Development of the Electrical Conductivity of PEM Fuel Cell

Raid K. Salim
Technical college- Baghdad, Foundation of Technical Education /Baghdad
Email:uot_magaz@yahoo.com
Nirvana A. A bud
Technical college- Baghdad, Foundation of Technical Education /Baghdad

Received on: 2/11/2011& Accepted on: 1/3/2012

ABSTRACT

This research is aimed to develop the electrical conductivity of PEM fuel cell through the using of a series of graphite plates. The effect of width, thickness of plates in addition to the current and gas flow rate (hydrogen and oxygen) were studied. Results showed that electrical conductivity can be reached to the optimum value (850S\cm), when cell thickness, current and gas flow rate are 0.3cm, 8.13A and 0.6 L\min respectively.

Keywords: electrical conductivity, PEM fuel cell, graphite plates

تطوير التوصيلية الكهربائية لخلايا الوقود نوع PEM

الخلاصة

يهدف هذا البحث الى تطوير التوصيلية الكهربائية لخلايا الوقود نوع PEM من خـلال اسـتخدام مجموعة من الالواح الكرافيتية. تم في هذا البحث دراسة تأثير كل من عرض و سمك الصفائح اضافة الى التيار ومعدل جريان غازي الهيدروجين والاوكسجين.

بينت النتائج انه يمكن الوصول الى افضل قيمة للتوصيلية الكهربائية (850S\cm) عنـدما يكـون سمك لوح الكرافيت بالاضافة الى التيار المستخدم و معدل جريـان الغـاز 0.3cm , 8.13A ,0.6 L\min على التوالي.

INTRODUCTION

The polymer electrolyte membrane (PEM) fuel cell is one of the most promising power sources for stationary and transportation in the future due to many attractive features. These features include high efficiency, high power density, relatively low operation temperatures, convenient fuel supply and long lift time. However, the high cost of PEM fuel cells have became one of the major barriers to fuel cell commercialization. The automotive industry has invested considerable effort in the commercialization of PEM fuel cell for cars, which are expected to eventually compete with internal combustion engine vehicles [1].

https://doi.org/10.30684/etj.2012.57243
2412-0758/University of Technology-Iraq, Baghdad, Iraq

The ideal performance of a fuel cell depends on the electrochemical reactions that occur with different fuels and oxygen. Fuel cells are classified primarily by the kind of electrolyte they employ. This determines the kind of chemical reactions that take place in the cell, the kind of catalyst required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development each with its own advantages and limitations: polymer electrolyte membrane (PEM) fuel cells, direct methanol fuel cells, alkaline fuel cell, phosphoric acid fuel cells, molten carbonate fuel cells, solid oxide fuel cells and regenerative fuel cells [2].

Polymer electrolyte membrane fuel cells operate at relatively low temperatures, around 80°C (176°F). One type of PEM that meets most of these requirements is Nafion. The Nafion membrane belongs to a class of poly-perfluoro-sufonic acids which consists of a hydrophobic tetra fluoro ethylene backbone with pendant side chains of perfluoronated vinyl-ethers terminated by sulfonic acid groups [3].

The most popular bipolar plates used in PEM fuel cells are graphite plates. Graphite bipolar plates possess were consider a good electrical conductivity, excellent corrosion resistance, and lower density than metal plates. The problems of graphite plates are their brittleness and pours structure as well as high cost. The high cost of graphite plates is associated with the machining of gas flow channels on the surface of plates and post processing such as resin impregnation to make the plate impermeable to the fuel and oxygen due to the brittleness of graphite,
Graphite plates should be a few millimeters thick in order to maintain sufficient mechanical strength for machining flow channels and stacking assembly [4].

Kuan has developed a novel composite bipolar plate for a polymer electrolyte fuel cell by a bulk molding component (BMC) process. The electrical resistance of the composites material decreases from 20,000 to 5.8 Ω\cm when the graphite content increases from 60 to 80 wt%. Polymer mixed with higher loadings of graphite can lead to the higher conductivity of composites [5].

SUGGESTIONS

For future researches, a several suggestions can be used to develop the electrical conductivity of PEM fuel cell. This may be summarized in:

1. Comparison study between different plates like between aluminum and copper.
2. Fuel cells consist of many series of plates at different thicknesses.

EXPERIMENTAL WORK

In this work fuel and electrolysis cells were manufactured as following:

1. <u>Fuel cell</u>

Figure (1) shows a schematic representation of the fuel cell, in which two graphite electrodes surrounded the polymer electrolyte membrane. One electrode is negative (anode), while the second is positive and it is called the (cathode). Also figure (1) shows the reactant\product gases and the ions conduction flow direction through the cell. Gaseous fuel (hydrogen) is fed continuously to the anode (-ve electrode) compartment and oxygen is fed to the cathode (+ve electrode) compartment. Electrode chemical reactions take place at the electrodes to produce an electrical current. Hydrogen diffuses from the anode through the gas diffuses layer to the catalyst layer (anode electrode) in which hydrogen molecules split into protons and electrons according to the following half cell electro-chemical reaction:

$$H_2 \rightarrow 2H^+ + 2e^- \qquad (1)$$

The protons travel through the electrolyte membrane to the cathode while the electrons are conducted to the cathode through the external circuit. At the cathode, oxygen diffusion cathode diffusion layer to the cathode catalyst. At the catalyst, oxygen reacts with protons and electrons forming water and producing heat via this half reaction:

$$2H^+ + 1\backslash 2\ O_2 + 2e \rightarrow H_2O \qquad (2)$$

ELECTROLYSIS CELL

It is well known that hydrogen and oxygen can be produced by electrolysis techniques. In this technique as shown in figure (1) water is split by passing an electrical current through it. The water electrolysis is thus the exact reverse of hydrogen fuel cell. Electrolysis technology can be implemented at any scale whenever there is supply of electricity. Reactions in the PEM electrolysis cell are following in these steps:

$$\text{Anode:} \qquad 2H_2O \rightarrow 4H^+ + O_2 + 4e^- \qquad (3)$$

$$\text{Cathode:} \qquad 4H^+ + 4e^- \rightarrow 2H2 \qquad (4)$$

The dimensions of graphite plates are shown as follows:

Table (1): The dimensions of graphite plates

samples	Length, L (cm)	Width, W(cm)	Thickness, T(cm)
A	5	5	0.2
B	5	5	0.3
C	5	5	0.4
D	5	3	0.3
E	5	4	0.3

The flow rates of hydrogen\oxygen gas used were 0.4, 0.5 &0.6 L/min. after determine the current and voltage of cells; the electrical conductivity was calculated according to ASTM D-99 using the formula below:

$$E.C = \frac{I*L}{V*W*T} \qquad (5)$$

Where: E.C. electrical conductivity (S\cm, voltage drop (volts), I: current (A) W: sample width (cm), T: sample thickness (cm) and L: sample length (cm)

RESULTS AND DISCUSSION

The electrical conductivity of the graphite plates was measured in series fuel cells to evaluate the performance with different conditions. The flow rates conditions of hydrogen \ oxygen gas were 0.4, 0.5and 0.6 L\min. In addition, table (1) shows the samples dimensional include thickness (T), surface area (S) and width (W). During the experiments, the currents and voltages were also investigated as shown in tables (2 and 3).

Figures (2-4) exhibit that electrical conductivity increases with increasing in flow rate of hydrogen and oxygen gases, the maximum value was (850.7S\cm) at 0.6 L\min. While the other flow rates of 0.4 and 0.5 L\min is slightly increased.

Increasing in electrical conductivity twice at 0.6 L/min flow rate than0.4 L/ min due to quantity of hydrogen gas, hydrogen has the highest energy density per unit weight than any other chemical fuel for many applications. It can be converted directly into electricity by fuel cell in an electrochemical process [3].

EFFECT OF CURRENT ON ELECTRICAL CONDUCTIVITY

The figures (2-11) also indicate that electrical conductivity increases with increasing in the current while the voltage of fuel cell decreased for the same flow rate. The experimental results exhibited when the current reached (8.13 A), the voltage of fuel cell decreased to the (0.04 v) at specimen E as shown in table 4.

EFFECT OF PLATE DIMENSIONS ON ELECTRICAL CONDUCTIVITY

In figure (8) shows the effect of different thicknesses on electrical conductivity was also investigated in this work. The measured conductivity increases with increasing thickness of the plates and then decreased according to equation (5). The graphite plate exhibited the maximum electrical conductivity at 0.3cm in comparison to other thicknesses as well increase with flow rate as shown in figure (8).

EFFECT OF CURRENT ON POWER

Figures (9-11) show the distribution of power vs current for graphite plates at 0.4, 0.5 &0.6 L/min flow rate. The maximum power was 2.66, 3.13 &3.5 W, respectively. At low current, the graphite plates exhibited the maximum power in comparison to those at high current.

CONCLUSIONS

In this experimental work the electrical conductivity increase with increasing in flow rates of hydrogen as well as when the current reached to the maximum, the electrical conductivity exhibits high improvement. Thickness of the plate is affected on the electrical conductivity values.

REFERENCES

[1].Yuhua, W.,"conductive thermoplastic composite blends for flow field plates for use in polymer electrolyte membrane fuel cell (PEMFC), master of applied science in chemical engineering, Waterloo, Canada, (2006).

[2].EG and G., " Fuel cell hand book", 5th edition, (2000)

[3].Pakkanen, A., "Hydrogen fuel cell vehicle and a standalone renewable energy based re- fuelling station", masters degree of programmers in renewable energy, University of Jyvaskyla, (2007).

[4].Hurnung, R. and G. Kappelt, "Bipolar plate materials development using Fe-based alloys for solid polymer fuel cell", J. Power Source, (1998).

[5].Kuan, H. "Preparation, electrical, mechanical and thermal properties of composite bipolar plate for fuel cell", J. Power Source, (2004).

Table (2): E.C of fuel cell at 0.4 L/ min flow rate of each O_2&H_2 gases

samples	I, (A)	V, (Volt)	E.C, S\cm	Power, (W)
A	2.75	0.6	22.91	2.06
B	5.5	0.1	183.15	0.68
C	3.5	0.5	17.5	2.18
D	2.51	0.85	16.38	2.66
E	6.1	0.08	317.2	0.61

Table (3): E.C of fuel cell at 0.5 L/ min flow rate of each O_2&H_2 gases

samples	**I, (A)**	**V, (volt)**	**E.C, S\cm**	**Power, (W)**
A	3.1	0.81	19.13	3.13
B	6.2	0.08	258	0.62
C	4.1	0.47	21.8	2.4
D	3.3	0.58	31.57	2.39
E	7.5	0.06	520	0.56

Table (4): E.C of fuel cell at 0.6 L/ min flow rate of each O_2&H_2 gases

samples	I, (A)	V, (volt)	E.C, S\cm	Power, (W)
A	3.5	0.8	21.87	3.5
B	6.82	0.07	324	0.59
C	4.88	0.41	29.75	2.5
D	3.67	0.55	37.03	2.52
E	8.13	0.04	850.7	0.4

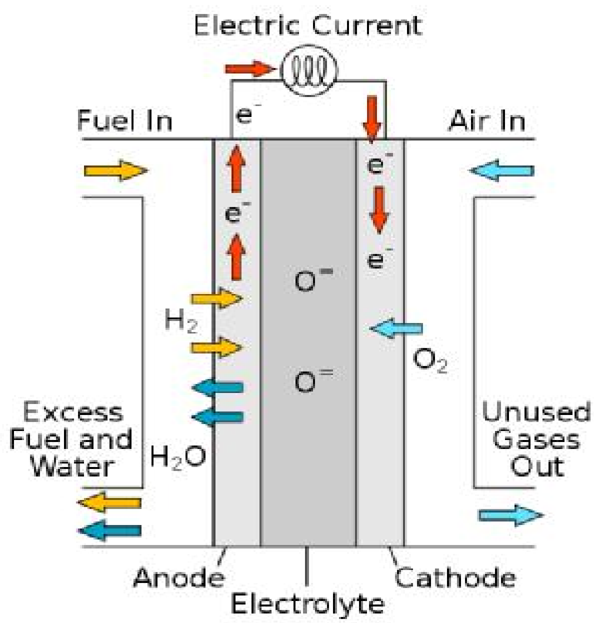

Figure (1): a schematic representation of the PEM fuel cell.

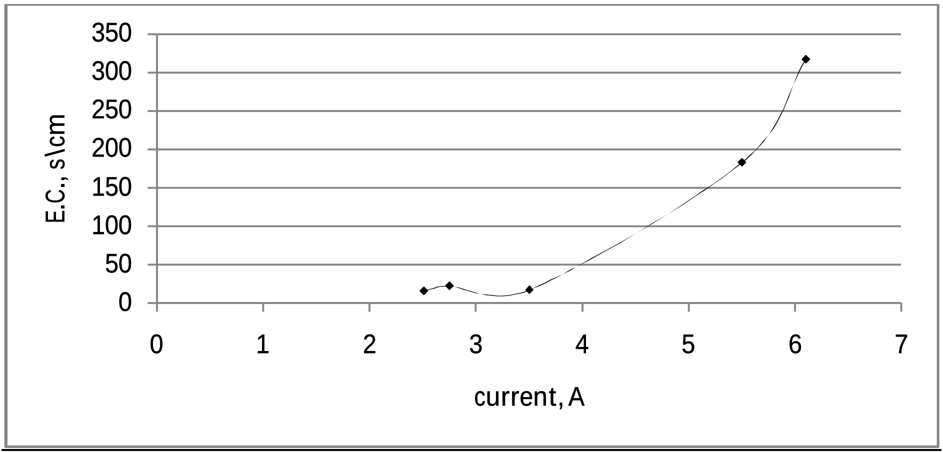

Figure (2): E.C. with current at 0.4 L\ min flow rate of O_2 &H_2 gases

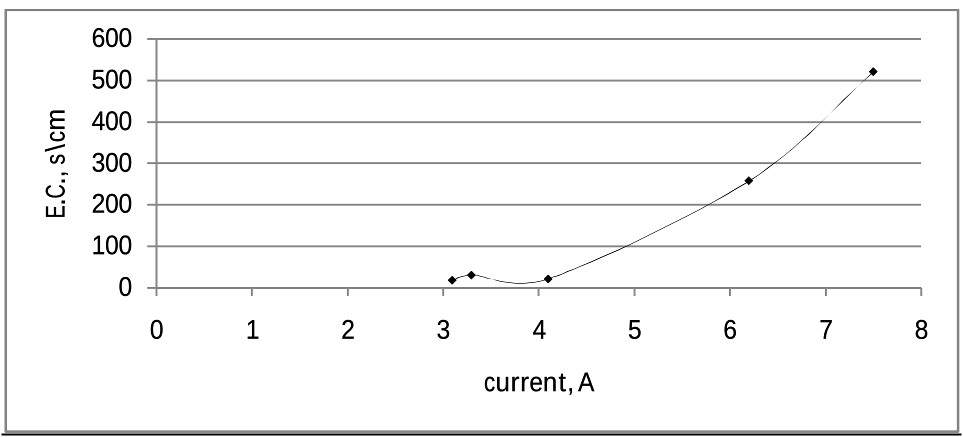

Figure (3): E.C. with current at 0.5 L\ min flow rate of O_2 &H_2 gases

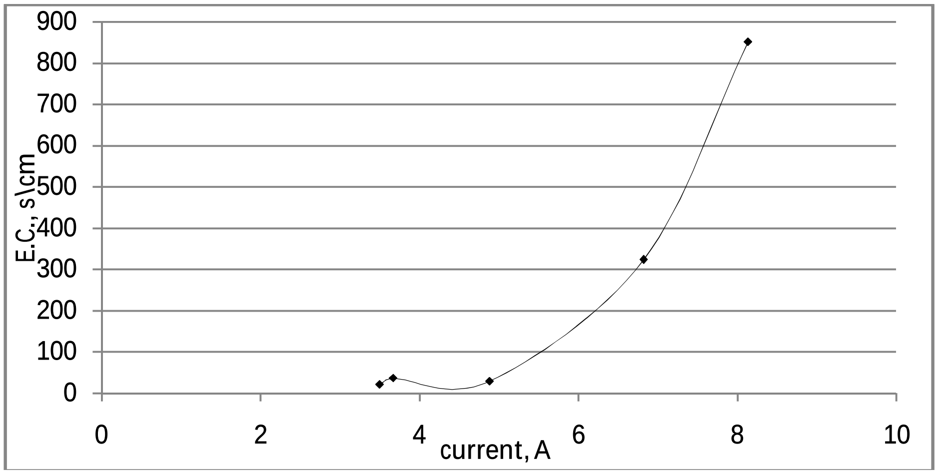

Figure (4): E.C. with current at 0.6 L/ min flow rate of O2 &H2 gases

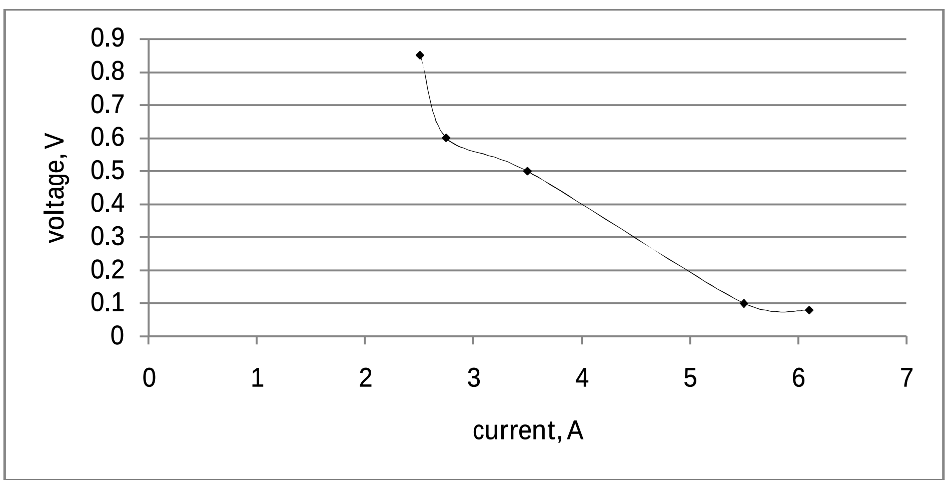

Figure (5): current-voltage of graphite plate at 0.4 L/min flow rate

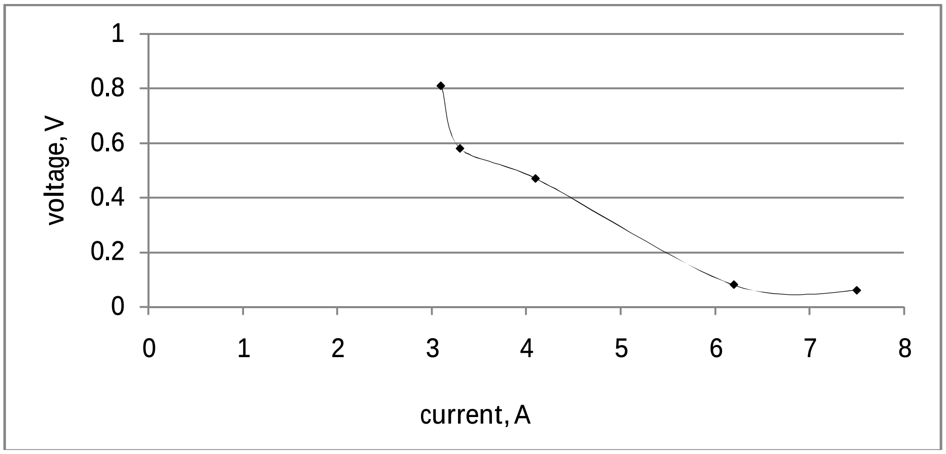

Figure (6): current-voltage of graphite plate at 0.5 L/min flow rate

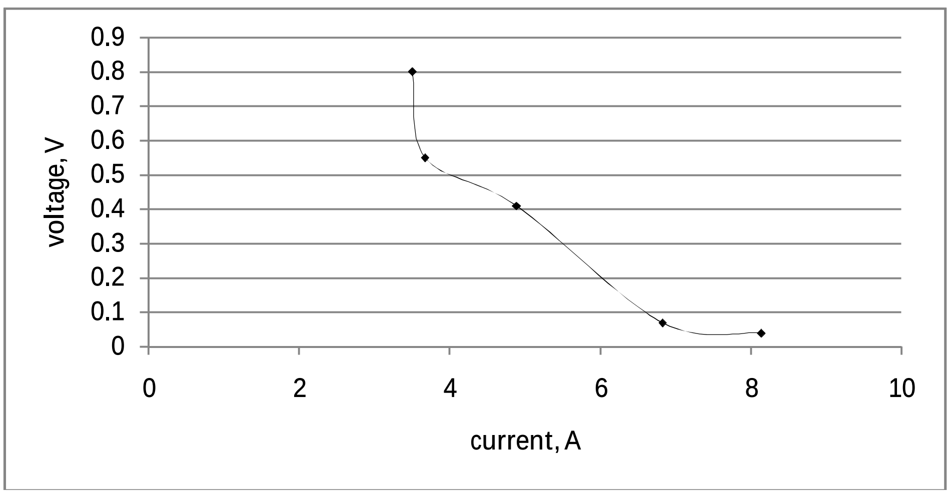

Figure (7): current-voltage of graphite plate at 0.6 L/min flow rate

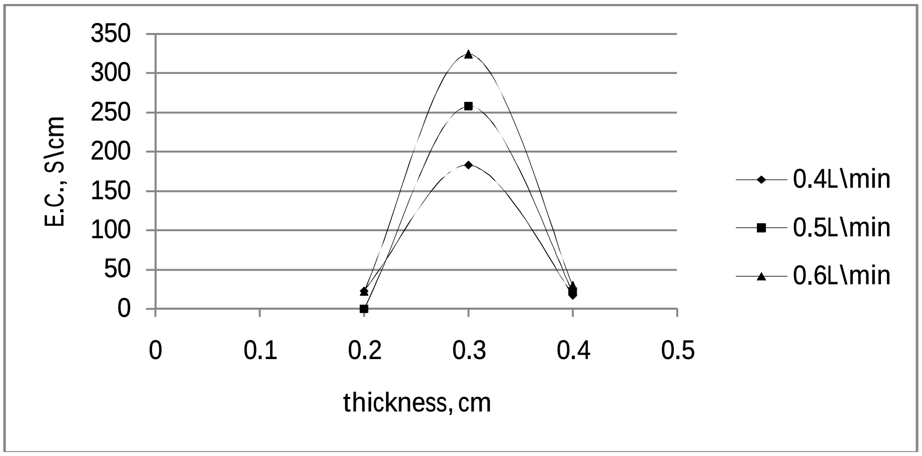

Figure (8): E.C. with different thickness

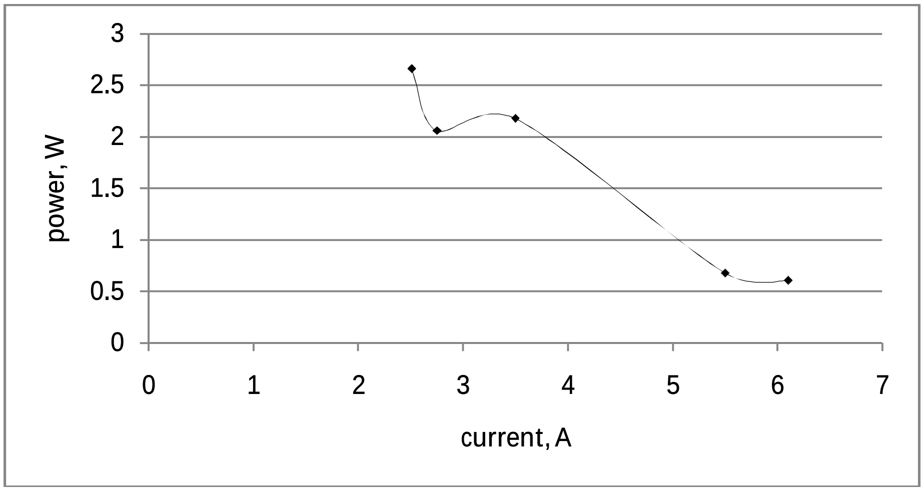

Figure (9): power- current of graphite plate at 0.4 L/ min flow rate

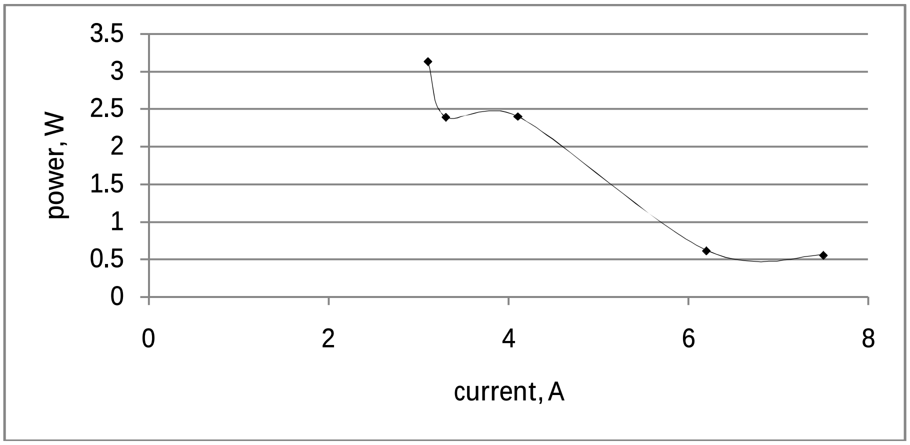

Figure (10): power- current of graphite plate at 0.5 L/min flow rate

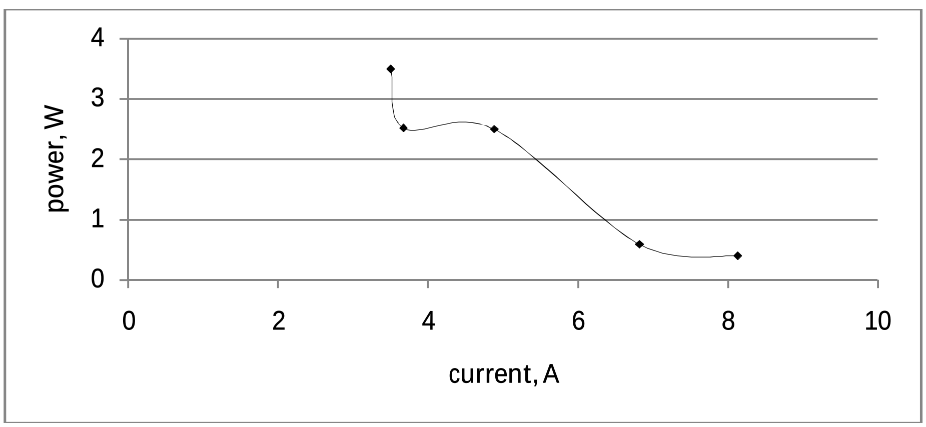

Figure (11): power- current of graphite plate at 0.6 L/ min flow rate