

Experimental investigation of an electrochemical cell from the power generation view point

A. Bahlake^{*}, M. Rezaei Ansari and S. Khajeh Talkhonchek

Chemical Engineering Department, Quchan Institute of Engineering and Technology, Quchan, Iran

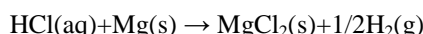
ABSTRACT

In this research we are introducing a new cell composed of electrodes of Graphite –Mg and electrolyte of HCl-KMnO₄. Along this topic we are trying to discuss the effect of concentration changes of the electrolyte and temperature of cell as well as surface area effect of each one of the electrodes. To estimate the usefulness duration of the cell all of the reactions have been kinetically analyzed. After making some changes in the structure of the cell and differing the electrode type and replacing some metals like Cu and Zn instead of Mg, the produced powers have been compared. From the experimental observations and theoretical analyses, it is found out that using other metals instead of Mg decreases the produced power. Finally this kind of cell is compared with fuel cell.

Keywords: Graphite- Mg cell, Fuel cell, HCl electrolyte.

INTRODUCTION

The recent advances in carbonaceous and alternative anodes, in medium and high-voltage cathodes and in liquid and polymer electrolytes discussed earlier[1]. Various forms of graphite are most common as the anode active material in today's cells. Natural graphite (NG) will be favored over the synthetics for use in batteries for transportation applications because of lower cost[2]. The Mg electrode used in this cell is Mg ribbon in the shape of spring (twisted). Here we can consider the reaction of Mg oxidation with HCl(aq) as the main reaction.



On the other side, the natural Graphite electrode plays the role of Ion exchanger and KMnO₄ decreases on the surface. Therefore, KMnO₄ is the main reactant and we shouldn't consider it as the catalyzer, since no reaction occur on the negative pole without KMnO₄.

MATERIALS AND METHODS

Effect of Graphite electrode Surface Changes: The electrochemical behaviour of a graphite electrode already is investigated[3] and the properties of natural Brazilian graphite have been investigated in different cells too[4]. In this experiment we analyzed the changes of produced voltage and current and finally the produced power of the cell by changing the surface of Graphite electrode was used in the electrolyte.

Other parameters related to the system and its surrounding are fixed. The temperature of the laboratory is 25⁰ C. In this case, the surface area of Mg electrode and the acid concentration are kept fixed at 4800 mm² and 0.6 M, respectively. Also the electrolyte solution contains 2 gr of KMnO₄ per 100 cm³. It has been found out that the way power and produced current of the cell change is exactly opposite of produced voltage change. It means by increasing the surface area of Graphite electrode the produced current raises, but the amount of produced voltage decreases. Although, the final amount of power which is obtained by multiplying voltage and amperage increases.

When we increase the surface area of Graphite electrode, the voltage decreases and amperage increases in a way that the sensitivity of the cell to the changes of surface area can not be so great. If we increase the amperage the power is weakened by voltage reduction and as a reason the rate of power enhancement is decreased.

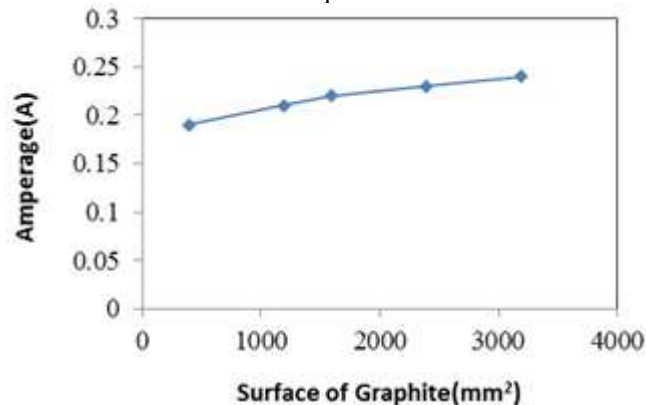


Figure 1. produced current changes vs. Graphite surface

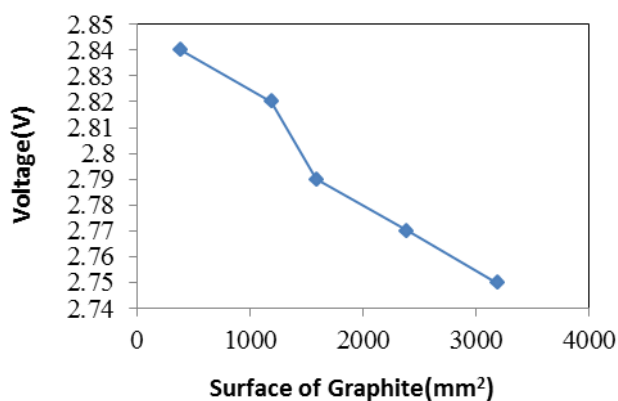


Figure 2. produced voltage changes vs. surface

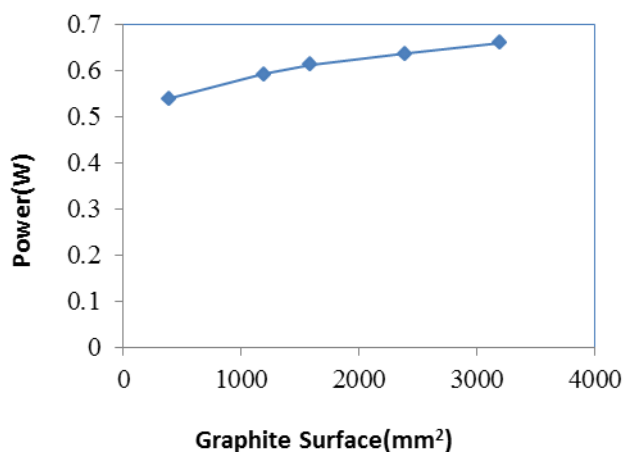


Figure 3. produced power changes vs. Graphite surface

Thermal Treatments: The thermal activation of graphite felt was investigated by Sun and Skyllas-Kazacos [5] at a range of temperatures and treatment times so as to enhance the electrochemical performance of this material for use in the similar cells. But in this work we have analysed the whole system. Since the increase in the temperature of the cell enhances the reaction rate in the cell and on the other hand, Ion exchange rate on the Graphite surface increases,

it is expected that temperature increment will raise the produced power of the cell. According to the performed experiment in the cell with concentration of 0.3 M containing 2 gr of MnO_4 per 100 cm^3 in the temperature of 25°C and the results are shown in figures 1-3. Because of exothermic reactions in the cell, the inner temperature is always higher than surrounding. Therefore we have started the power measurements in emperatures higher than the cell's surrounding. This change in temperature of the cell beginning from 27°C to the boiling point of the electrolyte (83°C) is made by a heater.

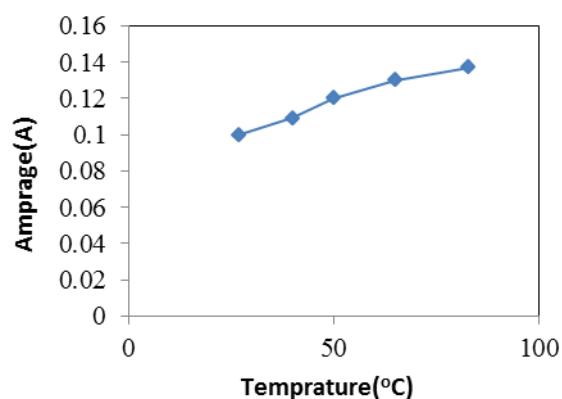


Figure 4. produced current vs. electrolyte temperature

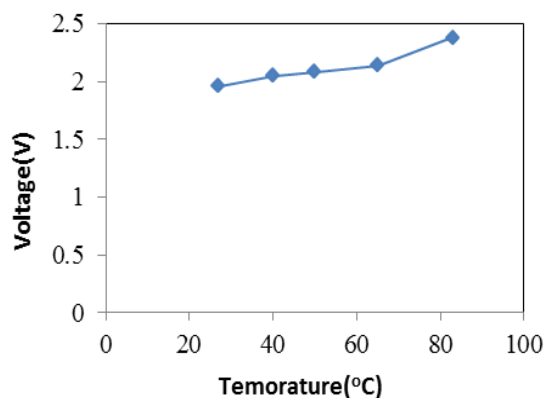


Figure 5. produced voltage vs. electrolyte temp.

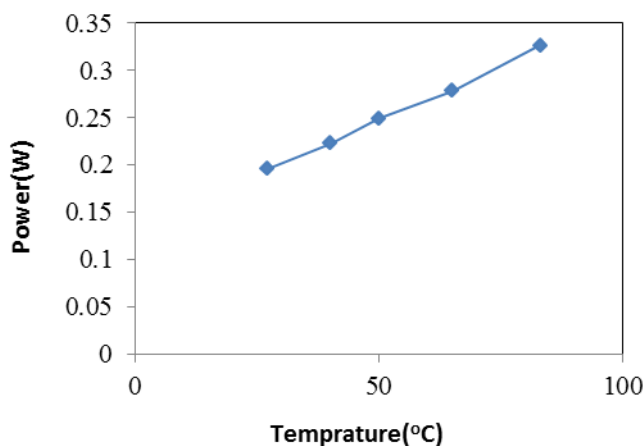


Figure 6. produced current vs. electrolyte temperature

As we expected increasing the temperature raises the power of the cell. Although the increase in the cell temperature raises the produced power, it decreases the life of the cell because the reaction rate of the Mg electrode enhances. So, depending on the conditions the optimum temperature of the cell should be adapted. To obtain the optimum value, it is better to consider the kinetic studies of the reactions and thermal treatments on the power at the same time. Also we should consider another factor in this examination and that is the cost of consumed energy to heat the cell. If we have to heat the cell depending on various conditions, we suggest to isolate the wall of the cell before heating. This will be greatly helpful since, as previously mentioned because of exothermic reactions, the temperature of the system is always higher than its surrounding. Thermal treatments are noticeable in figures 4-6.

Effect of changing Mg Electrode Surface: experiments which have been done with the surface areas of 200, 280, 360, and 720 mm^2 of mg electrode in contact with electrolyte point out an important issue. If other factors are kept constant, the sensitivity of the cell to the changes of the mg surface area will be so slight that it can be neglected. For example, when the surface of graphite electrode is 2190 mm^2 and the concentration of the electrolyte solution is 0.6 M containing 2 gr KMnO_4 per 100 cm^3 in the temperature of 25°C the produced power of the cell for all of four surfaces mentioned above remain fixed (0.65 W, 2.96V, 0.22 A).

Also examination of KMnO_4 effect on the cell shows that the cell has a very slight sensitivity to the amount of this material. Although, little amounts of KMnO_4 , about 0.05 gr per 100 cm^3 of electrolyte, is essential for the reactions in the cell, its increase doesn't have any effect on the produced power. On the other hand, experimental observations show that this material will settle at the bottom of the electrolyte and cause the gradual reduction of cell power in the long duration of time if its concentration is more than 2 gr per 100 cm^3 .

Examination of Electrolyte Concentration: Our examinations show that the increase in the concentration of HCl will increase the produced power of the cell. In the results shown in figure 7, the surface area of Mg electrode and Graphite electrode have been kept fixed at 460 mm^2 and 2000 mm^2 , respectively. Results in the temperature of 25°C has been drawn.

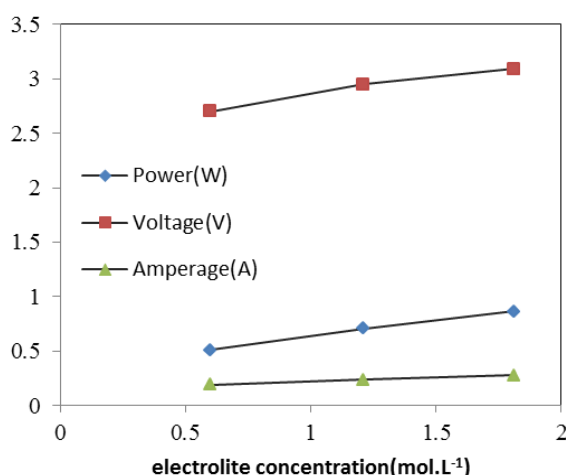


Figure 7. produced current,voltage and power of the cell vs.electrolyte concentration

Replacement of another Positive Electrode : In one experiment, Zn with the surface of 20.8 cm^2 and in other experiment, Cu with the same surface were used instead of Mg electrode. In the fixed concentration of 0.4 M of the electrolyte containing 2 gr MnO_4 in 100 cm^3 of the electrolyte, the following results have been obtained and shown.

Table 1. experimental data from the replacing Mg with other metals

Type of electrode metal	Voltage(V)	Current(A)	Power(W)
Mg	2.4	0.17	0.408
Zn	1.7	0.05	0.085
Cu	0.26	0.011	0.003

It is obvious that if we relinquish the economically issues, using Mg as the electrode, because of its power production, is the best choice.

Kinetic examination of Mg-Acid Reaction in the cell: The kinetics of Li-ion intercalation/alloying into Cu_6Sn_5 electrode was determined by potentiostatic intermittent titration technique (PITT) and electrochemical impedance spectroscopy (EIS) method earlier[6]. In this investigation the produced power of the cell will fall down over the time and by oxidation of Mg electrode. Therefore, examining the rate of decomposition of Mg to measure the life of the cell seems useful. In this experimental study, the effect of HCl concentration changes have been analyzed. Since the duration of the reaction and the decomposition of the whole Mg is long, we have measured the half time of the Mg-Acid reaction. From another point of view this analyzing helps us to estimate the rate of formation of the H_2 .

We have shown the data coming from experiment in the following table (table 2). Hydrogen will be released during the decomposition of Mg. Considering the fact that Hydrogen can't be found single in the nature, this cell can be used as the source of the Hydrogen.

Table 2. reaction rate of Mg in variety electrolyte concentration

Moles of Mg in electrode	Electrolyte concentration(M)	Half time of reaction(min)	Decomposition rate of Mg(molee/min)
0.004	0.36	40	0.00005
0.004	0.6	22	0.00009
0.004	0.96	9	0.00022

RESULTS AND DISCUSSION

This cell can be compared with Fuel cell from the viewpoint of power production. It should be said that life of the cell is shorter than the fuel cells, but it is easy to make. Some kinds of Fuel cells like Methanol Fuel cell need a chemical reactor to provide Hydrogen needed by the Fuel cell. This will increase the equipment and costs of the Fuel cell. Maybe we will be able to use the Graphite - Mg cell instead of this reactor. In this case, in addition to supply of Hydrogen for the Fuel cell, produced water from the Fuel cell can be used as the solvent of electrolyte solution. The big advantage of replacement of this cell instead of reactor is this cell's ability in producing power in addition to Hydrogen production. Therefore if this cell is set parallel to the Fuel cell it is expected that the power of overall system increases greatly (figure 8). However, this work has its own difficulties which should be studied. Studies to increase the produced Hydrogen from the cell are important. Because the Fuel cell needs adequate Hydrogen, we can't consider the produced Hydrogen of this cell as its only source. Although using of series of these cells could be practical the economical studies should be done.

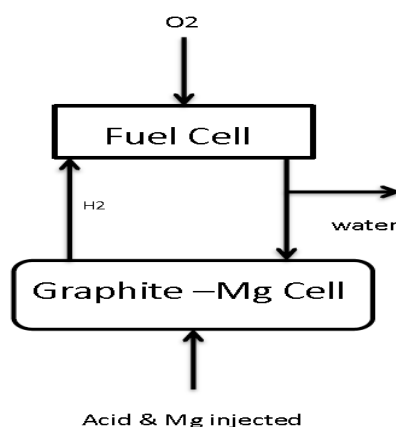


Figure 8. Fuel cell and graphite –Mg cell set in parallel

An important result that obtained from these experiments is the short life of Graphite – Mg cells. On the other hand, helpful factors to increase the life of the cell will decrease the cell power production. So an optimum life time of the cell should be adopted. Of course another solution to this problem which seems more reasonable is to store the produced power in an electrical capacitor and using it if it is necessary. This cell in an experimental scale has been set on the car with an electrical engine. The power needed to run this engine by the single cell has been analyzed. It was observed that car which weighs 0.3 Kg runs with the speed of 0.3 meter per second. Noticing that the amount of Mg electrode has no effect on amount of produced power, theory of creating tiny cells can be promoted. It is better to make the cell with the internal surface covered with Graphite to increase the surface of Ion exchanges and raise the produced power. The spherical shape offers the best volume to area ratio [7] and we can use this shape to have small cells.

CONCLUSION

Graphite –Mg cell with electrolyte of HCl –KMnO₄ was introduced and Effective experimental factors on the cell were analyzed. According to the experimental results, with changing graphite surface area, cell temperature, type of electrode and concentration of electrolyte, the produced power could be changed. However, changing surface area of Mg electord does not have a significant effect on produced power and the change of power can be neglected. According to different operating conditions and economical restrictions, arbitrary power can be produced With changing effective factors found in experiment. Although, the mimimum amount of KMnO₄ is necessary for beginning of reactions, extra concentration of it does not change the produced power. This cell produces hydrogen as a co-product. Although, life time of this cell is less than fuel cell, it can be found as a source of hydrogen.

REFERENCES

- [1] Bruno S, *Electrochimica Acta*, **2000**, 45, 2461
- [2] K A. Striebel, A. Sierra, J. Shim, CW. Wang and AM. Sastry, *Journal of Power Sources*, **2004**, 134, 241
- [3] W. Congxiao, N.Hiroyoshi, K.Hiroshi, Y.Masaki, Y.Hideya, *Journal of Power Sources*, **1998**, 74, 142
- [4] V.Manev, I.Naidenov, B.Puresheva, P.Zlatilova, G.Pistoya, *Journal of Power Sources*, **1995**, 55, 211
- [5] B.Sun, M.Skylas-kazacos, *Electrochimica Acta*, **1992**, 37, 1253
- [6] Z.Jing-jun, H.Ping, X.Yong-yao, *Journal of Electroanalytical Chemistry*, **2008**, 624, 161

[7] H.Vasilchina, A. Aleksandrova, A.Momchilov, B.Banov, L.Predoana, A.Barau, M.Zaharesku, Spherical graphite as anode in high efficient lithium batteries, Proceedings of the international workshop “Portable and emergency sources – from material to systems” , **2005**.