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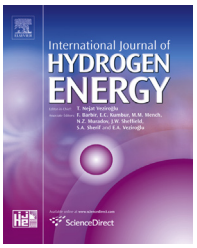

Investigation of noble metal loading CoWZn electrode for HER

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ABSTRACT

It is important to metal deposition on the electrode surface to increase the electrocatalytic activity of the electrodes. CoWZn coated the graphite rod was used to prepare the cathode electrode. Moreover, then Pt and Ru metals were deposited on the electrode surface. These electrodes were named as CoWZnPt and CoWZnRu. Cyclic voltammetry, electrochemical impedance spectroscopy, and potentiodynamic polarization techniques were used for characterization of electrodes in alkaline media. Hydrogen evolution efficiency was determined by accumulated of hydrogen gas. The catalytic activity for hydrogen evolution reaction of CoWZn, CoWZnPt, and CoWZnRu electrodes was compared. It was reported that modification of the CoWZn electrode with low amounts of Ru enhances the HER activity of the electrodes. The enhancement in the hydrogen evolution activity of the electrodes was attributed to the increase in their real surface area and/or a possible synergistic effect between Co, W, Zn and Ru as well as the well-known intrinsic catalytic activity of Ru.

Introduction

Hydrogen is considered as the fuel of the future due to unit capacity and high combustion heat when compared to oil and petroleum products. Hydrogen combustion products are not harmful to the environment. Hydrogen is the best fuel has been reported in previous studies [1].

Electrolysis of water is the best way to produce hydrogen. Electrolysis of water to produce hydrogen and oxygen gasses is a long multistep process. Water electrolyzer produces hydrogen and oxygen with electricity by the direct current source of pure water [2]. Increasing performance in hydrogen production with electrolyzer technology at low temperature and reducing the operation cost are needed. Electric power consumption forms the largest fraction of the cost of the hydrogen production by electrolysis of water [3]. There are several ways to reduce the cost of hydrogen production. For example; the original design of the electrolysis stack array, improving electrode performance, reducing the energy consumption of auxiliary devices.

The disadvantage of the electrolysis is low electrode efficiency and production cost [4–6]. The efficiency of the electrode material is improved by the synergistic combination of electrocatalytic components or by increasing the ratio between the real and the geometric surface area of the electrode [7]. The choice of electrode materials is evaluated in many ways. Good electrode materials are needed to maximum electrical conductivity, high corrosion resistance, and minimum overvoltage. To develop new and cheaper electrode

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Table 1 – All of the bath compositions for electrodeposition.

	Bath composition	Time (s)
CoWZn	0.314 g $CoSO_4 \cdot 7H_2O$, 0.025 g $Na_2WO_4 \cdot 2H_2O$, 5.44 g Sodium Citrate, 0.015 g $ZnSO_4 \cdot 7H_2O$, 0.56 g H_3BO_3	2700
Pt	2.49 mg Pt + 0.1 M KCl (50 mL volume)	70
Ru	2.05 mg Ru + 0.1 M KCl (50 mL volume)	203

materials with high electrocatalytic activity for HER attracts great interest for research [8–10].

Carbon-based materials have attracted much attention because of the unique mechanical and electrical conductivity and thermal properties [11–13] and expensive applications such as flow channels in the fuel cell, the probe of the electron microscope and field emission sensors [14,15]. Catalytic activity increases as a combination of low overvoltage and the high surface area with deposition of a transition metal on the carbon substrate.

Deactivation of the cathode is determined by either current loss in electrode potential or the increase in hydrogen overvoltage at constant current. Many researchers have focused on this issue to avoid deactivation problem and improve the energy efficiency of water electrolysis cells [16]. To the electrodeposition of ionic species on cobalt, electrode increases the efficiency and drops the overvoltage. The electrodeposition reduces the gap between the electrode and bulk solution. This approach reduces ohmic drops and provides more efficiency. The transition metals such as Ni, Fe, Co, Cu, and Zn can deposit on the electrode surface to achieve higher efficiency in hydrogen evolution reactions from water [17–20]. The development of materials with low overvoltage may be based on two fundamental characteristics for HER; increasing activity using more layered catalysts and increase the actual surface area.

For several years some noble metals have been used as ideal catalysts for many electrochemical processes. Their high catalytic activity, low overvoltage, and electrochemical stability are their advantages. The most suitable materials for the hydrogen evolution reaction according to the literature are Pt, Ir, Rh and Ru [21,22]. So many studies were carried out to develop high-performance of the electrodes with low Pt installation [23]. However, the use of Pt as solid metal for industrial processes is not appropriate because of its high cost and low abundance [24,25]. Therefore, it is important to increase the activity with less use of noble metals [26]. The studies such as C/Ni–NiIr, Mild Steel/Ni/NiZn–Pt, Cu/Ni/NiZn–PtRu, NiCoZn–Pt, Cu/Ni/NiZn–Pd and 3D-AgND showed that these metals are catalytically active [27–32]. The activity of C/Ni–NiIr electrode was also higher than that of the C/Ni and C/Ni–Ir [27]. The deposition of a small amount of Pt over the MS/Ni/NiZn could further improve its catalytic activity compared to MS/Ni/NiZn [28]. The alkaline leached Cu/NiZn electrode had good electrocatalytic activity towards the HER. Moreover, the deposition of small amounts of Pt, Ru and PtRu binary composites over the NiZn layer enhanced the hydrogen evolution performance of the electrode markedly. The Cu/Ni/NiZn–PtRu electrode had the best activity toward the HER [29]. NiCoZn–Pt electrode was found to be more effective for HER when compared to NiCoZn–Pd and NiCoZn–Ag [30]. The enhanced hydrogen evolution activity of the Pd-modified electrodes (Cu/Ni/NiZn–Pd) was assigned to the well-known better intrinsic catalytic activity of Pd, large active sites which afford abundant, accessible catalytic sites for the HER as well as to the possible synergistic effect between

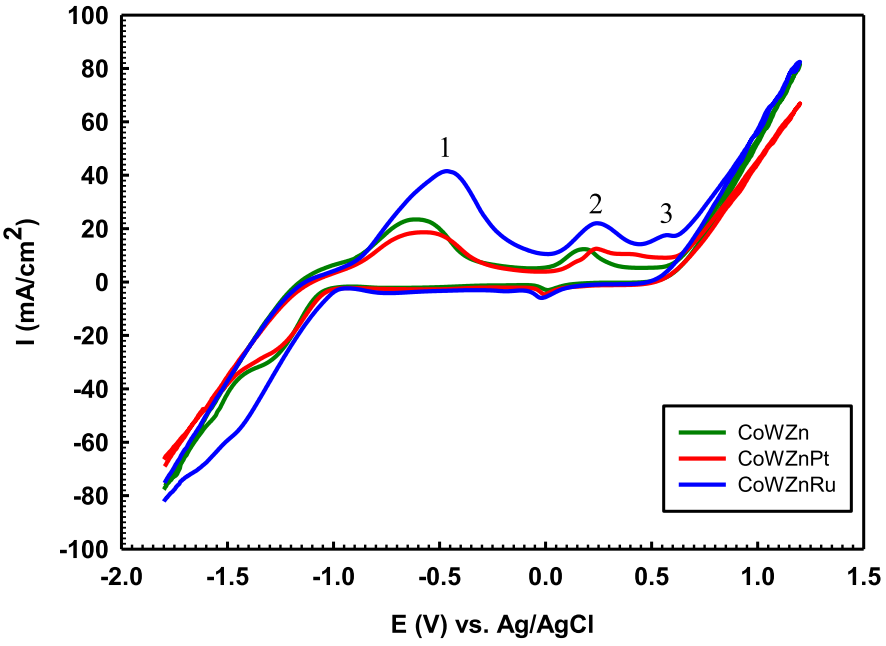

Fig. 1 – Cyclic voltammograms of CoWZn, CoWZnPt and CoWZnRu electrodes in 1.0 M KOH solution at room temperature.

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