STUDY OF NICKEL ON STEEL CATHODE USED FOR WATER ELECTROLYSIS

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Abstract: Present paper presents a study of Ni/steel cathode, used in alkaline water electrolysis. Continuous cathodic electrolysis of a nickel coated steel electrode in a saturated NaOH aqueous solution were carried out to assess the electrode's durability. The electrode's potential under the same operation conditions was exponentialy dependent of the current density.

Key words: alkaline water electrolysis, cathode, hydrogen, potential, steel, nickel

Introduction

Hydrogen and oxygen evolution, by water electrolysis, is a process of great technological importance since it solves the problem of conversion of electrical energy, into hydrogen.

Research into water electrolysis has concentrated mainly on the development of catalysts lowering the voltages involved in the process.

The electrodes for most of all types of the electrochemical cells need to be stable, i.e., to be insoluble, for anodic and cathodic reactions; the anodic reactions are oxygen evolution and/or chlorine evolution, and the cathodic reaction is usually hydrogen evolution.

Therefore, steel substrate with nickel coating is the most popular configuration and is utilized as both of anode and cathode; Ni/steel electrodes are produced by nickel electroplating.

In this study, we focused on H_2 and O_2 evolution behaviors of the Ni/steel electrode prepared at different temperatures.

Ni/steel electrodes were prepared by electrodeposition:

$NiSO_4{\bullet}7H_2O$……….250-310 g/l
$NiCl_2{\bullet}6H_2O$………….50 –60 g/l
H_3BO_3…………………40-45 g/l

The bath's temperature was of 25 °C and current density of1 A/dm^2.

As a substrate steel was used. This is highly corrosion resistive at low temperatures.
Polarization curves were measured in the wide potential range where H_2 evolution occurred.

Constant current electrolysis

The catodic electrolysis of the electrode was carried out using a conventional three-electrode cell equipped with a platinum plate counter electrode and a calomel electrode as reference electrode. A 6 mol dm^{-3} NaOH solution was used in both the working and reference compartments, which were connected each other with a liquid junction. The potential of the electrode and the cell voltage between the working and counter electrodes were monitored during the electrolysis.

Commercially available electrochemical instrumentations such as a potentiostat/galvanostat and two digital multimeters were used for all experiments. Temperature was controlled within 293 K using a thermostat with circulating water.

Results and discussion

The electrode showed a low decomposition potential (980 mV) for H_2 evolution compared to the uncovered steel electrode, as shown in fig. 1.

Nickel on steel electrode is better than steel, on the electrocatalysis for H_2 evolution. However, for H_2 evolution the coating layer, nichel is a good catalyst for H_2 evolution. Hydrogen evolution potential and cell voltage is presented in fig. 1

Equation for curve that fits the experimental data is :

Model: Exponential
Equation: $j = A + B*\exp(R_0*V)$ (1)
$A = -22.0865 \pm 15.43039$
$B = 0.16226 \pm 0.08045$
$R_0 = 0.00522 \pm 0.00035$

The above equation (1) shows that current density j(mA/cmp), depends exponentially of electrode's potential(V). The constant A in equation(1) is not part of Butler -Volmer equation, and it might be the missing part in theory, that shows that "j" is a function of electrode's material (Z), and of concentration of the electrolyte.

The potential and the current density values are listed in the table below (tab.1). As can be seen the potential decreases as the electrolyte's temperature rises.

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Table 1 *Potentials and current densities for Ni/steel hydrogen electrode*

$J (mA/cm^2)$	10	20	30	40	50	60	70	80	90	100	150	200
$V_{20°C}$(mV)	1015	1045	1083	1120	1156	1184	1209	1240	1270	1296	1440	1540
V_{steel}(mV)	1010	1062	1104	1149	1182	1224	1258	1290	1320	1368	1540	1660
$V_{steel} – V_{Ni/steel}$	-5	17	21	29	26	40	49	50	50	72	100	120

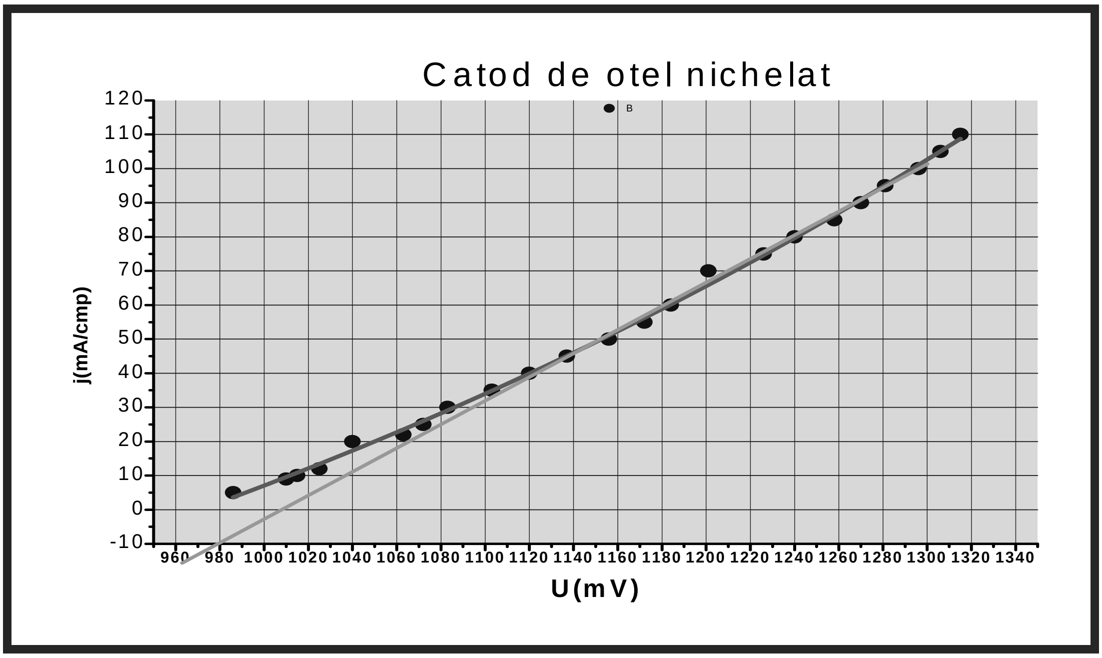

Fig. 1 *Current potential curve for Ni on steel*

Figure 1 shows the potential of an Ni on steel electrode vs. current density at 293 K.

The cathodic curve, corresponding to hydrogen evolution from basic aqueous solutions, show a decrease of 100 mV for the overvoltage, compared with steel electrode.

The current density of Ni/steel electrode, for hydrogen evolution, in a 6 mol dm^{-3} NaOH solution, increases as cathodic potential increase.

Therefore, the Ni/steel electrode is expected to posess a high durability in the alkaline solution.

For a cathode made of steel, that is currently used in commercial electrolyzers, the equation j(V) is:

Model: Exponential

Equation: $j = A + B \exp(R_0 * V)$ **(2)**

A = -104.31084 ± 12.77676

B = 20.48325 ± 5.29357

The potential values for steel are listed in the table below (tab.2). As one can see, these values are higher than those for steel with electrodeposited nickel, at the same current densities.

Table 2 *Potentials and current densities for steel electrode*

$J (mA/cm^2)$	10	20	30	40	50	60	70	80	90	100	150	200
V_{otel}(mV)	1010	1061	1104	1149	1182	1224	1258	1290	1320	1368	1540	1660

Conclusion

It has been shown that the overpotential for water electrolysis decreased with 100 mV.

A Ni/steel coated electrode shows little variation in hydrogen evolution potential, during constant current electrolysis, in a NaOH solution. The consumption rate of the coating is relatively small.

However, the electrode has a high durability for hydrogen evolution in the concentrated alkaline solution. A Ni/steel system is expected to apply for both of hydrogen evolution cathodes, and for oxiygen electrodes, used in alkaline water electrolysis, for hydrogen gas production.

Compared to steel electrodes, steel with electrodeposited nickel, decreases the potential for the same current density. The average of potential reduction, is between 8.6 % and 26.38 %, as the current density increases. The amount of hydrogen is higher, as "j" increases.

Table 3

j (mA/cmp)	10	20	30	40	50	60	70	80	90	100	150
V(mV)	8.6%	7.9%	9.3%	10.3.%	11.75%	13.48%	14.94%	15.89%	16.97%	19.15%	24.02%

That means that Ni/steel, used as hydrogen electrode, lowers the electric energy costs and increases both of electrolyzer's efficiency and the hydrogen production.

References

1. **Otogawa R., Morimitsu M., Matsunaga M.**
Electrochim. Acta, 44, 1509 (1998).

2. **Stănoi C.**
Energetica electrolizei apei
Ed. Universitas, Petroşani, 2007

3. **Kunihiro T., Morimitsu M., Matsunaga M.**
J. Appl. Electrochem, 30, 359 (2000)

4. *H. Journal of New Materials for Electrochemical Systems* 7, 323-327 (2004)

5. *Journal of New Materials for Electrochemical Systems* 7, 323-327 (2004)