidize water molecules, releasing oxygen$(2H_2O + 4h^+ \to O_2 + 4H^+)$. The main problem with traditional materials (e.g., titanium dioxide) is the rapid recombination of charges and the ability to absorb mainly the ultraviolet spectrum, which accounts for less than **5%** of solar radiation.

Novel materials and the Z-scheme

To overcome these limitations, modern research is focused on the development of multicomponent heterostructures, particularly systems operating on the Z-scheme, mimicking natural photosynthesis. Novel materials include halide perovskites and metal-organic frameworks (MOFs), which have an adjustable band gap and can efficiently absorb a wide spectrum of visible light. The addition of cocatalysts (e.g., platinum nanoparticles or nickel-based compounds) significantly reduces the activation energy of the reaction and provides active sites for intensive hydrogen evolution.

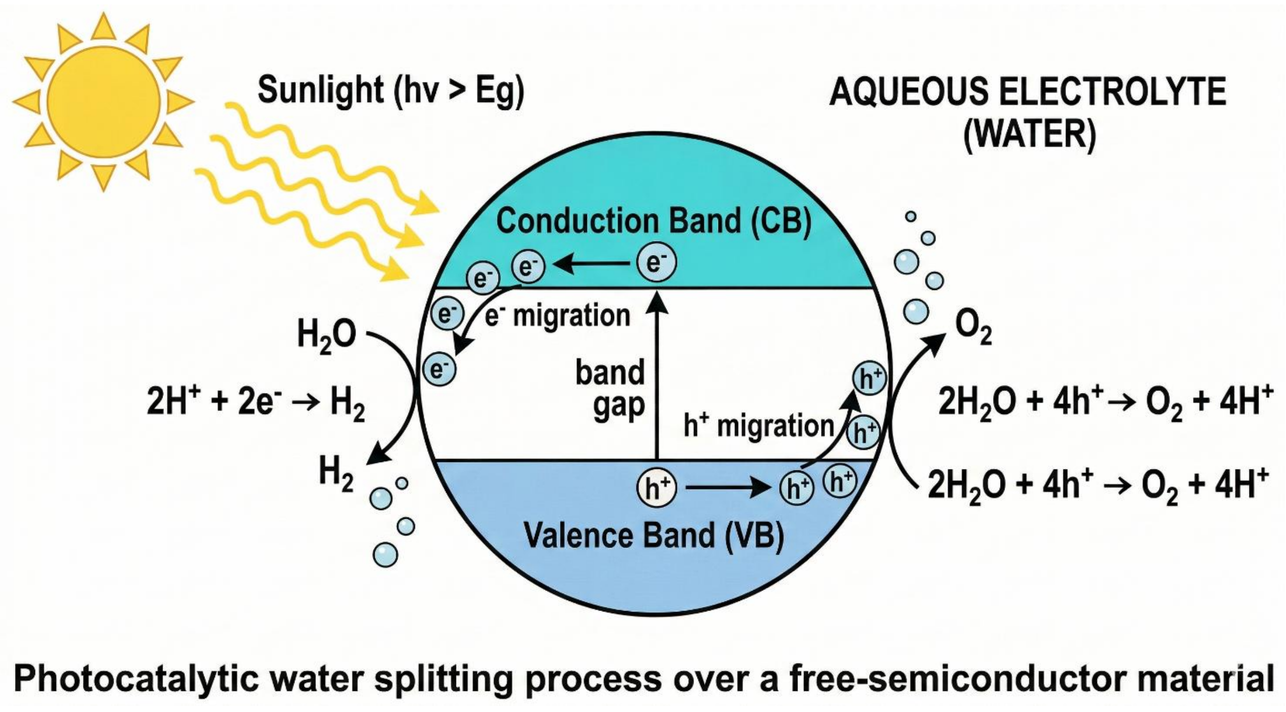

Fig. 1. Schematic representation of the photocatalytic water splitting process over a semiconductor material

Integration into power systems

The produced "green" hydrogen has a high energy density and zero emissions when burned or used in fuel cells. This makes it an ideal energy carrier for balancing electrical grids. In particular, the use of hydrogen storage is critically important for ensuring voltage stability in open-loop power grids, where the integration of local renewable sources often leads to significant fluctuations in electricity parameters.

Conclusion

The synthesis of new photocatalytic materials for water splitting opens a new era in the energy sector, combining energy generation and storage into a single process. The application of perovskites and heterostructures significantly increases the quantum yield of the reaction. Industrial scaling will substantially reduce the cost of "green" hydrogen, turning it into a reliable foundation for carbon-neutral power grids.

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