

알칼리 용액에서 알루미늄 재활용 캔을 이용한 수소생산에 미치는 환경 인자의 영향

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Effects of Environmental Variables on Hydrogen Generation from Alkaline Solutions using used Aluminum Cans

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ABSTRACT

This study examined the effect of environmental variables, such as the NaOH concentration and solution temperature, on the rate of hydrogen generation from NaOH solutions through the corrosion of used aluminum cans as a potential candidate material for the safe and economic production of hydrogen. Corrosion of the used aluminum cans was promoted by increasing the NaOH concentration and solution temperature because of the loss of aluminum passivity. The measured rate of hydrogen generation from the NaOH solutions increased with increasing NaOH concentration due to the catalytic activity of NaOH in the hydrolysis process. However, at higher solution temperatures, the rate of hydrogen generation rate was less affected by the NaOH concentration than that at lower temperature.

KEY WORDS : Used aluminum can(알루미늄 재활용 캔), Hydrogen generation(수소발생), Corrosion(부식), Hydrolysis(가수분해), Activation energy(활성화 에너지)

1. Introduction

Fossil fuels, such as petroleum and coal are used as mainly power sources for electricity generation and transportation. However, fossil fuels are expected to become exhausted in the near future

due to the limited reserves.

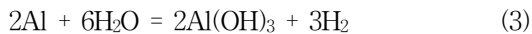
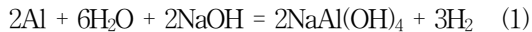
In addition, the emission of CO₂, NO_x and SO_x by the combustion of fossil fuels has accelerated global warming and air pollution. Therefore, considerable effort has been made to develop potential alternative energy sources. Hydrogen is currently produced industrially from the steam reforming of natural gas, oil, or coal¹⁾. However, pollutants can

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also be produced during this process. Recently, a method for producing hydrogen from aqueous solutions by corroding pure aluminum or aluminum alloys has attracted considerable attention²⁻⁹⁾. This method is quite attractive because it uses abundant water to produce hydrogen. The hydrogen content in water is $111\text{kg}\cdot\text{m}^{-3}$, which is higher than that in liquid hydrogen ($71\text{kg}\cdot\text{m}^{-3}$) and gasoline ($84\text{kg}\cdot\text{m}^{-3}$)¹⁰⁾. In addition, aluminum is one of the most abundant minerals in the earth and is currently used as a material for buildings, electrical appliances, transportation and packaging. Aluminum is also one of the most recycled resources. In a garbage bin for recycling, we can easily find several aluminum cans or cases. Aluminum can be used as a reactant to produce hydrogen in a fuel cell vehicle. This method is economical and environmental friendly.

The following reactions can occur when aluminum is immersed in an alkaline NaOH solution¹¹⁾.



Reaction (1) and (2) occur in series. The overall reaction (3) indicates that aluminum reacts with water and produces hydrogen. Interestingly, NaOH does not participate in the overall reaction. It acts as a catalyst to promote the corrosion and hydrolysis reaction. The fact that NaOH is not consumed in the reaction indicates that the environment is not changed during the corrosion reaction.

It is generally known that the corrosion process is strongly affected by environmental parameters, such as pH and temperature¹²⁻¹⁴⁾. Therefore, hydrogen generation induced by the corrosion of aluminum may also be affected by the environment. This study examined the effects of temperature and NaOH

concentration in solution on hydrogen generation from NaOH solutions through the corrosion of used aluminum cans.

2. EXPERIMENTAL

The side parts of 0.08mm thick aluminum beer cans were used for the experiments. The chemical composition of the parts analyzed was Mg : 1.4 wt%, Mn : 1.0wt%, Fe : 0.5wt%, Cu: 0.2wt% and Al: balance, according to inductively coupled plasma mass spectroscopy (ICP-MS, ICPM-8500). Pieces of aluminum foil were cleaned in an ultrasonic bath containing sulfuric acid to remove the paint on the surface.

Before the experiments for hydrogen generation, the overall corrosion behavior of the aluminum cans was analyzed using potentiodynamic polarization tests at a scan rate of $1\text{mV}\cdot\text{s}^{-1}$. Aluminum foil with an exposed area of 1cm^2 , platinum wire and a saturated calomel electrode (SCE) were used as the working, counter, and reference electrodes, respectively. The solution temperature and NaOH concentration were varied from 25 to 75°C and from 2 to 6 M, respectively. The corrosion potential and corrosion current in each environment was analyzed

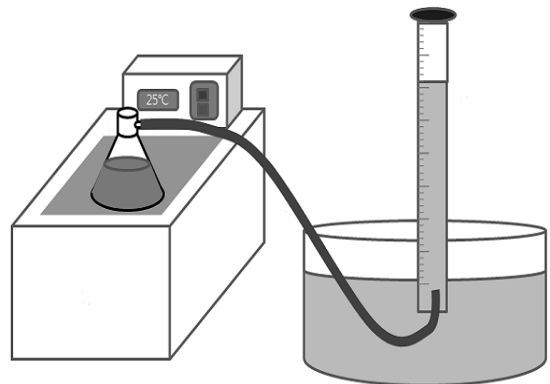
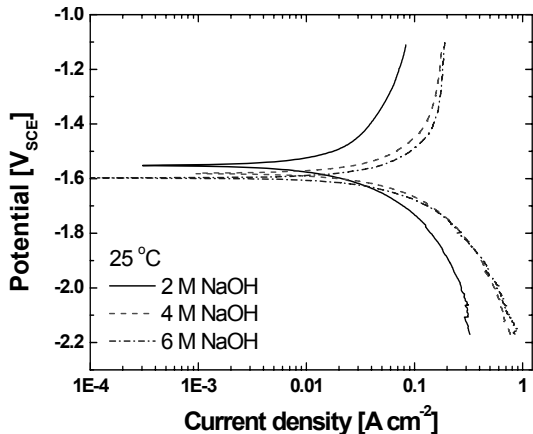
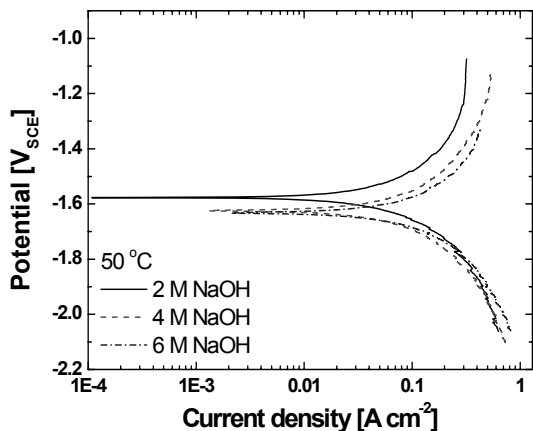


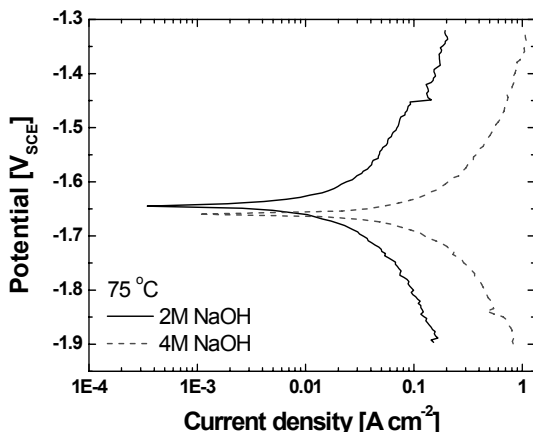
Fig. 1 Experimental setup for measuring the hydrogen volume generated from the NaOH solutions.



(a)

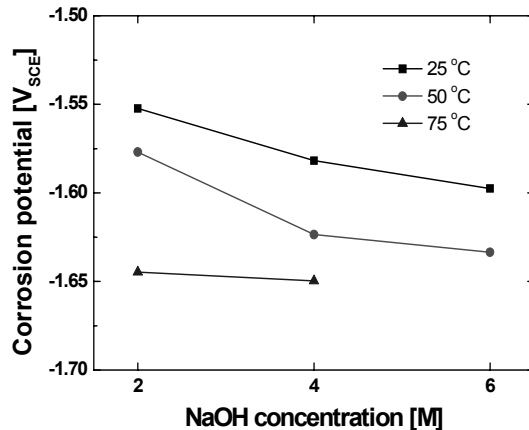


(b)

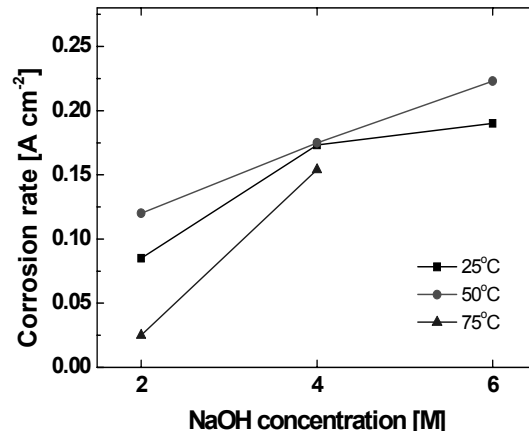


(c)

Fig. 2 Potentiodynamic polarization curves for the aluminum samples with increasing NaOH concentration in the NaOH solutions at (a) 25°C, (b) 50°C and (c) 75°C.



(a)



(b)

Fig. 3 Effect of NaOH concentration and solution temperature on (a) corrosion potential and (b) corrosion rate of the aluminum samples.

using the Tafel extrapolation method¹⁵⁾.

The kinetics of hydrogen generation from a 70 ml NaOH solution by the corrosion of a 0.2g aluminum piece was measured using the water displacement method, as shown in Fig. 1. The hydrogen generated from the flask moves to a cylinder filled with water and displaces the water.

3. RESULTS AND DISCUSSION

Fig. 2 shows the polarization curves for the

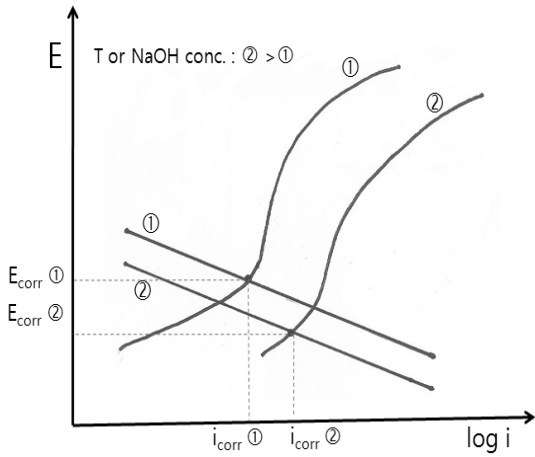


Fig. 4 Schematic diagram showing the effect of the NaOH concentration or solution temperature on the anodic and cathodic reaction curves and the resulting corrosion potential and rate.

samples taken from a used aluminum can. The results at 75°C and 6 M NaOH could not be obtained because the environment was so corrosive that the sample corroded immediately upon immersion. Under all experimental conditions, the aluminum samples did not exhibit passivation behavior. The corrosion potential (E_{corr}) and corrosion rate (i_{corr}) were analyzed from the polarization curves and are shown in Fig. 3. The corrosion potential of the aluminum sample decreased with increasing solution temperature and NaOH concentration. The corrosion rate of the aluminum sample increased with increasing solution temperature and NaOH concentration from 25 to 50°C and from 2 to 6 M, respectively. In contrast, the corrosion rate of the sample obtained at 75°C appeared to be smaller than that obtained at 25°C. It should be noted that the corrosion of the aluminum samples was so severe the surface area was reduced through corrosion at 75°C. This suggests that the exposed area of the sample may not be maintained at 1 cm², which is the initial input data for calculating the current density. A loss of area will produce a lower current

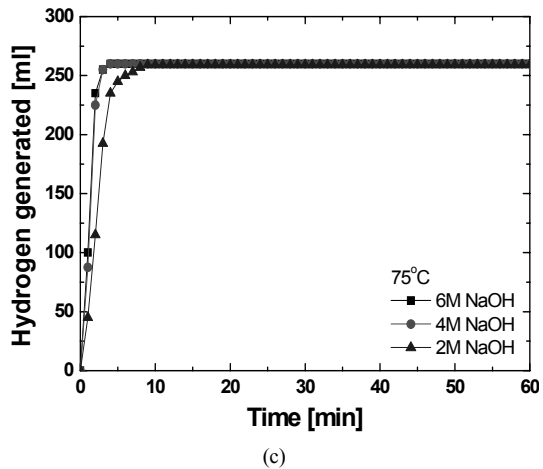
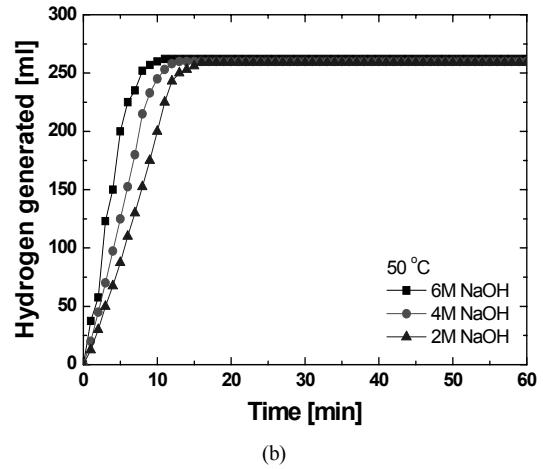
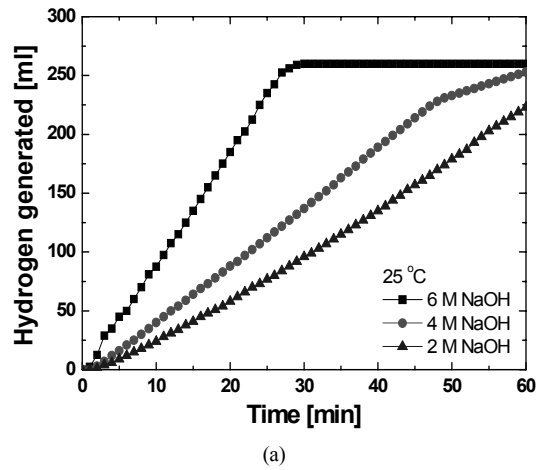


Fig. 5 Effect of NaOH concentration on the hydrogen generation kinetics of the aluminum samples from NaOH solutions at (a) 25°C, (b) 50°C and (c) 75°C.

even though the actual current density is higher. The fact that the corrosion of aluminum was most severe at 75°C can be also confirmed by the large fluctuation of current density shown in Fig. 2. Therefore, it can be concluded that the corrosion rate of the aluminum sample increased with increasing solution temperature and NaOH concentration. Fig. 4 shows a schematic diagram of the change in corrosion potential and corrosion current due to a change in the anodic and cathodic reaction curves with increasing solution temperature and NaOH concentration. The corrosion potential indicates the potential where oxidation rate of the metal and hydrogen evolution rate are identical¹⁵⁾. Therefore, a higher corrosion rate indicates a higher rate of hydrogen generation.

Fig. 5 shows the hydrogen generation kinetics as a function of the NaOH concentration and solution temperature. In the graphs, the slope of the line in the linear region of the curve indicates the rate of hydrogen generation from solutions by the corrosion of aluminum samples. Overall, the hydrogen generation rate increased with increasing NaOH concentration. Martinez et al also reported that the hydrogen generation was greater with increasing NaOH/Al ratio⁸⁾. According to reactions (1)~(3) shown in the introduction, NaOH acts as a catalyst for the hydrolysis reaction. Nevertheless, the rate of hydrogen generation was less affected by the NaOH concentration at higher solution temperatures. Furthermore, the rate of hydrogen generation rate also increased with increasing solution temperature, indicating that the hydrogen generation reaction through the hydrolysis of water and the corrosion of aluminum is a thermally activated process and is promoted at higher temperatures.

4. CONCLUSIONS

The corrosion potential of aluminum samples taken from used aluminum cans decreased and the corrosion rate increased with increasing NaOH concentration and solution temperature due to the loss of aluminum passivity. The rate of hydrogen generation increased with increasing corrosion rate. The rate of hydrogen generated from NaOH solutions increased with increasing NaOH concentration due to the catalytic action of NaOH in the hydrolysis process. However, at higher solution temperatures, the rate of hydrogen generation was less affected by the NaOH concentration compared to that at lower temperatures.

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