Overview of Water Electrochemistry

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Seawater is the most abundant supply of water and the ideal and cheapest electrolyte. Because it is a green and renewable chemical process, water electrolysis has earned a lot of interest among the different hydrogen production techniques. Basis of water electrolysis include general theoretical concepts: chemical, physical, and electrochemical concepts. Research has focused on the specific seawater electrolysis parameters: cathodic evolution of hydrogen; concurrent anodic evolution of oxygen and chlorine; specific seawater catalyst electrodes, and seawater electrolyzer efficiency. A sustainable technology development must also capitalize on known and emerging technologies; protecting the environment; utilization of green, renewable energies as sources of electricity; and above all, economic efficiency as a whole.

seawater electrolysis for hydrogen production electrocatalyst sustainability

1. Introduction

As hydrogen is a carbon-free alternative energy source with several advantages including environmental friendliness and high energy density, it can be used in future energy frameworks. There are many methods for producing hydrogen from water electrolysis that offer both high purity and sustainability. The growing number of scientific reviews on the topic of hydrogen production by the electrochemical splitting of water demonstrates the considerable interest in and financial support for this line of research [1][2][3][4][5][6][7][8][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24]. The hydrogen economy is viewed as a workable solution to the aforementioned issues in light of the rising costs of fossil fuels and increasing environmental degradation. Water electrolysis takes on a special strategic function in this situation [1].

Conventional DC water electrolysis can produce hydrogen. However, the process is not ideal for the environment if the electrical energy for the electrolysis is generated in thermal power plants from fossil fuels due to the release of carbon dioxide. The future of fuel cells is bright, and numerous technologies are being researched globally. Compared with thermal power plants, the amount of carbon dioxide produced during the production of hydrogen from natural gas for fuel cells can be reduced, although carbon dioxide is still produced. While photo-catalysis is a better method for producing hydrogen, it is still a relatively inefficient process for use in actual applications. Since the cost of energy is declining, by using renewable resources as wind, hydroelectricity, and nuclear power, water electrolysis has recently been considered a method for producing hydrogen [2]. A highly interesting method for producing hydrogen by saltwater electrolysis is the in situ generation of power from waves [25].

A way to lessen environmental pollution caused by power production based on current methods is to produce hydrogen by seawater electrolysis using electricity from local sources and then utilize it in fuel cells.

Two essential components are required for seawater electrolysis to produce hydrogen: cathodes that actively evolve hydrogen during the process and anodes that efficiently develop oxygen rather than chlorine. The most active noble–metallic material for the hydrogen evolution reaction is platinum, but it cannot be used to produce hydrogen on a large scale. Other cathodic materials, such as nickel and several Ni alloys and composite materials, have shown promise for hydrogen generation over the past ten years [21].

High electrochemical reactivity, high energy density, theoretically infinite availability (as long as water can be split), and the combustion byproduct (water) are all benefits of using hydrogen as a fuel in fuel cells.

The need for hydrogen is expected to treble globally over the next five years, and it should also become a cost-effective and sustainable energy source. Hydrogen obtained from different methods, e.g., steam methane reforming, methane pyrolysis, and coal gasification have different effects on environment power systems; the transportation, hydrocarbon and ammonia manufacturing, and metalworking industries all use hydrogen.

Most of the actual hydrogen production, which accounts for around 95% of the 60 million tons produced each year in the context of climate change, is not sustainable, requiring the development of cleaner hydrogen production techniques.

2. An Overview of Water Electrochemistry

From a broad standpoint, seawater and water electrolysis have very similar electrochemical behavior: At the cathode, reduction reactions (electrons acceptance) take place, while at the anode, oxidation reactions take place (electrons releasing). **Figure 1** presents a general scheme of water electrolysis that is also valid for an alkaline electrolyzer (AE). What creates a difference is the electrolyte, which can be water with additional bases, acids, or salts (as in seawater). Depending on the physico-chemical and technological operating parameters of the electrolysis cell, different secondary reactions may take place at both electrodes depending on the nature of the electrolyte. These reactions may affect the efficiency of the cell, the yield of hydrogen production, and the consumption of raw materials and electricity. The abovementioned issues regarding hydrogen production from water electrolysis lead to the conclusion that this solution is far from an optimum one even though it appears to be a straightforward electrochemical reaction. The subject will remain of high interest for researchers in order to discover the best answer in terms of energy efficiency and costs, even though research and technical advancement in recent years has brought technology extremely near commercial solutions. The electrochemical process called water electrolysis produces extremely pure hydrogen and oxygen. Due to its high purity, electrolytic hydrogen is frequently utilized in the chemical industry, particularly in the energy sector, or for smaller applications such as the semiconductor and food sectors. Hydrogen is also employed in catalytic hydrogenation reactions and ammonia production.

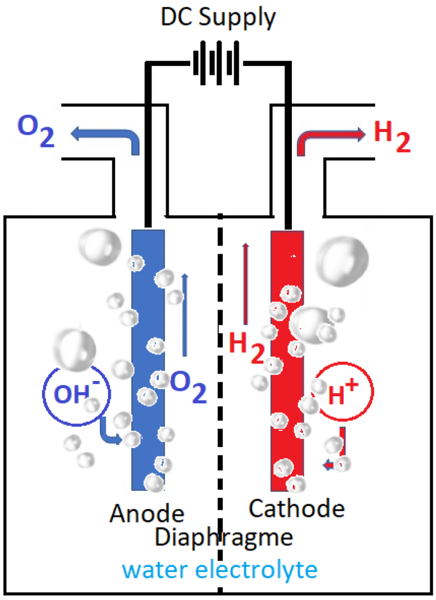

Figure 1. General scheme for water electrolysis.

The need to use pure hydrogen in fuel cells, the low density at standard pressure and temperature, the difficulties of storage, and the possibility of explosion are all drawbacks of hydrogen utilization.

Using electricity, water is electrolyzed and breaks down into hydrogen and oxygen. A direct current (DC) source, an electrolyte, and two electrodes—a cathode and an anode—make up a basic water electrolysis cell.

An ion-containing water solution, a proton exchange membrane (PEM), or a ceramic oxygen ion exchange membrane can all be used as electrolyte.

The electrode that is attached to the negative pole of the direct current source is called the cathode. This is where hydrogen is obtained because of the reduction reaction. The electrode that is attached to the positive pole of the current source is known as the anode. It is the location of oxidation reactions and the production of oxygen.

Pure water has a very low electrical conductivity, about 1×10^{-6} S/cm^{-1}, which makes it poorly conductive for electric currents. Under these circumstances, extremely high voltages would be needed to produce hydrogen and oxygen. For this reason, salts, acids, or bases are added to make water more conductive. Due to the increased mobility of hydrogen ions (H^+) and hydroxyl ions (HO^-), acidic and alkaline solutions have higher electrical conductivities than neutral solutions. Although acidic solutions are more conductive than alkaline solutions, the corrosion of metallic components, usually made of steel, causes the increased material consumption of the electrodes, which counts as losses in the process. The electrical conductivity of alkaline electrolytes decreases in time due to the development of carbonates under the influence of carbon dioxide in the air, which results in a 75% reduction in initial conductivity.

When using seawater as electrolyte, it can be used either on its own or in combination with sodium hydroxide.

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