International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

WATER ELECTROLYSIS METHOD FOR HYDROGEN PRODUCTION USING ELECTRODES

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ABSTRACT :

Water electrolysis is a quite old technology started around two centuries back, but promising technology for hydrogen production. This work reviewed the development, crisis and significance, past, present and future of the different water electrolysis techniques. In this work thermodynamics, energy requirement and efficiencies of electrolysis processes are reviewed. Alkaline water electrolysis, polymer electrolysis membrane (PEM) and High temperature electrolysis are reviewed and compared. Low share of water electrolysis for hydrogen production is due to cost ineffective, high maintenance, low durability and stability and low efficiency compare to other available technologies. Current technology and knowledge of water electrolysis are studied and reviewed for where the modifications and development required for hydrogen production. This review paper analyzes the energy requirement, practical cell voltage, efficiency of process, temperature and pressure effects on potential kinetics of hydrogen production and effect of electrode materials on the conventional water electrolysis for Alkaline electrolysis, PEM electrolysis and High Temperature Electrolysis .

INTRODUCTION :

The atmosphere is polluted by plenty of greenhouse gases; SOx, NOx, CO2 and CO from hydrogen production by hydrocarbon source that are fossil fuel sources which can affect seriously the ecosystem. Hence the clean technology is needed for production of hydrogen that can be achieved if hydrogen is produced by renewable source like water electrolysis and no emission of SOx, NOx, CO2 and CO will be possible and to achieve “hydrogen economy”. There are many important non-fossil fuel based processes like Water electrolysis, photocatalysis processes and thermochemical cycles for hydrogen productions in practice. The use of solar energy and wind energy are sustainable methods for hydrogen production by water electrolysis with high purity, simple and green process. For hydrogen production, water electrolysis has its various merits like pollution free process if renewable energy sources use purity of high degree, very simple process and plenty of resources. Water electrolysis is an around 200 year old technology; around 1800 AD the principle demonstrated by experiment by J. W. Ritter in Germany. In the same year William Nicholson and Anthony Carlise decompose water into hydrogen and oxygen in England. The application of this technology started to use after tens of year. As hydrogen could be produced at lower cost by steam reforming, water electrolysis technology advanced only slowly. The hydrogen production in total around the world is about 500 bill. Nm^3/year, mostly steam reforming. Only 4 % of hydrogen produced by water electrolysis as shown in figure 1. Due to low efficiency of production processes [19]. Currently, the efficiency hydrogen production by water electrolysis is too low to be economically competitive .

Water electrolysis technologies are considered extremely promising for sustainable hydrogen production and energy storage, as they can be driven by renewable or waste electricity/heat sources. Furthermore, the oxygen by-product has no negative environmental effects and can be used in other applications to enhance the economic profitability of the electrolysis input energy conversion/storage process. The three main types of current water/steam electrolyzer technologies have distinct advantages and disadvantages. AWEs (alkaline water electrolyzers) are the only technology globally commercially-available at MW scale. PEMWEs (proton exchange membrane water electrolyzers) have advantages for operation with variable power supply and at lower part loads than AWEs. SOSEs (solid oxide steam electrolyzers) have higher efficiencies than either AWEs or PEMWEs, but face durability challenges at high-temperature operation. This Research Topic collection is intended to disseminate research progress in the development of renewable energy-driven water electrolysis, and to encourage further research and investments in this technology.

CONCEPT AND FUNDAMENTALS

When a water molecule passes through electrochemical process water molecules spilt in hydrogen and oxygen gases, this process is called water electrolysis. Electricity is used for the splitting the hydrogen and oxygen into their gaseous phase. The basic equation of water electrolysis is written as Eq.1. This technique produces clean energy without emission of pollution by utilizing electricity.

For water electrolysis the energy is required as electrical energy from a DC power source. At room temperature the splitting of water is very small, approximately 10 moles/liter because pure water is the very poor conductor electricity. Therefore, acid or base is used to improve the conductivity. In an alkaline electrolyzer, KOH, NaOH and H_2SO_4 solution mainly is used with water. The solution splits into ions positive and negative ions and these ions readily conduct electricity in a water solution by flowing from one electrode to the other .

Water electrolysis technology can de divides into three main classifications on the basis of electrolyte used in the electrolysis cell.

- Use of Liquid Electrolyte : Alkaline Water Electrolysis (AWE)
- Electrolysis in acid ionomer environment: Polymer Electrolyte Membrane Electrolysis (PEM)/Solid Polymer Electrolysis (SPE)
- Use of Solid Oxide Electrolyte: Steam electrolysis (High temperature electrolysis - HTEL or SOEL)

The figure 2 shows the fundamental principle for electrolysis cell. The general principle for all three technologies is the same. When a high voltage is applied to an electrochemical cell in presence of water, hydrogen and oxygen gas bubbles evolve at cathode (negative electrode) and anode (positive electrode) respectively.

METHODOLOGY OF WATER ELECTROLYSIS :

Electrolytic cells for hydrogen production can be classified based on the nature of electrolyzers or electrolytic cell used. Some basic design technologies are as follows:

POLYMER ELECTROLYTE MEMBRANE ELECTROLYZERS

In a polymer electrolyte membrane (PEM) electrolyzer, the electrolyte is a solid specialty plastic material.

- Water reacts at the anode to form oxygen and positively charged hydrogen ions (protons).
- The electrons flow through an external circuit and the hydrogen ions selectively move across the PEM to the cathode.
- At the cathode, hydrogen ions combine with electrons from the external circuit to form hydrogen gas. Anode Reaction: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ Cathode Reaction: $4H^+ + 4e^- \rightarrow 2H_2$

ALKALINE ELECTROLYZERS

Alkaline electrolyzers operate via transport of hydroxide ions (OH^-) through the electrolyte from the cathode to the anode with hydrogen being generated on the cathode side. Electrolyzers using a liquid alkaline solution of sodium or potassium hydroxide as the electrolyte have been commercially available for many years. Newer approaches using solid alkaline exchange membranes as the electrolyte are showing promise on the lab scale.

SOLID OXIDE ELECTROLYZERS

Solid oxide electrolyzers, which use a solid ceramic material as the electrolyte that selectively conducts negatively charged oxygen ions (O^{2-}) at elevated temperatures, generate hydrogen in a slightly different way.

- Water at the cathode combines with electrons from the external circuit to form hydrogen gas and negatively charged oxygen ions.
- The oxygen ions pass through the solid ceramic membrane and react at the anode to form oxygen gas and generate electrons for the external circuit.

Solid oxide electrolyzers must operate at temperatures high enough for the solid oxide membranes to function properly (about 700°–800°C, compared to PEM electrolyzers, which operate at 70°–90°C, and commercial alkaline electrolyzers, which operate at 100°–150°C). The solid oxide electrolyzers can effectively use heat available at these elevated temperatures (from various sources, including nuclear energy) to decrease the amount of electrical energy needed to produce hydrogen from water.

Why Is This Pathway Being Considered?

Hydrogen produced via electrolysis can result in zero greenhouse gas emissions, depending on the source of the electricity used. The source of the required electricity—including its cost and efficiency, as well as emissions resulting from electricity generation—must be considered when evaluating the benefits and economic viability of hydrogen production via electrolysis. In many regions of the country, today's power grid is not ideal for providing the electricity required for electrolysis because of the greenhouse gases released and the amount of fuel required due to the low efficiency of the electricity generation process. Hydrogen production via electrolysis is being pursued for renewable (wind) and nuclear energy options. These pathways result in virtually zero greenhouse gas and criteria pollutant emissions.

CONCLUSION :

Water electrolysis is a well-established technology that has been used for almost one century for miscellaneous application in the industry (food industry, power plants, metallurgy, etc.). Nowadays, it is also considered as a key process that can be used for the production of high-purity hydrogen from water and renewable energy sources. It is expected that in the near future, water electrolyzers will occupy an increasingly prominent place for the decentralized production of hydrogen, for example, in hydrogen-fueling stations. Thus, in spite of its long industrial history, this is still the focus of several ambitious R&D programs and investments worldwide. There are different water electrolysis technologies. The difference between them comes from the temperature of operation and the pH of the electrolyte. The alkaline process is the oldest and a more mature one. But SPE water electrolysis has been making very significant progresses over the last years and because of its large potential for further improvement, it is expected to play a significant role in view of the so-called hydrogen economy and the large production of hydrogen of electrolytic grade from renewable energy sources. The high-temperature water electrolysis process is probably more efficient. However, it is faced with critical challenges (especially, in material science). Such challenges will have to be overcome before any market application can be considered.

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