International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Hydrogen Production Technology using Photocatalysis and Solar Energy

Ambati Revathi[1], PillaRamana[2], Kuncham Neeraja[3]

[1,3]*B.Tech Student, Department of Electrical and Electronics Engineering, GMR Institute of Technology,Vizianagaram District, A.P, India*
[2]*Professor, Department of Electrical and Electronics Engineering, GMR Institute of Technology,Vizianagaram District, A.P, India.*

A B S T R A C T

The development of renewable energy sources continues to advance. Reducing CO_2 emissions and energy demand is the major justification for utilizing renewable energy. There are numerous renewable energy sources, including biomass, wind, and solar. Solar energy is free from cost and more efficient. Hydrogen meets the future energy demand because it does not create any environmental pollution. Hydrogen is clean and efficient energy. Advanced technology using Photocatalysis and solar energy for producing hydrogen. Photocatalytic has consisted of TiO2 Semiconductor. It converts solar energy into chemical energy and another main advantage of Photocatalytic is to store solar energy. This Review presents hydrogen production using photocatalysis and solar energy.

Keywords: Photocatalyst, Hydrogen, Visible Light, Titanium oxide

1.Introduction

The depletion of fossil fuels is accelerating. The major disadvantage of fossil fuels is produced greenhouse gas, carbon dioxide CO_2. So, to decrease the usage of fossil fuels instead of that using renewable energy like solar, wind, and hydro. Renewable energy sources are free, easily available, and pollution free. wind energy cannot be stored. Hydro energy also spent more money to construct dams. hydro and wind produce noise and it consists of turbines (moving parts) then which will take more maintenance. Geothermal energy is more difficult to handle. So finally solar energy has more advantages compared to the above energies. There is no noise pollution and rotating parts and it's low cost.

Hydrogen is an abundant gas. It is ecologically benign because its end users will not emit pollution or greenhouse gas emissions or otherwise negatively influence the environment. Hydrogen may be kept in three forms: liquid, metal hydride, and gaseous. Hydrogen production is achieved by steam reforming, biomass, and photocatalysis. Steam reforming is used methane as fuel, and steam.

The combination of these two produces a carbon-hydrogen ratio again using that carbon monoxide (CO) and steam to produce furthermore hydrogen and carbon dioxide(CO_2). Another coal gasification taken as fuel withhigh-temperature steam produces hydrogen, carbon monoxide(CO), carbon dioxide(CO_2), and other compounds.

Biomass like organic waste will be used for the production of hydrogen in absence of oxygen but it produces carbon products. Steam reformation and biomass all produce carbon products so these methods are created pollution to the environment.Therefore, it is not the best strategy to prevent pollution in the environment. The major effective method is using solar energy and photocatalyst. So this method is proven to improve but it has also some limitations.

Low efficiency and a lack of sun sensitivity are the main drawbacks of photocatalysts. Because it only absorbs a small amount of sunlight, its efficiency declines. Advanced compression processes require energy and expensive equipment to overcome these constraints, which raises overall prices. Hydrogen fuel has applications in hybrid vehicles, but one drawback is that it is more expensive than a petroleum-based vehicle.

2.Methodology

Three steps are typically needed to complete a photocatalytic reaction on a semiconductor. The semiconductor photocatalyst absorbs photons in the first step of light absorption. If the photons' (HV) energy is greater than the semiconductor's bandgap energy, electrons (e-) are excited and transferred from the valence band to the conduction band first, leaving a hole (h+) in the VB. In this stage, "e—h+ pairs"—pairs of electrons with negative charges and positively charged holes—are created. Charge separation and transfers come next. Even though some photoinduced e- and h+ mix in the majority of the photocatalytic activity, the photoinduced e-h+ couples are divided and transported to the surface of the semiconductor (volume recombination). The surface oxidation and reduction processes are the last phases. Chemical species react with photoinduced charges on the semiconductor's surface. While this is happening, some photogenerated e- and h+ mix again without engaging in a chemical process. The below figure from ref(4).

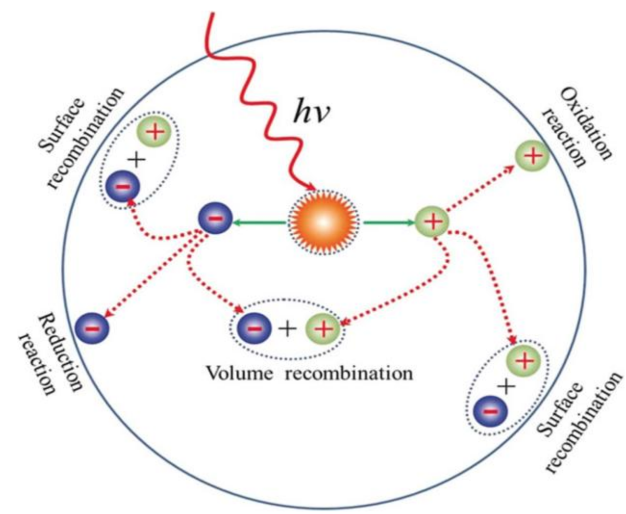

Figure1: Basic principles of semiconductor-driven photocatalysis From Ref(4)

How to improve tio$_2$ using different sacrificial agents

TiO_2's photocatalytic activity has been consistently improved, and attempts have been made to improve its reactivity to visible light to tackle the difficulties described above that and make solar photocatalytic water splitting of TiO_2 possible. In H_2 manufacturing, sacrificial agents, and other procedures are used. Some of them have been shown to assist improve TiO_2's photocatalytic activity.

Water splitting for hydrogen production using TiO_2 catalysts in pure water is difficult because photo-generated VB holes and CB electrons quickly recombine.By using sacrificial reagents or electron donors to react with photogenerated VB holes, the electron-hole separation may be enhanced, resulting in greater quantum efficiency. The disadvantage of this method is that since electron donors will be used up during the photocatalytic process, additional ones must be added constantly to maintain the reaction.

Metal oxide

The benefits of metal oxides are their inexpensive cost, excellent structural stability, and minimal toxicity. They can also be adjusted using various tactics, enhancing their performances, and they are simple to prepare. Additionally, good redox capacity is given to metal oxides by the correct band locations in the H_2 generation using photocatalysis.The activity of TiO_2 in photocatalysis is greatly enhanced by loading metals, such as Rh, Ni, Cu, Pt, Au, Pd, and Ag

Titanium dioxide (TiO_2) is the semiconductor material most commonly studied for photocatalytic H_2 generation. Ref(4)an atomic-scale defect engineering approach for generating and regulating traps for Pt single atom (SA) sites on thin sputtered TiO_2 films for photocatalytic H_2 generation was provided The density of defect centers on centers can be carefully regulated, resulting in a density of Pt SA sites that can be perfectly controlled. When compared to conventional Pt nanoparticle-modified TiO_2, these decorated Pt SA sites increased TiO_2 photoactivity by 150 times. Cho et al. Ref [4] revealed that pre-reduced TiO2 support may reverse the interaction with Nanoparticles and strengthen the metallic form of Pt, resulting in a three-fold improvement in H_2 generation rate when compared to typical Pt/TiO_2 supports. The active triple connections are Pt/TiO_2/H_2O.H_2 generation catalytic sites in the presence of CH3OH

gC3N4 photocatalysts

Carbon-nitride-based photocatalysts are now receiving a lot of interest for their photocatalytic H_2 production due to their unusual electronic structure. This section covers recent notable advances in the creation of C3N4-based photocatalytic for H_2 evolution. The below figure from ref(2)

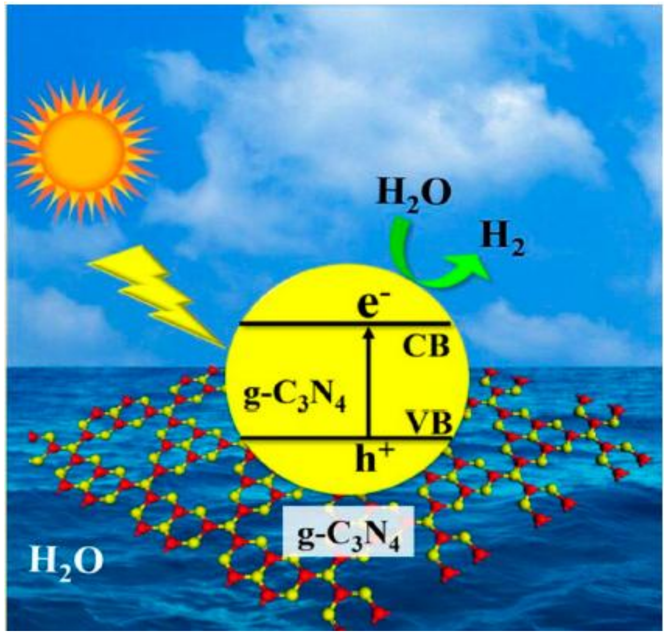

Figure 2. Proposed mechanism of graphitic carbonnitride (g-C3N4)-based photocatalysts. From ref(2)

From the CB (g-C3N4) to the MoS_2, electrons might move thanks to the establishment of band alignment. As a result, the MoS2/gC3N4 nano connection considerably improved Hydrogen evolution efficiency, achieving the highest Hydrogen production rate and optimum quantum efficiency.As a result, the MoS_2/gC3N4 nano junction achieved the highest Hydrogen production rate and optimal quantum efficiency of up to 2.1% (420 nm), which was greater than that of the g-C3N4/Pt junction. The performance of g-C3N4-based H_2 generation can be increased by inserting noble-metal particles such as Pd or Au, which accept electrons in the CB and limit the rate of charge recombination. Many researchers are working on metal-free catalysts for H_2 evolution, and recent studies included non-noble-metal catalysts into g-C3N4 catalysts, which displayed better photocatalytic performance when compared with noble-metal catalysts.

Z-scheme photocatalyst

The Z-scheme is used to separate water. During a Hydrogen production evolution process, the oxidation of an electron donor (D) by VB holes and the reduction of protons by CB electrons occur on the surface of the photocatalyst resulting in the matching electron acceptor (A), where the electron acceptor produced by the paired H_2 evolution photocatalyst is transformed to D and the water oxidation reaction occurs through the valence band holes. As a result, water splitting is feasible

3. Conclusion

This study covers recent substantial advances in photocatalytic renewable energy generation based on semiconductor photocatalysis, with a focus on H_2 production and CO_2 reduction. These research efforts have largely concentrated on solving two scientific issues linked with photocatalytic activity to increase photocatalytic performance: light intensity and photoinduced charge separation. Various techniques based on photocatalytic structure have been used to enhance light usage rate and photogenerated charge separation: 1. Metal loading 2. gc3n4 3. The Z scheme. To build a low-cost and good-for-the-environment water-splitting process, new technologies must be designed in combination with a solid theoretical foundation for a greater grasp of the hydrogen-generating mechanism.

REFERENCES

1. Hydrogen Production from Semiconductor – based photocatalysis via water splitting. Year of publication 17 October 2012. Chi-Hung Liao 1,2, Chao-Wei Huang 1,2 and Jeffrey C. S. Wu 1,*. www.mdpi.com/journal/catalysts

2. Photocatalytic hydrogen evolution via water splitting. Year of publication 12 December 2018. Yifan Zhang 1, Young-Jung Heo 1, Ji-Won Lee 1, Jong-Hoon Lee 1, JohnyBajgai 2, Kyu-Jae Lee 2,*and Soo-Jin Park 1,* Catalysts 2018.

3. Study on solar photocatalytic hydrogen production. Year of publishing 2011Yilin Cui Jun Zhao Thermal Engineering Tianjin University Tianjin, China

4. Recent advances in photocatalytic renewable energy production. Year of the publication 29 Jan 2022.Xiaolang Chen#, Jingjing Zhao#, Guisheng Li, Daqing Zhang, Hexing Li. Chen et al. Energy Mater 2022;2:200001

5. Recent progress for hydrogen production by photocatalytic natural or simulated seawater splitting. Year May 17, 2020. Jining Zhang Wenping Hu, Shuang Cao, and Lingyu Piao www.editorialmanager.com/nare/default.as

6. Wang Y, Zhao J, Chen Z, et al. Construction of Z-scheme MoSe2/CdSe hollow nanostructure with enhanced full spectrum photocatalytic activity. ApplCatal B-Environ 2019;244:76-86. DOI

7. Zhang G, Wang X. Oxysulfide semiconductors for photocatalytic overall water splitting with visible light. Angew Chem Int Ed Engl2019;58:15580-2. DOI PubMed

8. Pan R, Hu M, Liu J, et al. Two-dimensional all-in-one sulfide monolayers driving photocatalytic overall water splitting. Nano Lett2021;21:6228-36. DOI PubMed

9. Chen X, Shi R, Chen Q, et al. Three-dimensional porous g-C3N4 for highly efficient photocatalytic overall water splitting. NanoEnergy 2019;59:644-50. DOI

10. Lin Y, Su W, Wang X, Fu X, Wang X. LaOCl-coupled polymeric carbon nitride for overall water splitting through a one-photonexcitation pathway. Angew Chem Int Ed Engl2020;59:20919-23. DOI PubMed