Performance Comparison between Graphite and Metallic Bipolar Plates in Direct Methanol Fuel Cell (DMFC)

Raja Crowley

Office of Science, Faculty and Student Team (FaST)

Farmingdale State University

Brookhaven National Laboratory

Upton, New York

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Prepared in partial fulfillments of the Office of Science, Department of Energy's faculty And Student Team under the directions of H. Tawfik in the IRTT, Farmingdale State University of New York & D. Mahajan in the Energy Sciences & Technology Department (EST) at Brookhaven National Laboratory.

Participant: ______________________
Signature

Research Advisor: ______________________
Signature

Table of Contents

ABSTRACT

Performance Comparison between Graphite and Metallic Bipolar Plates in Direct Methanol Fuel Cell (DMFC). RAJA CROWLEY (Farmingdale State University, Farmingdale, NY 11735) HAZEM TAWFIK (Farmingdale State University, Farmingdale, NY 11735) DEVINDER MAHAJAN (Brookhaven National Laboratory, Upton, NY 11973).

The use of Direct Methanol Fuel Cell (DMFC) is an electrochemical process without combustion as an alternative source of energy. A DMFC can produce energy constantly, unlike a Lithium battery which stores energy and after all energy is used up, a battery must be recharged for a long period of time. Since methanol is available in a liquid form, it requires minimum storage volume and is easy to transport. DMFCs have been used in different hand held applications such as cell phones and laptop computers. There are many parameters that have an effect on the performance of the DMFC such as the methanol concentrations, fluid and air flow rate, temperature, and the humidity level inside the air side of the cell. In this experiment a performance comparison between graphite and metal treated plates was studied with different methanol concentrations with and without humidification. Membrane Electrode Assembly (MEA) for DMFC with an active area of 2.54cm x 2.54cm, Pt/Ru catalyst in the anode side and Pt. catalyst in the cathode side, were used in two single fuel cells, one with graphite plates and the other with treated metal plates. The liquid methanol was fed to the cell at a rate of 6 ml/min. Methanol concentrations of 3%, 5%, 7%, and 10v% diluted in distilled water were used in both cells, under room temperature, 15psi air pressure, and an air flow rate of 1.0 SCFH. 3% and 5% methanol concentrations showed an optimum performance in graphite and metallic plates respectively. The

3% methanol concentration yielded 29% higher performance in the metallic bipolar plates and the 5% methanol showed 45 % higher performance in the metallic plates relative to graphite. Graphite Plates with 3% and 5% methanol concentrations with 40% humidity at the air side resulted in 16% and 21% improvement in performance respectively. While metallic plates with 3% and 5% methanol concentrations, after similar humidification was applied, showed 2%, and 9% improvement in performance respectively. Accordingly, it was concluded that the metallic bipolar plates showed higher performance than the graphite plates, and controlled humidification in the vicinity of 30% to 50% has positive influence on the performance of the cell. Humidification had more effect on the graphite plates than the metallic plates and was attributed to the surface energy of both materials. Future work will focus on optimization of the performance of the single cell and to build a stack of DMFC to power a mobile phone.

INTRODUCTION

We are all aware of the problem the world faces with energy today. In the present time, the US and the world rely on the fossil fuel economy for energy. The race is on for an alternative energy solution. Many scientists and researchers around the world believe that the hydrogen economy is the solution to this problem as an alternative source of energy. The hydrogen could be reformed from more widely available fuels such as natural gas or any other hydrogen containing fuel, such as methanol. Since the methanol is supplied in a liquid form, it is easier and safer to transport than hydrogen.

This project focuses on the use of the Direct Methanol Fuel Cell (DMFC). DMFC is a subcategory of proton exchange fuel cell, where chemical energy is converted to electrical energy without combustion and the only byproduct is water and some carbon dioxide. The liquid methanol is fed directly to the cell without reforming, which make the DMFC an excellent candidate for small to mid-size applications such as mobile phones and laptop computers.

The DMFC comprises of two graphite or metallic bipolar plates where a Membrane Electrolyte Assembly (MEA) is placed inside. Metallic plates are more robust, easier to manufacture and more cost effective than graphite. The MEA is responsible for all the chemical reactions at the anode and the cathode. The liquid methanol is fed to the cell through the anode side, where it gets oxidized into carbon dioxide, six hydrogen protons, and six electrons, for the chemical reactions of the system see table 1, and for the schematic of the DMFC see diagram 1. Since the anode is electrically charged, it rebels the electrons to an outside circuit, which is electricity, while the hydrogen protons continue their journey through the membrane into the cathode side where they meet up with the electrons from the external circuit and oxygen, which is applied to the cathode side, to form water and complete the electrochemical process.

MATERIALS AND METHODS

The liquid methanol solution was prepared with different concentration levels, a percentage of 3%, 5%, 7%, and 10v% pure methanol (CH_3OH) diluted in distilled water. Five layers Membrane Electrolyte Assembly (MEA), from E-TEK, for Direct Methanol Fuel Cell (DMFC) was acquired. The MEA consisted of GDL based on woven web with an active area size of 1”x 1” and membrane area size of 3”x 3” with a Pt/Ru catalyst on the anode side and Pt catalyst on the cathode side. The experiment was conducted with the use of two graphite plates and two metallic bipolar plates with 1” x 1” channels in the middle to accommodate the MEA. An air powered pump to deliver the fluid at an adjusted rate.

The experiment began by assembling the two types of fuel cells, the graphite plates, and the metallic bipolar plates; each cell, with the Mea inside, was placed in the middle of two aluminum plates and secured tightly with hard wares such as screws, washers, and hex nuts. The cell with the graphite bipolar plates was used first; it was connected to an air operated pump which delivered the liquid methanol to the anode side of the cell at a rate of 6ml/min., while air was flowing to the cathode side of the cell at a rate of 15psi., with an air flow rate of 1.0 SCFH, a Dynoload device was used to measure the performance. The experiment was conducted at room temperature.

Different methanol concentrations of 3%, 5%, 7%, & 10% were prepared and utilized to power both graphite and metallic bipolar plate’s single cells. Each methanol concentration was fed to the cell four times at a half an hour interval and an average of the performance was recorded. The graphite plate's fuel cell exhibited the highest performance with 3% concentration, while the metallic bipolar plate's fuel cell yielded the highest performance with 5% methanol concentrations. The overall performance improved even further after humidification was applied to both the graphite and the metallic bipolar plate's fuel cells.

RESULTS

Figures 2 and 3 show the performance curves of the different methanol concentrations of the 3%, 5%, 7%, and 10% using the graphite plate's fuel cell, the 3% methanol concentration showed the highest performance, while the 5% methanol concentration exhibited the highest performance using the metallic plate's fuel cell. When compared, the metallic plates showed a 29% higher performance than the graphite plates using the 3% methanol concentration, see figure 4. Again, the metallic plates showed a 45% higher performance than the graphite plates using the 5% methanol concentration, refer to figure 5. Figure 6 and 7 show the humidification effect on both the graphite plates and the metallic bipolar plate's fuel cell. When a 40% humidification was added to the air side of the graphite bipolar plate's fuel cell with 3% and 5% methanol concentrations, the cell yielded a 16% and 21% improvement in performance respectively. Again, 40% humidification was applied to the metallic bipolar plate's fuel cell using the 3% and 5% methanol concentrations, 2% and 9% improvement in performance was observed respectively, as shown in figure 8 and 9.

DISCUSSION AND CONCLUSION

It was concluded, after applying different methanol concentrations to the graphite and the metallic plate's fuel cell, that 3% and 5% methanol preformed best with the graphite and the metallic bipolar plates respectively. It was observed that when the methanol concentration increases more than the 3% and 5%, the performance of the cell decreases this due to the problem of the methanol crossover to the cathode and hampering the electrochemical reaction inside the cell. The metallic bipolar plates gave higher performance than the graphite plates. This is attributed to the fact that aluminum plates that are used in the current project are more conductive than graphite and therefore the electrical losses are lower and the performance is higher in the case of metallic plates. After 40% humidification was applied to the air side of both cells, it showed that humidification had more influence on the performance of the graphite plates than the metallic bipolar plates. This is because of the surface energy of the plate's materials.

ACKNOWLEDGMENTS

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Anode Reaction:	**$CH_3OH + H_2O \Rightarrow CO_2 + 6H+ + 6e-$**
Cathode Reaction:	**$3/2\ O_2 + 6\ H+ + 6e- \Rightarrow 3\ H_2O$**
Overall Cell Reaction:	**$CH_3OH + 3/2\ O_2 \Rightarrow CO_2 + 2\ H_2O$**

Table - 1 Direct Methanol Fuel Cell Chemical reactions

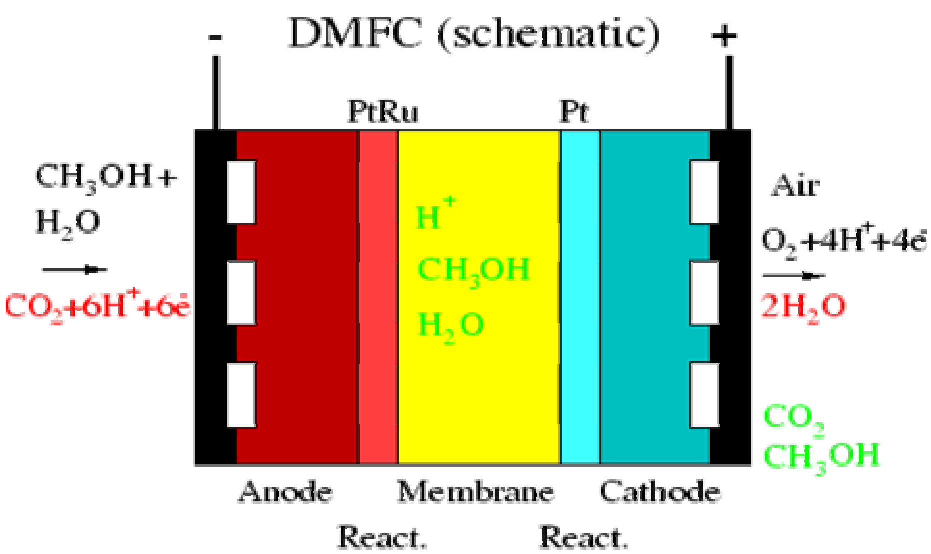

Figure - 1 Schematic of the Direct Methanol Fuel Cell

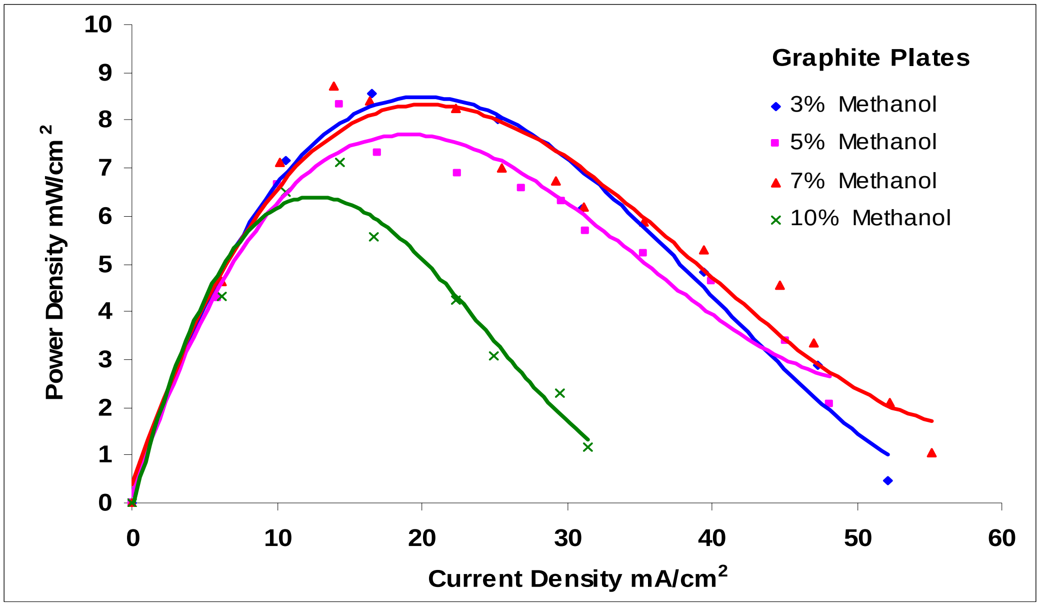

Figure - 2 Power Density Performance Curve for Graphite Plates With Different Methanol Concentrations

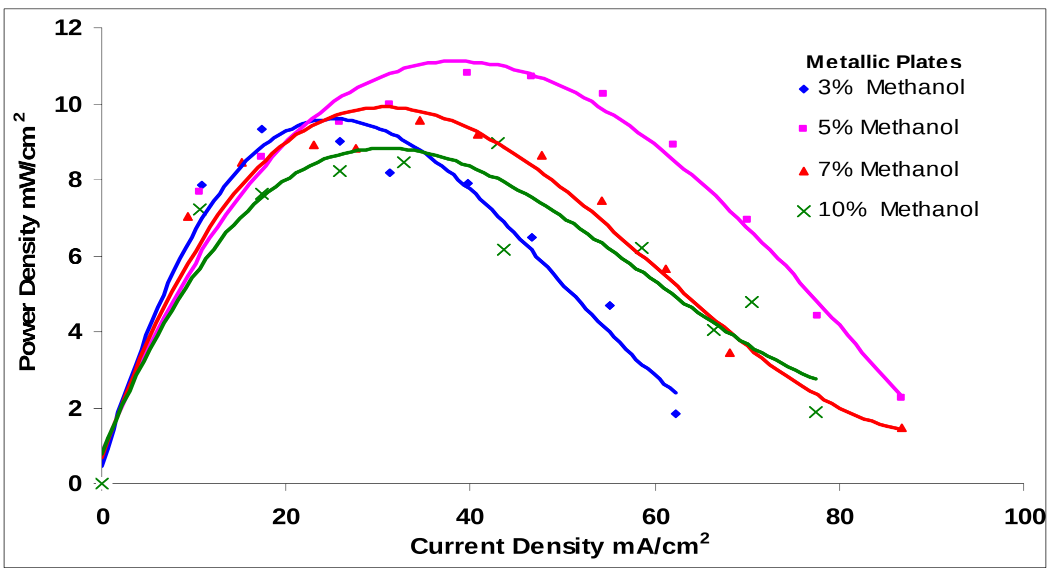

Figure – 3 Power Density Performance Curve for Metallic Plates With Different Methanol Concentrations

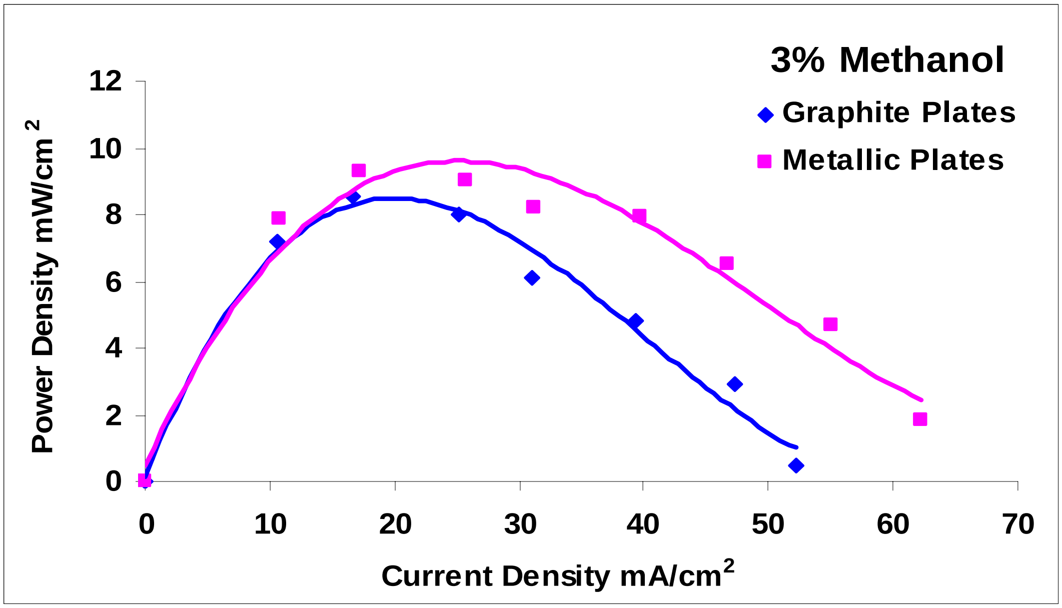

Figure - 4 Comparison of Performance in Graphite and Metallic Plates Using 3% Methanol

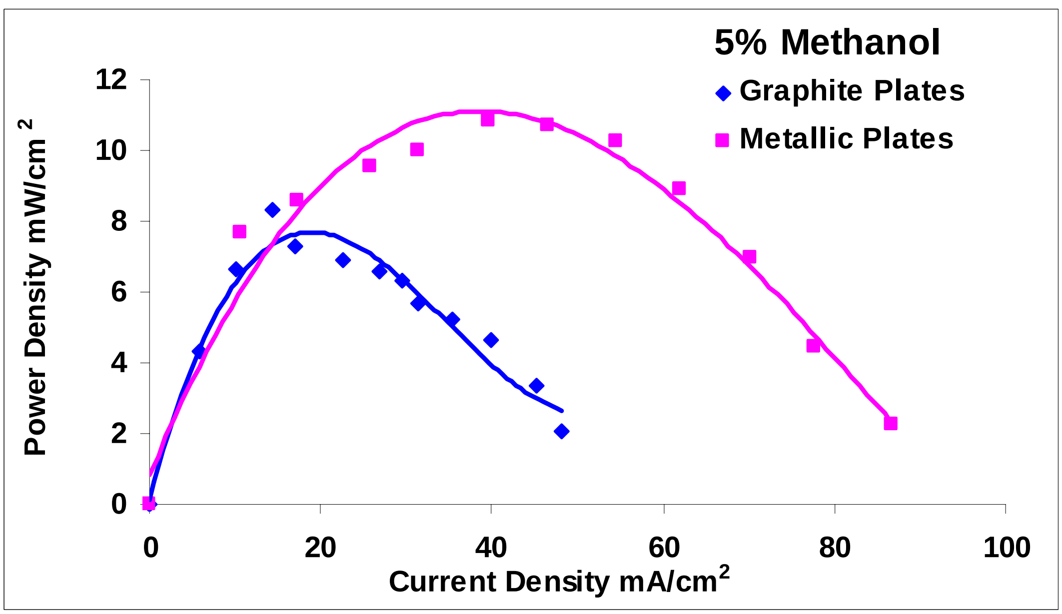

Figure - 5 Comparison of Performance in Graphite and Metallic Plates Using 5% Methanol

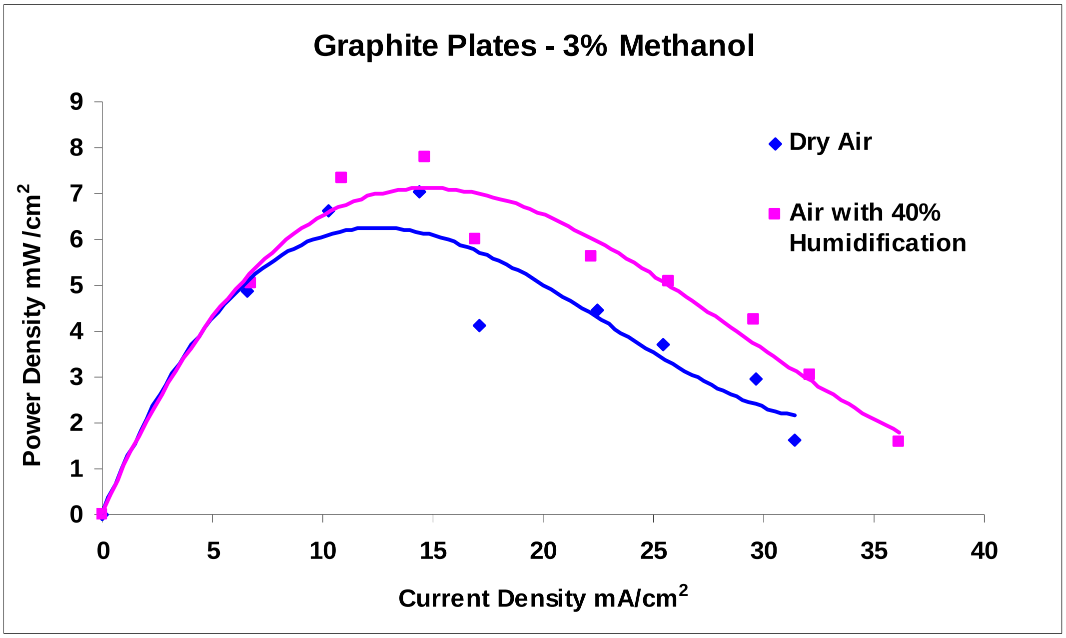

Figure – 6 Power Density Performance Curve Before and After Humidification

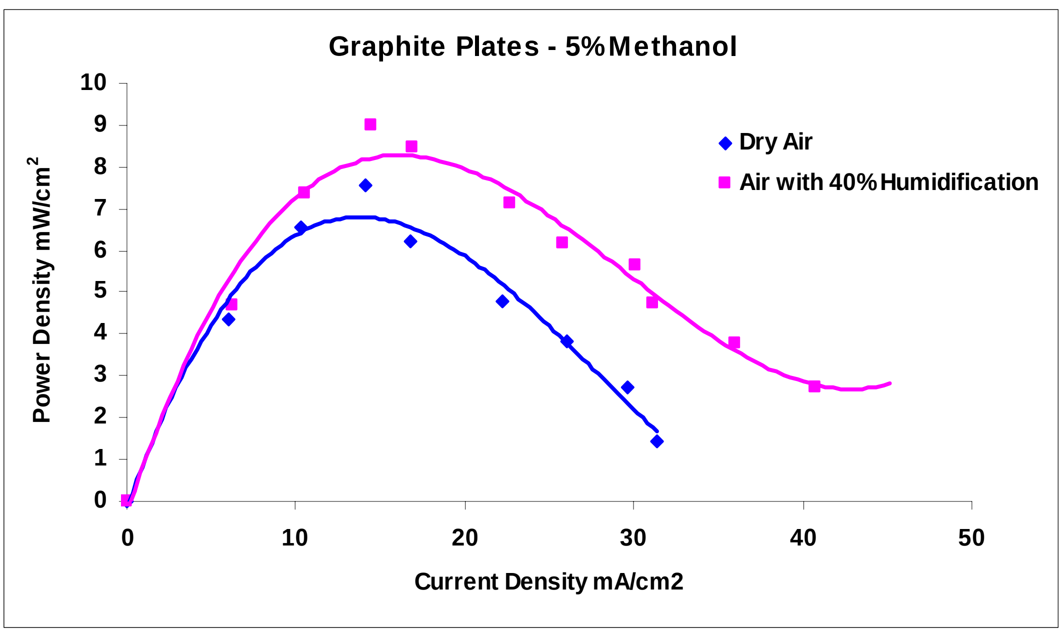

Figure – 7 Power Density Performance Curve Before and After Humidification

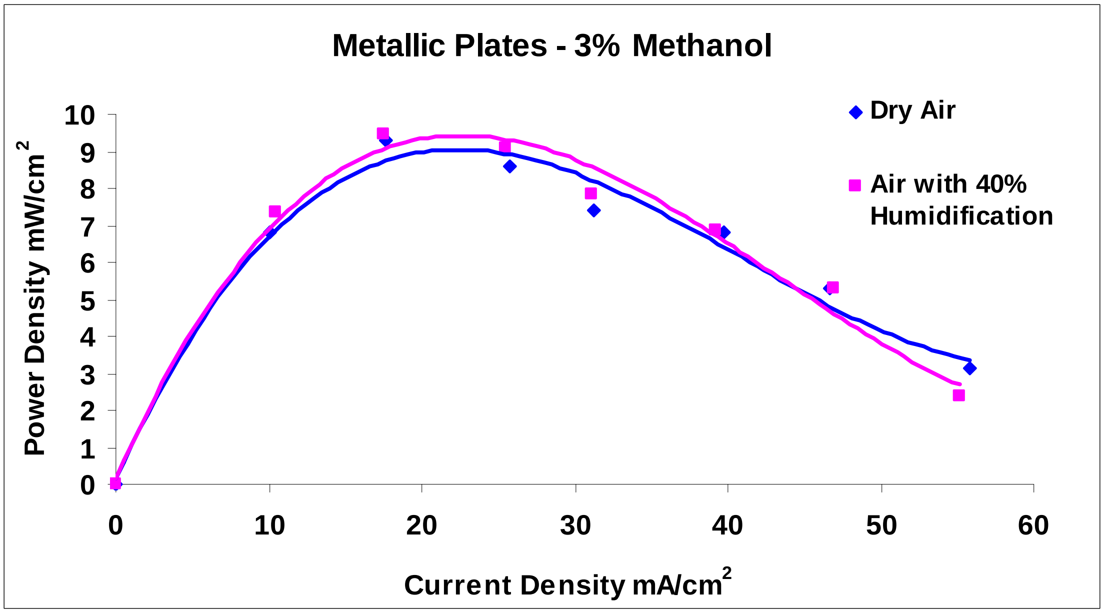

Figure – 8 Power Density Performance Curve Before and After Humidification

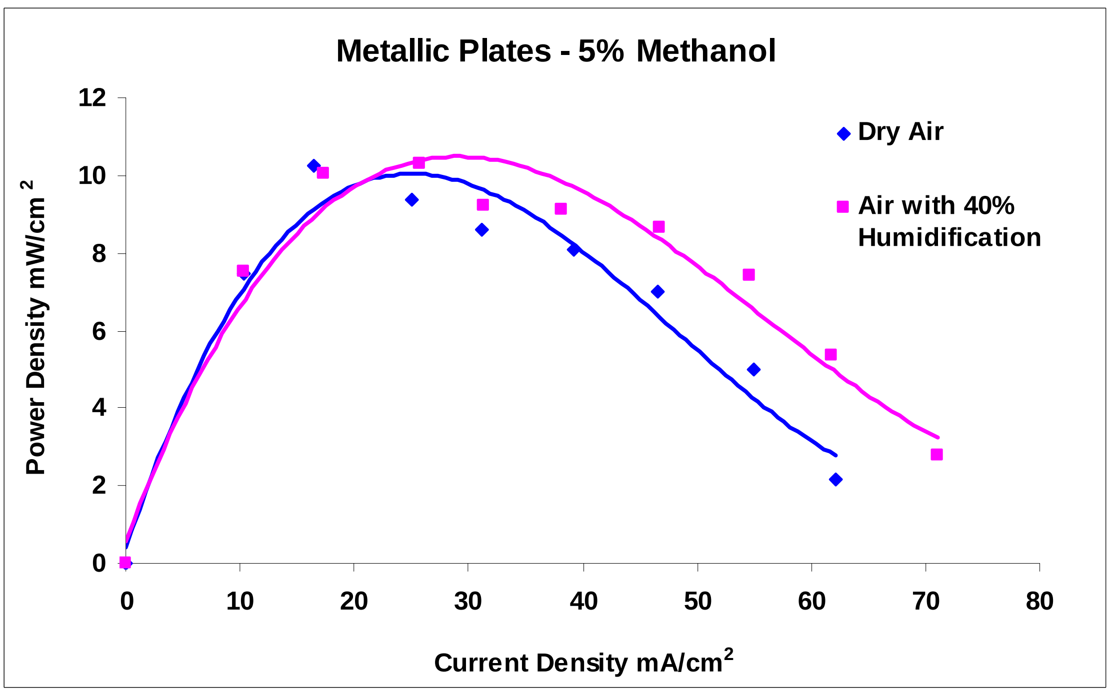

Figure – 9 Power Density Performance Curve Before and After Humidification