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The investigation of eco-friendly energy production via hydrogen production

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Abstract

Energy production has become one of the most essential elements determining industry, economy, and international relations in the technological development era we are in. Although globalization can help countries surpass their borders, energy strategies are crucial in shaping these relationships. For this purpose, the resources chosen for energy production should be human and ecosystem-friendly, as well as cost-effective and renewable. The hydrogen is suitable energy carrier. In this study, the hydrogen production was achieved by electrolysis. The Pt anode and Ni modified Ni foam cathode electrodes were used in 1M KOH. The modified electrode surface was monitored by scanning electron microscope (SEM). The X-ray diffractometer (XRD) analysis was achieved for characterization. The amount of hydrogen gas was determined during 1800 seconds. The results showed that, Ni modified electrode was enhanced the hydrogen performance significantly.

Keywords: Electrolysis, Energy, Hydrogen

Hidrojen üretimi yoluyla çevre dostu enerji üretiminin incelenmesi

Özet

İçinde bulunduğumuz teknolojik gelişme çağında, enerji üretimi sanayi, ekonomi ve uluslararası ilişkileri belirleyen en temel unsurlardan biri haline geldi. Küreselleşme ülkelerin sınırlarını aşmalarına yardımcı olsa da, bu ilişkilerin şekillenmesinde enerji stratejileri çok önemlidir. Bu amaçla, enerji üretimi için seçilen kaynaklar, insan ve ekosistem dostu, uygun maliyetli ve yenilenebilir olmalıdır. Hidrojen uygun bir enerji taşıyıcısıdır. Bu çalışmada, elektroliz ile hidrojen üretimi gerçekleştirilmiştir. Modifiye edilen elektrot yüzeyi taramalı elektron mikrsokobu (SEM) ile incelenmiştir. Karakterizasyon X-ışını difraktometresi (XRD) ile gerçekleştirilmiştir. 1M KOH çözeltisinde, Pt anot ve Ni ile modifiye edilmiş Ni köpük katot elektrotlar kullanılmıştır. Üretilen hidrojen gazı miktarı 1800 saniye boyunca belirlenmiştir. Sonuçlar, Ni modifiye elektrotun hidrojen performansını önemli ölçüde arttırdığını göstermiştir.

Anahtar kelimeler: Elektroliz, Enerji, Hidrojen

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The overview of eco-friendly energy production via hydrogen production

1. Introduction

Clean, renewable energy is becoming one of the most critical requirements for people, nature, and international relations [1,2]. Energy demand should be met with alternative fuels that minimize carbon emissions. Hydrogen is a good alternative for this purpose because it produces no carbon dioxide when used as an energy source [3-5]. Hydrogen may be produced in a number of ways, but the most practical method is electrolysis, which creates extremely pure hydrogen gas. But, over potential is a major difficulty in this technology, thus scientists have been researching solutions to reduce it [6-10]. Electrocatalysts comprising Pt, Pd, and Ir are more favorable, but the costs are very high. In order to decrease hydrogen production costs, Ni based catalyst have been widely used in electrolysis systems [11-20]. Solmaz et al. [11] investigated the use of a NiZn electrode in an alkaline medium for hydrogen evolution. The electrocatalyst was prepared using the electrodeposition technique and then immersed in 30 percent NaOH for 24 hours to remove Zn from the surface. On this occasion, they increased the active surface area and revealed the design of the new Ni electrode. The idea behind this design is that the zinc that has been removed from the electrode surface creates random gaps on the surface, thereby increasing the surface area. Crnkovic et al. [12] prepared the Ni–Fe–Mo–Zn electrocatalyst and kept it in a 28 percent KOH solution at 80 C for 4 hours to increase the surface area of the electrocatalyst, and they obtained a larger surface area electrocatalyst. Felt electrodes were also used to obtain an electrocatalyst with a larger surface area [1]. Although carbon felt has a large surface area, it is inefficient at producing hydrogen gas. But metals with high catalytic activity can be enhanced by precipitating small amounts of hydrogen gas onto carbon felt [1]. On the other hand, Ni foam electrodes should be considered as one of the low-cost, simple-to-use options for this purpose [13-15]. Because they have a large surface as well as the benefit of being light. Ni foam is very suitable for electrodeposition applications due to high conductivity capability. Ni has also several advantages for electrocatalysis applications, especially water splitting reactions. Furthermore it is available and durable during long operating times. Instead of expensive noble metal catalysts such as Pt, Pd, Ir, etc. Ni is more suitable for hydrogen evolution reactions [5,6]. Several modified Ni foam were used as hydrogen evolution catalyst; d, f electron of transition metals and/or rare elements were used to synergize with Ni, Fe, etc. with paired d electrons improving the electrocatalytic performance of nickel foam [13-16 In order to enhance hydrogen evolution performance, the solvothermal synthesis of $Ni_{0.6}Co_{0.4}(HCO_3)_2$ and subsequent electrodeposition of Pt resulted in Pt particles modified NiCo hydrogen carbonate supported on nickel foam (Pt-$Ni_{0.6}$-$Co_{0.4}(HCO_3)_2$/NF) [14]. According to experimental results high exchange current density (4.2 mA cm^{-2}) and low Tafel slope (39 mV dec^{-1}) values were determined. The mass activity of modified catalyst was comparable and even higher than that of commercial Pt/C [14 NiCu deposited Ni foam electrode was used as cathode for hydrogen generation reaction [15].The catalyst efficiency was enhanced via NiCu deposition because Tafel slopes of the Ni foam, modified electrodes had 147.1, 93.9, and 82 mV dec^{-1}, respiectively. Briefly, Ni based catalysts have many advantages.

In this study Ni foam was preferred as catalyst and it was modified Ni particles in order to increase the active surface area. The galvanostatic method was used for decoration. The SEM and XRD achieved for characterization. The hydrogen production efficiency was determined with electrolysis method. The results revealed that the Ni enhanced electrode greatly improved hydrogen performance.

2. Materials and methods

In this study, the aqueous solution of KOH, an electrolyte suitable for the process of electrolysis of water, was preferred. The 1 M solution was prepared. The 56.11 grams of KOH was added to the

distilled water and mixed in the magnetic mixer until it reached a homogeneous consistency the volume was a liter. Ni foam electrode is used as cathode (working electrode) in two electrode system due to its high performance and large catalyst area. Copper wire is added to a Ni foam sheet (1cmx1cm) to provide conductivity when electrical potential is applied. The Pt sheet (1cmx1cm) was used as an anode (counter electrode) in hydrogen evolution experiments. The Ni modification was achieved on Ni foam with two electrode configuration in nickel bath 30% $NiSO_4.7H_2O$, 1% $NiCl_2.6H_2O$, and 1.25% H_3BO_3. In this experiment, the Ni sheet (1cmx1cm) was used as an anode (counter electrode). In order to achieve Ni deposition on Ni foam, the constant current density applied to system at 5 mA cm^{-2}.

Electrolysis was carried out using a direct current source and the amount of hydrogen produced both experimentally and theoretically at constant voltage. The theoretical calculations obtained by current-voltage curves with the help of Faraday Laws. A multimeter was used to determine the current flowing through the system. The hydrogen performance was determined with two electrode configuration, for this purpose a burette was filled with 1M KOH, it was inverted over the cathode various constant potential values (from 2.5 to 3.0 V by 0.1 V step) were applied to the system. The filled hydrogen gas in the burette was measured over 30 minutes for each potential.

The FEI Quanta 650 Field Emission SEM was used to get images. The structure of the electrodes was analyzed using the EMPYREAN X-ray diffractometer.

3. Results and discussion

The decomposition voltage is the minimum potential required for electrode reactions to begin. The theoretical decomposition voltage (Ed) can be calculated using the Nernst Equation in Eq. 1 to calculate the electrode potentials corresponding to the anode and cathode equilibrium states.

$$E_d = E_{anode} - E_{cathode} \quad (1)$$

The potential necessary for water to decompose at 25 °C is 1.23 V, which is where the evolution of hydrogen gas begins [5]. Due to the over voltages created by the solution and electrode metal, as well as the internal resistance of the voltage source and the cables used during the experiment, a higher potential must be provided. When alkaline water is electrolyzed, oxygen is produced at the anode (Eq. 2) and hydrogen gas is released at the cathode (Eq. 3). The net reaction was seen in Eq. 4.

Anode : $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$	$E_A=0.401+0.0592pOH$	(PO_2=1.0 atm)	(2)
Cathode: $4 H_2O + 4e^- \rightarrow 4OH^- + 2H_2$	$E_C=-0.828+0.0592pOH$	(PH_2=1.0 atm)	(3)
$2H_2O \rightarrow O_2 + 2H_2$	$E=E_A-E_C=1.229$ V		(4)

Because of the excess potentials in the system, we need apply greater potentials in order to generate hydrogen, so the catalytic activity of the electrode is critical. In this study the activity of Ni foam was enhanced by Ni deposition on surface. The observed hydrogen gas volumes for the Pt anode Ni modified Ni foam cathode system were presented in Fig.1. The 35.3; 40.2; 45.6; 54.6; 59.9; 66.1; 69.7; 72.2; 78.9 and 92.3 at 2.1; 2.2; 2.3; 2.4; 2.5; 2.6; 2.7; 2.8; 2.9 and 3.0 V, respectively. According to comparison with literature, values were comparable. Altunbaş Şahin et al. [8] produced Ni modified TiO_2 and Ti electrodes. For Ti, TiOx-30, TiO-45, TiOx-30/Ni, and TiO-45/Ni, the obtained hydrogen

gas volumes were 1.79, 3.63, 1.83, 13.8, and 9.38 mL, respectively, at -1.8 V for 30 minutes electrolysis period.

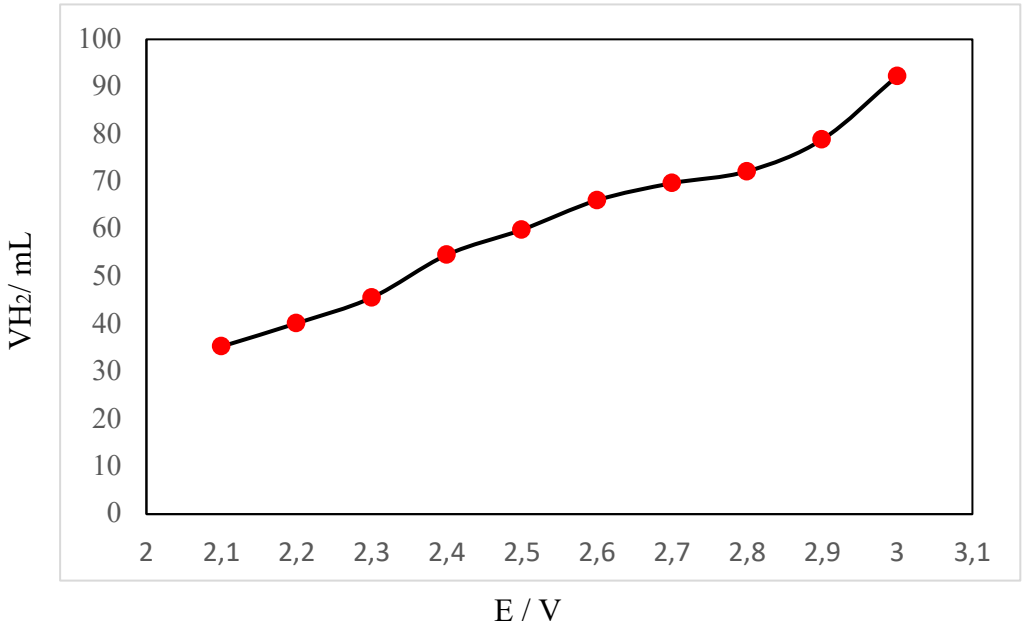

Figure 1. The hydrogen gas volumes vs. applied potenatials

Chakik et al. [9] used different cathodes for hydrogen production in alkaline medium. The cathodes were Zn95%Fe5%; Zn90%Fe10%; Zn85%Fe15%; Zn95%Cu5%; Zn90%Cu10%; Zn85%Cu15%; Zn95%Co5%; Zn90%Co10%; Zn95%Cr5%; Zn90%Cr10%. The highest efficiency was 99.13% for Zn95%Cr5% electrode at 5 V. The produced hydrogen gas was 6 mL for 154s. Muminah et al. [10] deposited NiFe on stainless steel and the modified cathode was used for hydrogen production in alkaline solution. At 1.5 V and 3 mA, the rate of hydrogen gas was 0.010 cc/minute. Pt anode and Ni modified Ni foam cathode were found to be preferable when compared to literature. The Ni modified Ni foam (cathode electrode) surface is seen in Fig.2. The spider web-shape, rough surface was detected, the larger surface may enhance the produced gas volume.

The XRD pattern of Ni modified Ni foam (cathode electrode) was given in Fig. 3. The 2θ values for (111), (200), and (220) lattice planes of fcc Ni was observed at 44.3°; 51.9° and 75.9°, respectively (JCPDS card No 04-0850).

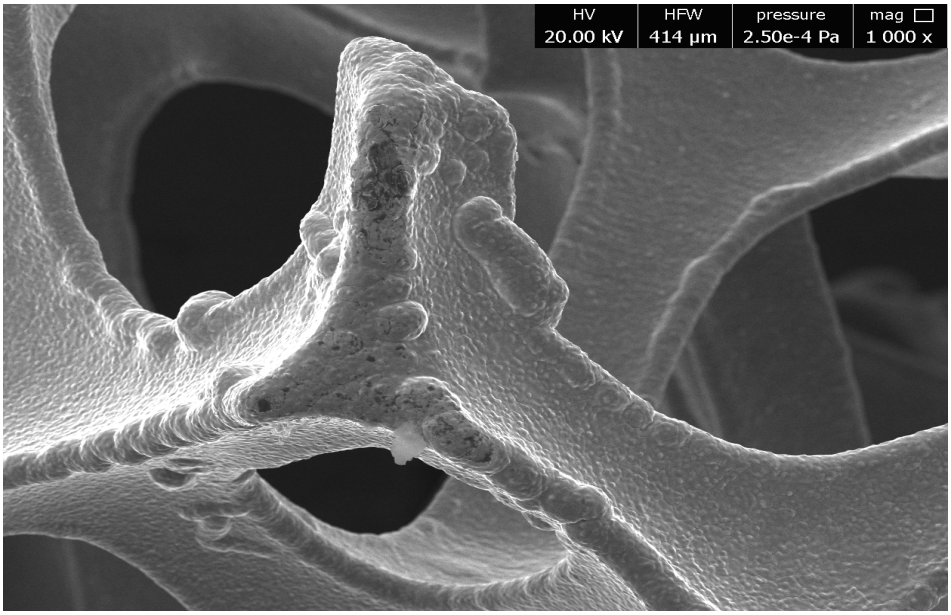

Figure 2. The SEM image of cathode

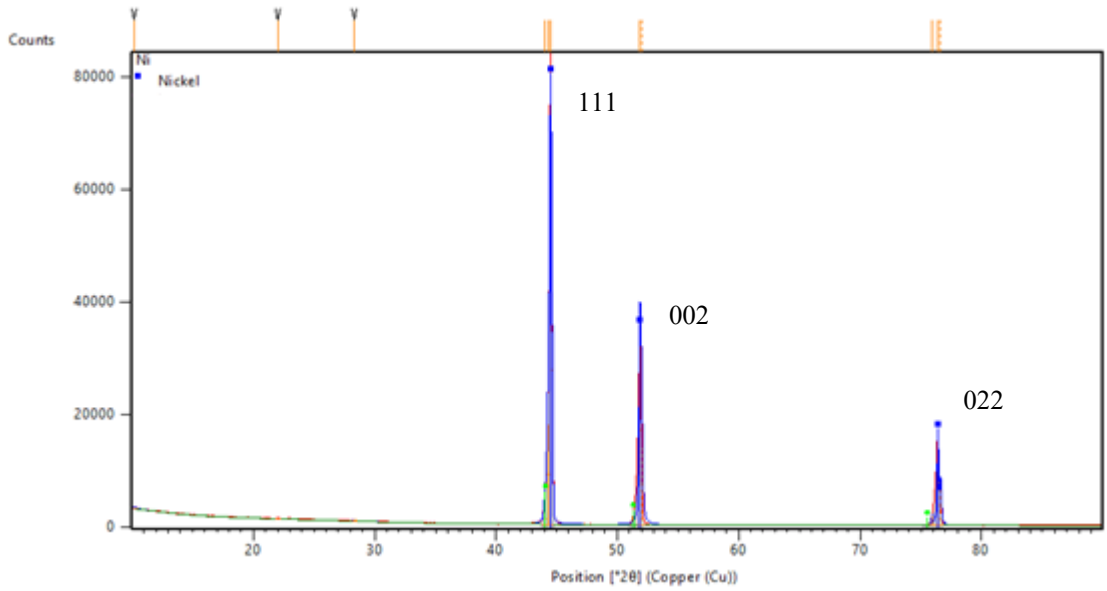

Figure 3. The XRD pattern of cathode

4. Conclusion

The following conclusions were obtained based on this study:

The Pt anode, Ni modified Ni foam cathode were effective catalysts for hydrogen production via alkaline electrolysis. The activity of modified cathode may be assigned to the larger active area which was seen in SEM images as spider web-shape. According to XRD results the (111), (200), and (220) lattice planes of fcc Ni was observed. The observed hydrogen gas volumes for the Pt anode Ni modified Ni foam cathode system were 72.2; 78.9 and 92.3 at 2.8; 2.9 and 3.0 V, respectively. As a result, this cell, which consists of a Pt anode and a Ni modified Ni foam cathode, may be an effective two electrode system for hydrogen production.

Contribution of authors: The study was achieved by Bahar Turunç.

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