

APPENDIX

Appendix Conferences and Publications

Conferences

Prakrong Plian-eke, Sunti Phewphong , Athorn Vora-ud , and T. Seetawan
 “Possibility of the Low Cost Sodium Chloride Battery”, The 3rd Southeast Asia
 Conference on Thermoelectrics; SACT 2014, Pakse Lao PDR, 22-23 December 2014
 (Poster presentation)

Publications

1. **P. Plian-eke**, S. Phewphong , A. Vora-ud , P. Chaiyachate and T. Seetawan
 “Possibility of the Low Cost Sodium Chloride Battery”, *Journal of Material Science
 and Applied Energy* 3(3) (2014) pp. 20-22

2. **Prakrong Plianaek**, Chokchai Kahattha, Penapa Muthitamongkol, Supasit
 Paengson, Sunti Peawpong and Tosawat Seetawan, “Electrochemical Cell of Pure Cu
 Anode/Al Cathode using NaCl+DI Water Electrolyte”, *International Journal of
 Recent Engineering Research and Development* (IJRERD) 02(9), (2017) pp. 24–29

3. **Prakrong Plianaek**, Chokchai Kahattha, Penapa Muthitamongkol, Supasit
 Paengson, Sunti Peawpong and Tosawat Seetawan, “Development of Al+Zn Alloy
 Cathode and Cu Anode for Electrolytic Cells”, *Results in Physics-Journal- Elsevier*,
IF=0.946....., (2017) pp.-.....

P. Pian-ek et al./Journal of Material Science and Applied Energy 3(3) (2014) 20-22

POSSIBILITY OF THE LOW COST SODIUM CHLORIDE BATTERY

P. Pian-ek^a, S. Phewphong^b, A. Vora-ud^{a, b}, P. Chaiyachate^a,
T. Seetawan^{a, b}*

^a*Program of Physics, Faculty of Science and Technology, Sakon Nakhon Rajabhat University, Sakon Nakhon, 47000, Thailand*

^b*Thermoelectrics Research Center, Research and Development Institution, Sakon Nakhon Rajabhat University, Sakon Nakhon, 47000, Thailand*

Received 22 December 2014; Revised 8 April 2015; Accepted 8 April 2015

ABSTRACT

We studied the possibility for development of a low cost sodium chloride (NaCl) battery. The NaCl ionic liquids were prepared by dissolving solid NaCl with 0.0, 1, 2, 3 and 4 mol/dm³ in 100 ml of distilled water at room temperature. Copper and zinc sheet of 1.5 × 8 cm² were used as cathode and anode electrodes to dip in the ionic liquid of NaCl, respectively, for open voltage (V_0) measurements. We found that a low cost NaCl battery makes significant measurements in distilled water with dissolved solid NaCl upto 4 mol/dm³. The open voltage and electrical current exponentially decreased with increasing dip time.

KEYWORDS: *possibility, low cost sodium chloride (NaCl) battery*

* Corresponding authors; e-mail: t_seetawan@snru.ac.th, Tel.&Fax +6642744319

INTRODUCTION

In recent years, electricity energy has become the primary energy resource of the world. Most of the primary energy resources are non-renewable and cause problems to the environment such as carbon dioxide (CO₂), carbon monoxide (CO), and other environmentally harmful emissions, etc. [1]. Therefore, electrical storage technology is very importance for electrical energy conservation, or a so-call electric battery. An electric battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell contains a positive terminal, or cathode, and a negative terminal, or anode. Electrolytes allow ions to move between the electrodes and terminals, which allows current to flow out of the battery to perform work. Now, many types of electrochemical cells have been produced, with varying chemical processes and designs, including galvanic cells, electrolytic cells, fuel cells, flow cells, voltaic piles and molten salt [2]. Currently, battery technology with high performance but low cost is not only important to electric vehicles, but also vital to using wind and solar energy efficiently [3]. On the other hand, sodium chloride (NaCl) batteries are one type of molten salt battery with a class of primary cell and secondary cell high-temperature electric battery that

uses molten salts as an electrolyte. In most cases, the salt used is a sodium salt and they are then often referred to as a liquid sodium battery. The sodium-based anode as an alternative to lithium has attracted extensive attention due to its natural abundance and low cost [3-7].

In this work, we are studying the possibility for development of the low cost sodium chloride battery and investigate for electrical storage.

MATERIALS AND METHODS

Low cost sodium chloride battery using NaCl ionic liquids were prepared by dissolving solid NaCl with 1, 2, 3 and 4 mol/dm³ in 100 ml of distilled water at room temperature as shown in Fig. 1 The cathode and anode electrodes used copper and zinc sheets with area size 1.5 × 8 cm² and 0.25 mm of thickness to dip in the ionic liquid of NaCl, respectively. The dipped depth of copper and zinc sheets was 5 cm. The dipped sheets in the ionic liquid of NaCl were measured for open voltage (V_0) and electrical current (I) real time by Picotest (Picotest, M3500A, 6 ½ digit multimeter) and software using resistance load at 1 Ω.

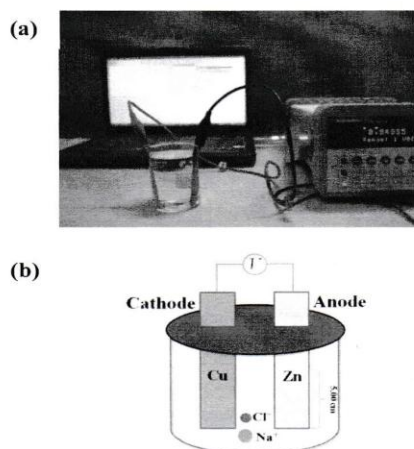


Fig. 1. (a) Low cost sodium chloride battery and (b) schematics

RESULTS AND DISCUSSION

Figure 2 shows the relationship of time and open circuit voltage of low cost sodium chloride battery with the NaCl ionic liquids dissolved as 1, 2, 3 and 4 mol/dm³ per 100 ml of distilled water at room temperature. The open circuit voltage exponentially decreased with increasing time for the same electrical current density as shown in Fig. 3. The maximums of open circuit voltage and electrical current density with NaCl of 0, 1, 2, 3 and 4 mol/dm³ were 2.43 μV, 2.62 mV, 3.94 mV, 8.23 mV and 8.68 mV and 0.666 μA, 0.37 mA, 0.582 mV, 0.593 mA and 0.574 mA, respectively. Calculations of electrical power are shown in Fig. 4.

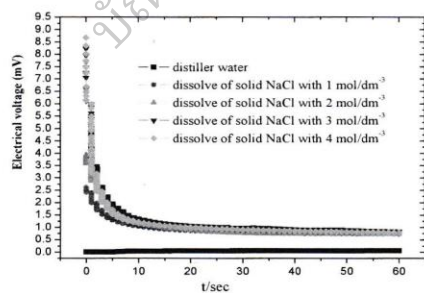


Fig. 2. The relationship of time and open circuit voltage of low cost sodium chloride battery

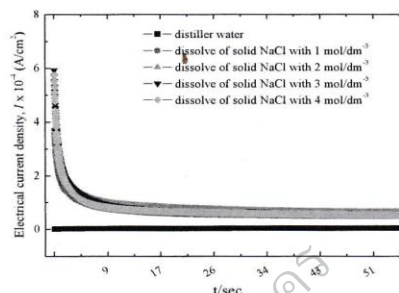


Fig. 3. The relationship of time and electrical current density of low cost sodium chloride battery

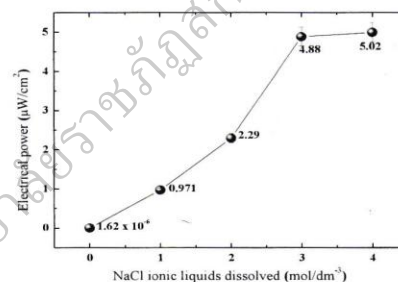


Fig. 4. The electrical power of low cost sodium chloride battery

Figure 4, the electrical power of low cost sodium chloride battery increased as the NaCl ionic liquids dissolved increased up to 4 mol/dm³. Figure 5 shows the relationship between electrical current density and open circuit voltage and electrical power of low cost sodium chloride battery with the NaCl ionic liquids dissolved at 4 mol/dm³. This is very interesting for further investigation on low cost sodium chloride battery development in the future.

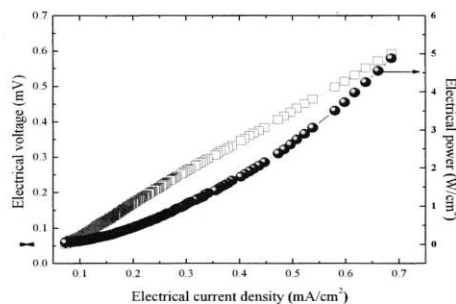


Fig. 5. The relationship between electrical current density and open circuit voltage and electrical

power of low cost sodium chloride battery with the NaCl ionic liquids dissolved as 4 mol/dm^{-3}

CONCLUSION

A low cost sodium chloride battery was studied for its feasibility by using NaCl ionic liquids at room temperature. The open circuit voltage exponentially decreased with increasing time and at the same electrical current density. The maximum electrical power of low cost sodium chloride battery used the NaCl ionic liquids dissolved as 4 mol/dm^{-3} and is very interesting for investigation of low cost sodium chloride battery development.

ACKNOWLEDGEMENTS

Financial supported by Thermoelectrics Research Center, Research and Development Institution, Sakon Nakhon Rajabhat University, Sakon Nakhon, Thailand.

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Electrochemical Cell of Pure Cu Anode/Al Cathode using NaCl+DI Water Electrolyte

**Prakrong Plianaek¹, Chokchai Kahattha¹, Penapa Muthitamongkol²,
 Supasit Paengson³, Sunti Peawpong³, Tosawat Seetawan^{1,3*}**

¹*Program of Physics, Faculty of Science and Technology, 680 Nittayo Rd., Mueang District, SakonNakhonRajabhat University, 47000 THAILAND*

²*National Metal and Materials Technology Center (MTEC) 114 Thailand Science Park (TSP), Phahonyothin Road, KhlongNueng, KhlongLuang, PathumThani 12120, THAILAND*

³*Battery Research Laboratory, Center of Excellence on Alternative Energy and Research and Development Institute, 680 Nittayo Rd., Mueang District, SakonNakhonRajabhat University, 47000 THAILAND*

Abstract: Primary Cu anode/Al cathode cell (non-Lead; Pb) was expected to promote importance for environmentally electrolytic cells and electrolyzed an aqueous solution of Sodium Chloride 2 moldm⁻³+dionized (DI) water (non-Sulfuric acid; H₂SO₄). The Cu anode and Al cathode metals were prepared by hotpress method from pure metal powders. The crystal structure, microstructure, density, microhardness, resistance, potential of electrochemical cells and discharging are investigated for enhanced electrolytic cells performance. The electrochemical cell Cu anode/Al cathode was discharged by the electrical power increase with increasing time and can be good discharging in NaCl+DI water by nonspontaneous redox reaction.

Keywords: Cu/Al primary cells, electrolytic cells, galvanic cells, cathode and anode metals, electrolysis

1. Introduction

The basic electrochemical unit being referred to is the "cell". A battery consists of one or more of these cells, connected in series or parallel, or both, depending on the desired output voltage and capacity [1]. Batteries are an important source of energy storage, most of which are used as backup power sources, to supply electric power to electrical equipment. In the modern, electrical energy is normally converted from mechanical energy, solar energy, and chemical energy etc. A battery is a device that converts chemical energy to electrical energy. The first battery was developed by Alessandro Volta in the year of 1800 [2]. In the year 1836, John Frederic Daniell a British chemist developed the Daniell cell as an improved version of the voltaic cell. From that time until today, the battery has been the most popular source of electricity in many daily life applications. In our daily life, we generally use two types of battery, one of them is which can be used once before it gets totally discharged. Another type of battery is rechargeable which means it can be used multiple times by recharging it externally. The former is called primary battery and later is called secondary battery [3]. Batteries can be found in different sizes and may be as small as a shirt button or may be so big in size that a whole room will be required to install a battery bank with this variation of sizes. The battery is used anywhere from small wrist watches to a large ship [3]. There are two types of batteries: primary and secondary such as primary include Zinc-Carbon, Alkaline and Lithium-Iron and secondary batteries include Lead acid, Nickel-Cadmium, Nickel-Melon-Hydrate and Lithium-Ion [3]. But most commonly used lead acid battery because of its long life and high discharge capacity [4]. Lead-Acid battery consists of anode, lead powder, peroxide, PbO₂, cathode, pure lead or porous lead, and electrolyte solution are sulfuric acid (H₂SO₄). Lead-Acid Battery is highly toxic from lead to human and environment. Lead is the most commonly encountered toxic metal pollutant in the environment as a result of its current and previous use in, for example, batteries, gasoline, plumbing, and paints. Considerable effort is, therefore, being directed toward solving this environmental problem. In this regard, the toxicological properties of lead are associated with its interactions with proteins and, in particular, 5-aminolevulinic acid dehydratase (ALAD). The influence of lead on the latter enzyme is particularly harmful because ALAD is responsible for the asymmetric dimerization of 5-aminolevulinic acid (ALA) to porphobilinogen, a monopyrrole which is essential for synthesis [5].

In this paper, we present of non Lead and non sulfuric acid used only pure Cu and Al and investigates the discharging of electrochemical cell. This work has objectives: to prepare Cu anode and Al cathode by hot press method, to measure characteristic, crystal structure, microstructure, resistance and to discharge of Cu anode and Al cathode and to study possibility of electrochemical cells of Cu anode and Al cathode in NaCl+DI water.

2. Materials and Method

The Cu cylinder anode (2.0 cm diameter, 1 cm thickness) was prepared by hotpress method at 900 °C, 1.0 MPa for 1 h in Ar gas from grinded Cu metal powders for 3 h in air. The anode of 0.1 cm thickness was cut and polished by saw low speed and polisher using sandpaper No.100 (30 min) and No.2400 (30 min). The Al cylinder cathode (2.0 cm diameter, 1 cm thickness) was prepared by hotpress method (vacuum heated pressing furnace; OTF-1200X-VHP-4) at 670 °C, 1.0 MPa for 1 h in Ar gas from grinded Al metal powders for 3 h in air. The cathode of 0.2 cm thickness was cut and polished by saw low speed (Isomet Low Speed Saw) and polisher (Metaseve 3000) using sandpaper No.100 (30 min) and No.2400 (30 min). The Cu anode and Al cathode were analyzed crystal structure by X-ray diffractometer (XRD; Shimadzu 6100), before and after drift in NaCl solution 2mol dm^{-3} for 1 h (annealing at 60°C for 1 h) observed microstructure by scanning electron microscope (SEM; SU8230, 5000X-10000X), density measured by Density Kit (MS204), Vicker hardness measured by micro hardness tester (HVM-2T), resistance measured by Picotest(M3500A, 6½ digit multimeter) and electrical chemistry properties measured by cyclic voltammetry technique(balance weight of and Cu anode and Al cathode). The anode Cu and cathode Al were connected Potentiostat-446 by anode Cu connected working electrode and Al connected reference electrode and counter electrode Al to show results on computer monitor. The program in Echem v2.2.2 was run by cyclic voltammetry technique using initial of - 300 mV, final of - 300 mV, upper of 300 mV, lower - 300 mV, rate of 50 mV s^{-1} , Number of Cycle 100 for 24s and get data for plot voltage applied with current graph as shown in Fig. 1. The electrochemical cell of Cu/Al was discharged by dip in NaCl+DI water for 40 min ($R_{\text{load}} = 1\ \Omega$) and then measured voltage and current by Picotest, model M3500A, 6½ digit multimeter, M35XX Excel Add-In program to evaluate the electrical power.

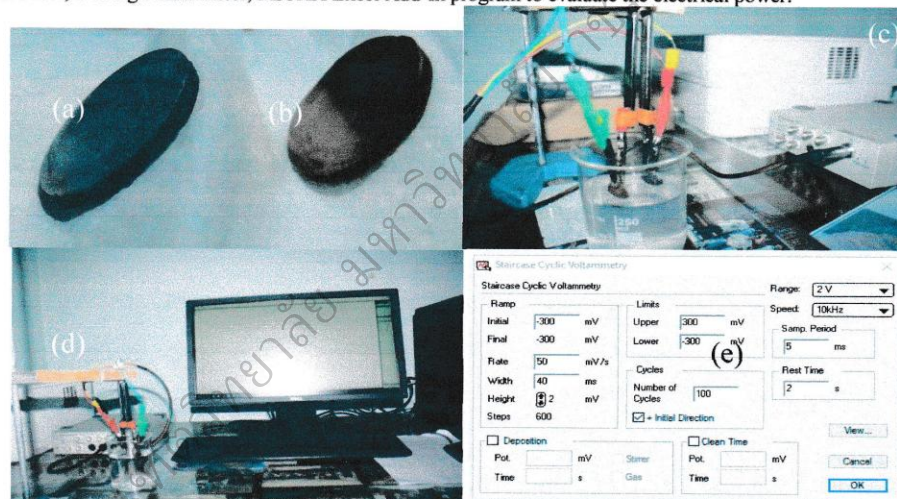


Figure 1: Cyclic voltammetry technique (a) Cu anode, (b) Al cathode, (c) dipping in NaCl+DI water, (d) connecting computer and (e) Staircase cyclic voltammetry

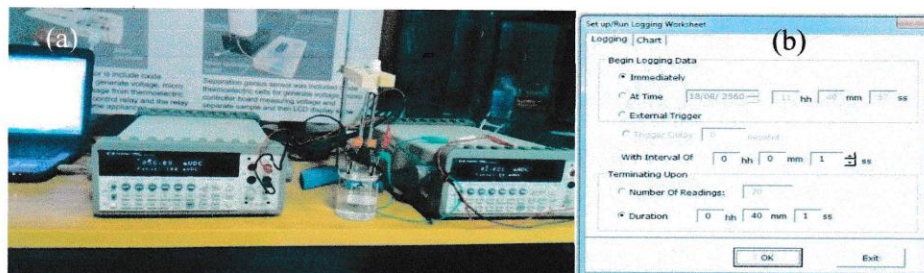


Figure 2: Discharging measurement (a) measured voltage and current of Cu anode/Al cathode dip in NaCl+DI water for 40 min by Picotest digital multimeter (b) program setup/run logging worksheet by M35XX Excel Add-In program to evaluate the electrical power

3. Results and Discussion

The crystal structure of Cu anode was obtained face center cubic structure, lattice parameters $a = b = c = 3.6193 \pm 0.0657 \text{ \AA}$, the plane composed of (111), (200) and (220) correspond with PDF#00-004-0836, are show in Fig. 3.

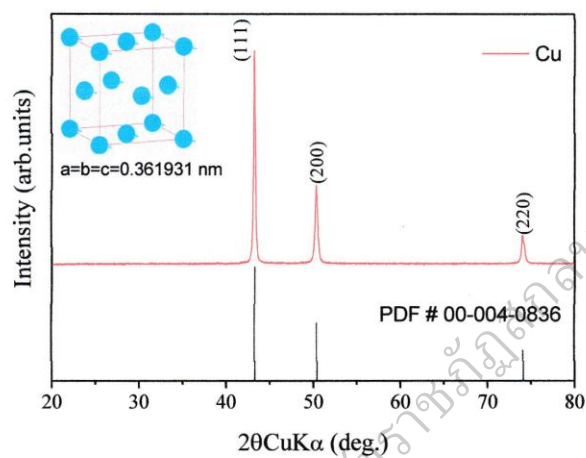


Figure 3: X-ray diffraction patterns of Cu anode together with PDF#00-004-0836

The crystal structure of Al cathode was obtained cubic structure, lattice parameters $a = b = c = 4.0623 \pm 0.0072 \text{ \AA}$, the plane composed of (111), (200), (220) and (311) corresponded with PDF#00-004-0787, are show in Fig. 4.

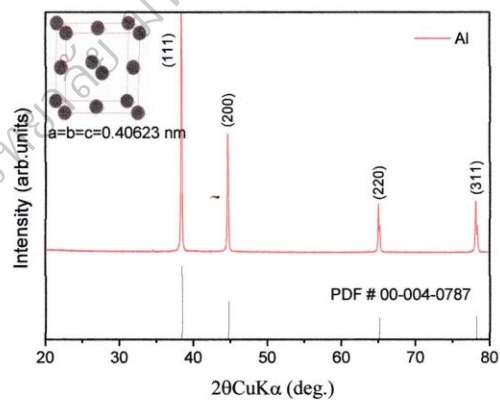


Figure 4: X-ray diffraction patterns of Al cathode

Figure 3 and 4 were confirmed single phase of Cu anode and Al cathode indicate that the successfully preparation of high purity of metal by hotpress method.

The morphology and microstructure of prepared pure Cu and Al metals were showed flash surface, only Cu as shown in Fig. 5(a) and (b) and Al metals (non impurity) as shown in Fig. 5 (c) and (d), which correspond with XRD results.

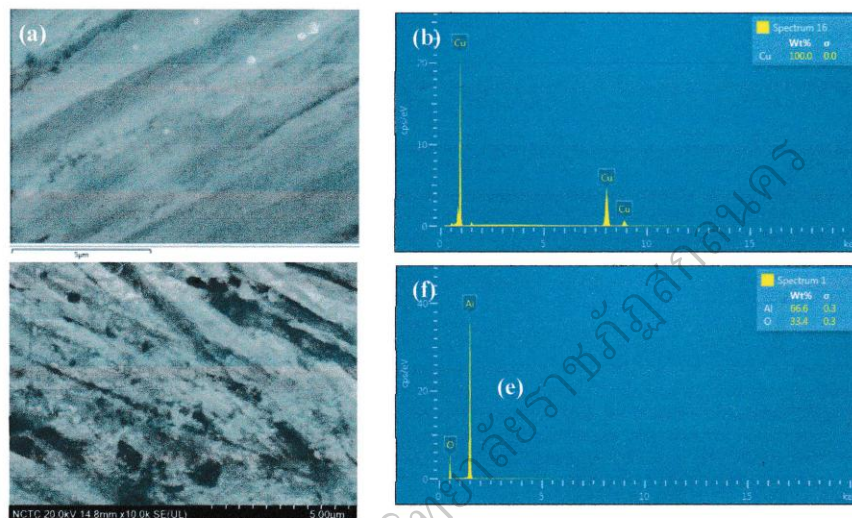


Figure 5: The morphology and chemical composition of pure Cu and Al before dip in NaCl+ DI water solution
 (a) SEM image of Cu, (b) EDS of Cu, SEM image of Al and (c) EDS of Al

The Cu anode and Al cathode were dipped in NaCl+DI water for 40 min show relationship between applied potentials with current, is seem in Fig.6. The relationship was corresponded to the further reduction of the hydrogen peroxide as following the equations:

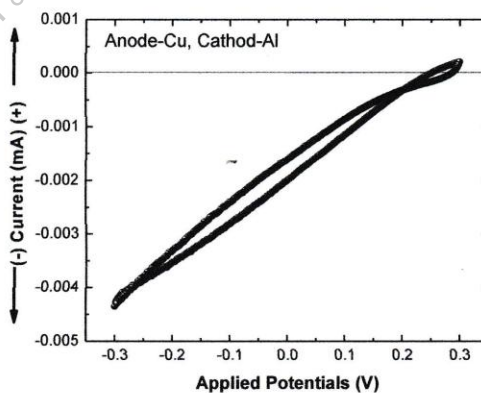
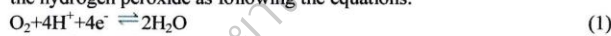


Figure 6: Polarogramsvolammatic behavior of Cu anode and Al cathode for 100 Cyclic voltammetry technique

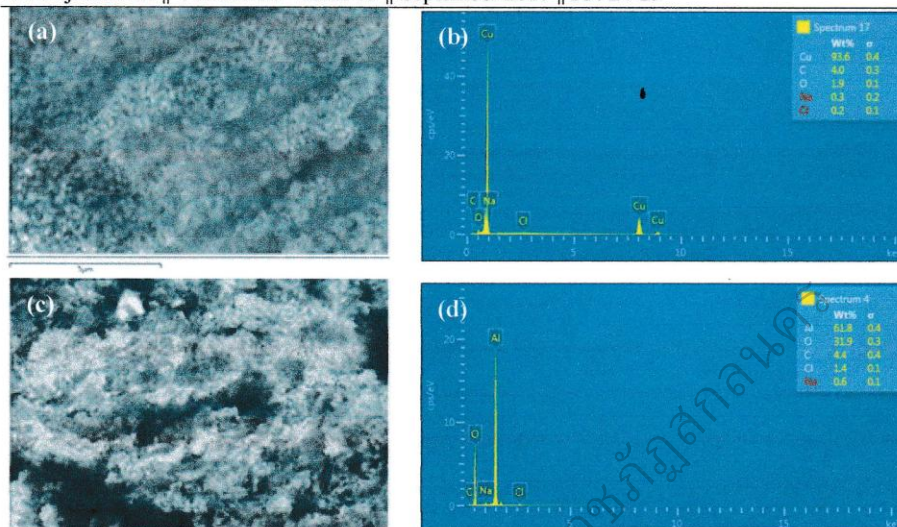


Figure 7: The morphology and chemical composition of pure Cu and Al after dip in NaCl+ DI water solution (a) SEM image of Cu, (b) EDS of Cu, SEM image of Al and (e) EDS of Al

The physical properties of Cu anode and Al cathode were obtained density, microhardness and resistance, are shown in Table 1.

Table 1: Physical properties of Cu anode and Al cathode before and after dip in NaCl+DI water solution

Sample	Density (g m^{-3})	Microhardness (MPa)	Resistance (Ω)
Cu	7.29	363	0.49
Al	2.02	151	0.63

The mass of Cu anode and Al cathode were dipped in NaCl+DI water, as shown in Table 2.

Table 2: Mass of pure Cu and Al before and after dip in NaCl+DI water solution

Sample	Before(g) dip	After(g) dip	difference (g)
Cu	2.6019	2.6105	0.0086
Al	1.2042	1.1636	-0.0406

The discharge of electrochemical cell Cu anode/Al cathode was obtained relationship of time with electrical power, is seen in Fig. 8. The electrical power was increased with increasing time indicate that the Cu anode/Al cathode can be good discharging of in NaCl+DI water nonspontaneous redox reaction.

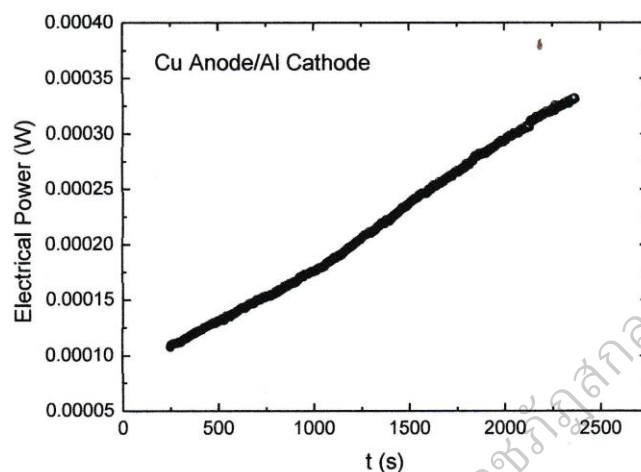


Figure 8: Relationship time with electric power after dip Cu anode and Al Cathode in aqueous NaCl

4. Conclusion

We have investigated Cu anode and Al cathode mechanical properties for fabricate the electrochemical cell by using NaCl+DI water. The electrochemical cell can be generated electrical power in order mW for 40 min in NaCl solution which possibility for base electrolytic sells.

5. Acknowledgements

This work is financially supported by National Research Council of Thailand and Center of Technology Transfer for supported voltammetric measurement.

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