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From Lab to Market – Microfluidic Fuel Cell Stack: An Undergraduate Capstone Project

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Introduction

Today, renewable energy is one of the most rapidly growing technology and commercial enterprise. In the recent decades there have been significant advances in the renewable energy technologies, energy efficiency and sustainability, but also an increased demand for engineers and technicians knowledgeable and experienced in these areas. This requires the development of innovative curricula, new courses and new laboratories to educate students to work in these fast changing industries. Engineering education moves into the twenty first century charged with an environmental agenda to respond to new economic realities. Enabling students to practice self-directed learning, to find solutions to design problems that are sustainable and to recognize that they are part of a global community are just a few of our educational goals. On the other hand, the renewable energy and sustainability are highly interdisciplinary, crossing over between a numbers of research areas, having strong potential for hands-on multi-disciplinary project-based learning. Renewable energy capstone projects typically involve more than one discipline (electrical, mechanical, computer, civil, and chemical engineering concepts) while still being accessible to undergraduate students. A natural and efficient way of embedding renewable energy and sustainability into engineering and engineering technology curricula is the problem-oriented and project-based learning approach. Renewable energy and sustainability topics for student-led projects allow students to work on current relevant leading edge research and technology.

Environmental concerns and the increasing needs for power generation, along with depletion of the fossil fuel reserves, and steady progress in power deregulation have created the framework for the development of environmentally conscious distributed power generation, such as: wind, solar/photovoltaic (PV), geothermal, wave and tide energy, and fuel cells (FC), with zero (or near zero) pollutant emissions. Given this rapid progress in renewable energy systems utilization, industry demand of trained professionals with adequate knowledge in this area increased as well. [1-3, 6] Due to these facts together with the interest of keeping students abreast of the current scientific and technological developments and trends, we believed that it was important and timely to include renewable energy projects in senior project design courses in our Drexel University Engineering Technology program. [6, 29, 30] Future engineers must be taught to be creative and flexible, and topics of renewable energy are an effective vehicle for developing multi-disciplinary instruction using a variety of content disciplines and academic standards.

Preparing engineering students with the skills and knowledge required to be tomorrow's successful engineers in the 21st century. Our educational strategy, embedded in our program's curricula, is based on experiential learning (including also self-directed learning), on discovering solutions to design problems that are sustainable, and is focused on helping students to recognize that they are part of a global community. Throughout our curricula we offer a relevant and validated curriculum that prepares students for post-graduation success. Although courses that cover traditional subject matter in mathematics, sciences, economics and other related topics provide the foundation of knowledge upon which specific skill sets are added, it is critical for engineering education to transition from theoretical work in the classroom towards experiential learning with applications of technology and design. This is exactly where Drexel Engineering

Technology capstone design projects fit perfectly: as they are the vehicle used to assess student's overall preparation in our program. The importance of project work in the curriculum of our undergraduate engineering programs is well understood and they traditionally include the best industrial practices also covering aspects such as engineering principles, standards and practices, design methodologies, modeling and optimization capabilities, systems analysis and integration techniques and new technologies and research areas. Creativity and creative thinking are inherent traits of any engineer. In fostering the enhancement of these capabilities, our students are required to independently put together all aspects of learning to solve a practical problem and look at alternatives. Hence, project work, and as a corollary the capstone senior design project work, is a very important constituent of our engineering technology curriculum.

The main objective of this paper, stemmed from a past two-year awarded NSF TUES project, is to continue disseminate the results of integration of *micro-fluidics* technology and applications into Engineering Technology (ET) curriculum. **In this paper, we are also discussing a capstone senior design project that approaches the interdisciplinary aspects of the translational research in the renewable energy and sustainability combined with the miniaturization offered by micro-fluidics applications.** The project structure and outcomes, lesson learned and future improvements are discussed in detail in the sections below.

As we described in our past papers, micro-fluidics related student-led projects and experiments were developed and integrated into our courses offered since AY 2011-2012. This combination of experimental activities and demonstrations created the framework for students to undertake capstone projects based on study of the aspects of micro-fluidic technology related to micro-scale fluidics, heat transfer, and instrumentation and control [32-36]. Based on student responses during AY 2011-2012, AY 2012 – 2013, and AY 2013-2014, **we concluded that students perceived that the projects and activities developed in the area of micro-fluidics provided an excellent opportunity to expand their understanding of the topics regarding micro-fluidic devices, while applying the fundamental principles of thermodynamics, heat transfer and fluid mechanics.** During AY 2013-2014, a senior design team undertook the challenging task of developing a micro-fluidic fuel cell based on an existing proof-of-concept and to create the framework for this product to be translated from the lab environment to a marketable consumer product. They chose to expand their project work beyond the course requirements, developing the prototype of a micro-fluidic direct methanol fuel cell stack that may be used to power a small portable device. Students were assessed continuously during the development of the project. The assessment focused on various aspects regarding their level of understanding of the fundamental principles, and the level of applying science to an engineering technology problem. Students were required to have weekly meeting with advisors as well as to complete a weekly activity report. These informal assessments were the basis for their formal assessment at the end of each of the three quarters. This project demonstrated the students' mastery of the techniques and knowledge learned during the courses taken as part of our curriculum. Students were able to apply the current engineering technology procedures and methods to a new and challenging engineering system, producing a practical solution based on detailed analysis of the system requirements.

Further harnessing of new energy sources may enable miniaturizing electronic devices and making them more portable or autonomous. Fuel cells, among other renewable energy sources, have been proven to offer higher energy densities as well as greater flexibility related to storage and system implementation, when compared to traditional battery systems. Scaling these systems to a micro-fluidic level may become the best option for powering the myriad of portable electronic devices that have been developed in the recent years. Students selected the micro direct methanol fuel cell proof-of-concept based on literature review, and then they been able to develop and investigate on how to make the jump from a laboratory setting to an actual consumer product. The goal of the project was to create a compact, rugged, and portable charging device that utilizes stacked microscale (< 1 mm feature size) direct methanol fuel cells that do not rely on a membrane, as fuel cell membranes are costly and problematic. Throughout this past academic year, a team of senior students were able to effectively progress towards reaching our overall project goal. They were able to successfully fabricate and power test the fuel cell design. Following power testing, multiple fuel cells were then created to be stacked in an orderly fashion for multiplying their power outputs. With this stacked assembly, the creation and testing of a new and innovative manifold design was performed to ensure proper feeding and extracting of our stacked fuel cell's fuel and oxidant.

The purpose of this paper is to describe the development of micro-fluidic direct methanol fuel cell stack as a capstone senior design project, during past AY by a team of four students. The lessons learned are presented and the ways that the experiential framework may impact our ET curricula are discussed. Our senior design project course is a 3-term core course usually taken by the students during their terminal year in the ET program.

Project Overview, Design Selection and Solution

Senior Design Project is a capstone sequence of three-quarter project-oriented design courses required for all the BSET concentrations in Drexel University ET department, and is focused on planning, development, and implementation of an original, innovative engineering project including formal report writing, project documentation, group presentations, and project demonstrations and testing of working prototypes. The goal of these courses is for students demonstrate their ability to manage and implement a commercially-viable project involving the design and implementation of products with a mixture of electrical and mechanical elements. In these project-based courses, the students are expected to effectively manage their time and team efforts to produce a working prototype of a product in three ten-week quarters. Students are assessed continuously by their advisors, and also are required to present quarterly reports and oral presentations to industry experts and faculty combined panels. Before beginning the projects, student teams are taught inventive problem solving, project formulation and resource analysis, performance goals and team expectations, public presentations of project work, and individual project supervision. Capstone projects represent the quintessence of the learning, skills and knowledge that our students acquire during their 5 year journey in our program.

ET senior design courses are focused on a sequential approach: first sequence is related to project objectives and problem definition. Based on this, students are expected to present a well-defined proposal of a practical system or product. The second step is conceptualization and approaches for realization of stated objectives. Once the students compile the answers to these questions, they are directed to perform system analysis, design, component purchase and fabrication, building and testing of the prototype, as well as the overall design improvements.

This particular project is an excellent example of combining undergraduate research with capstone design project. The uniqueness of this endeavor is related to the great amount of extracurricular learning that this team undertook. As presented above, this is an engineering technology program, and our students are more inclined to the practical and hands-on aspects of the learning process rather than highly theoretical one. In this case students took extra courses related to fuel cells and micro-fabrication to complete their knowledge. Having to perform an extensive literature research helped them to learn about research methods, topic that is not included in our curriculum. This topic included a series of new concepts and notions that were explained and taught by the advisors, or learned as directed instruction.

Project Statement, Constrains and Description

Both batteries and fuel cells convert chemical energy into electrical energy, but there are greater advantages when using fuel cells. For example, the density of energy is significantly higher in fuel cells with a range of up to 5000Wh/l, while batteries have an energy density up to 1500Wh/l. They are also a cleaner alternative energy source when compared to most power sources being used today. The materials that fuel cells are produced from can come from recyclables and are recyclable themselves, in contrast to batteries with toxic components that are pollute-landfills. Fuels cells can be realized with a wide variety of chemicals "fuels" and oxidants and materials of construction. The developed fuel cell is using methanol as the fuel and hydrogen peroxide as the oxidant.

As in most projects, there are challenges, problems, and setbacks, but we have continued on by using a pragmatic approached to solving the problems faced. Advancements in students work include designing and laser cutting individual fuel cells from thin sheets of acrylic, thermal bonding the chips with platinum electrodes in place, leak testing, chemical testing, completion of the case design, completion of electrical and pump design, assembly, and testing of the system. Students were highly encouraged that fuel cells are becoming high energy density power sources, and can provide the technology market with alternative options for portable applications. With our (faculty-student team) research contribution to fuel cells, we hope that any progression will assist with the transition from conventional power sources into the prominent power alternative provided by fuel cells.

Now that the main steps in student project development have been noted, let's take a more in-depth look at what they accomplished, as well as the social impact, and economic analysis for the project.

Chosen Solution

Membrane fuel cells are affected by temperature changes and with time the membrane tends to weaken. This will degrade fuel cell performance and could lead to failure. Our students' concept of design is relatively simple with few moving parts. In every aspect a microfluidic fuel cell is more advanced than batteries or membrane fuel cells. Just by concept, a microfluidic fuel cell will last longer and continuously produce the same amount of power. The proposed design provides stability and longer range of power compared to batteries. Incorporating a ladder design will allow them to create higher power yields with less fuel consumption (approx. 30% power increase) [10]. For the customer, this is an inexpensive alternative and is a much safer means to power their devices as compared to current fuel cell technology since the only byproduct of this concept is water vapor. Markets have had difficulties selling fuels cells due to their high price and the danger associated with them. This product minimizes the danger with a design will become compact, rigid, and more importantly not explosive, having a safe byproduct: water.

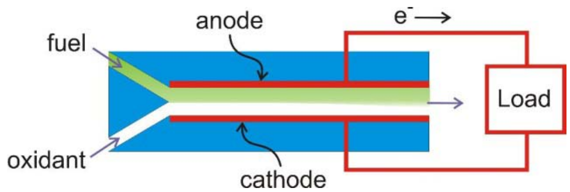

Figure 1. Generic fuel cell configuration

The fuel cell is chemically comprised of $14H_2O + 6CH_4O + 1H_2SO_4$ for the fuel mixture. For the oxidant mixture we have $14H_2O + 3H_2O_2 +1H_2SO_4$. This solution was found from Worcester Polytechnic Institute [37]. During testing, students used two types of anode and cathode wires: either 99.9% pure platinum or platinum coated tungsten. Platinum is used for of its catalyst effects and resistance to corrosion. Research performed by Johnson Matthey shows that the ideal anode and cathode material would be platinum plated ruthenium electrodes, in which the ruthenium is required due to CO poisoning effect[38] that lowers the overall efficiency of the reaction. However, this type of wire is highly expensive and difficult to obtain. A new trial is set to be done using for electrodes stripes of platinum cloth coated with ruthenium. Sulfuric acid is used as catalyst, also helping in lowering the activation energy by providing new intermediate states by which a reaction can proceed.

Testing

Students created a set up for testing the fuel cell (see Figure 2). They built a stand that would hold both the fuel and oxidant in syringes; these would then be connected to fuel cell using pipette tips. They tested if they could use the syringe pump machine to draw the fuel and oxidant through the cell (as opposed to pushing the two fluids through). At first they used a needle at the end of the syringe pump; this would be inserted into the tube of the outlet of the fuel cell. While this did not pull the fluids through as anticipated; in the next trial they used a pipette tip instead of the needle and repeated the process. This worked much better, as they were able to pull the colored water through the microfluidic device while maintaining co-laminar flow inside the channel of the fuel cell. Flow rates of 0.5 to 2.5 [mL/min] were tested. After all microchips were proven to be leak-free, the next step was testing with fuel and oxidant. Several trials were performed at various hydrogen peroxide concentrations as well as different flow rates for both fuel and oxidant.

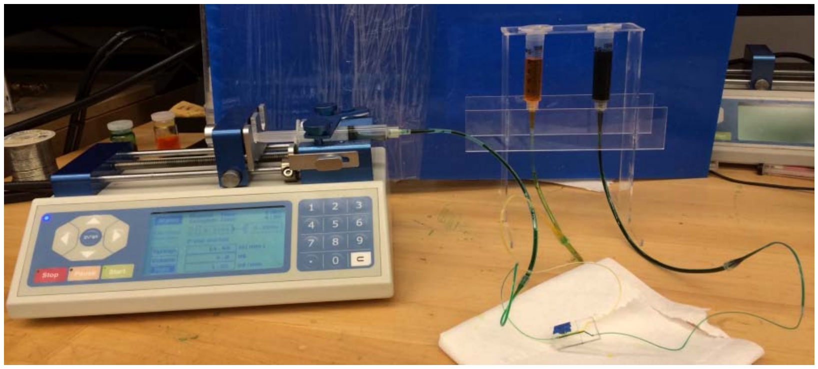

Figure 2: Testing set-up for micro-chips

Initially the following mixture was used:

$$\text{Fuel} \rightarrow 1\ CH_3OH : 0.5\ H_2SO_4 : 8.5\ H_2O$$

$$\text{Oxidant} \rightarrow 0.008\ H_2O_2 : 0.5\ H_2SO_4$$

The concentration of peroxide was later increased to 30% from 3%, as the peroxide concentration was too low to sustain the needed reaction. During these preliminary tests, students determine the necessity of priming the cells prior to activating the fuel cell and also they found that occasionally some air bubbles would come through the fuel cell. On the positive side they did find that our cell produced an open circuit voltage well above the noise level. Along with the inconsistent voltage levels they found that they had to use a higher flow rate (2.5 $[^{mL}/_{min}]$) being able to reduce the flow rate of fuel to 0.5 $[^{mL}/_{min}]$. The priming technique was improved by shortening the tubes leading to the inlets of the fuel cell. Figure 3 shows drawings of how the tubes were previously set up and the set up just described.

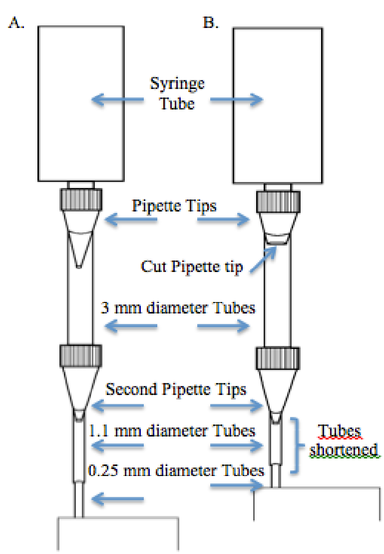

Figure 3: Old vs. new set-up for testing

The next testing batch was designed to improve the power of the chip by changing the fuel and oxidant concentrations as follows:

Fuel	Oxidant
1 H_2SO_4* : 6 CH_4O : 14 H_2O	1 H_2SO_4* : 3 H_2O_2 : 14 H_2O

Students used a fuel cell that had an electrode length of 0.8 mm, with a fuel and oxidant flow rate at 1.25 mL/min. Initially they took an open circuit voltage reading of 16 mV, and then they decided to apply different amounts of resistances to see how the voltage and current would be affected. The block diagram for how set up can be seen below in Figure 4. It started with a load of 1 kΩ. This resulted in a voltage of 0.3 mV (300 μV) and a current of 0.0003 μA. Next, we then started to increment the resistance by 1 kΩ up to 10 kΩ, and then increments of 10 kΩ up to 90 kΩ. These voltage levels were much smaller than the initial testing readings.

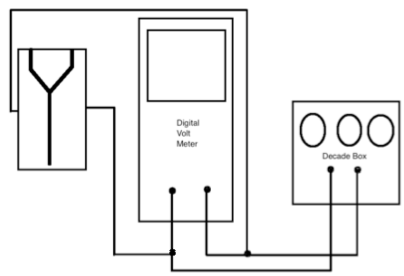

Figure 4: Electrical Testing Diagram, Decade box connected in parallel to the digital voltmeter.

Even though the open circuit voltage reading was much less than for the previous trials, they were able to draw VI diagram as shown in Figure 5 below. This diagram that we were far off from obtaining the smooth curve we were looking for. As students continued to test they noticed that results were becoming less and less favorable, finding about the poisoning effect of CO which resulted in decreasing fuel cell performance. In this respect the conclusion was that the cells were "single use". Since also research shows the need of adding ruthenium into the electrodes. The ruthenium part of the electrode would help reduce the amount of carbon monoxide (CO) that is absorbed by the platinum material thus maintaining cell performance. This would also allow for the fuel cell to be used multiple times, rather than single use as they currently are.

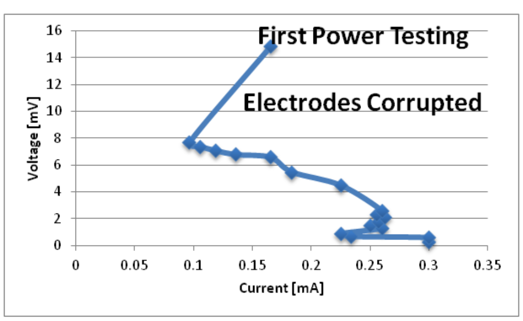

Figure 5 Power testing diagram

Several trials were performed by students, in their attempt to obtain a reading above 500mV. In this respect, they cleaned the electrodes using HCl and they saw much improved results. The results are shown in the Figure 6. This IV curve shows us potential for our fuel cell. We have a maximum fuel cell of 750 [mV] which is very promising.

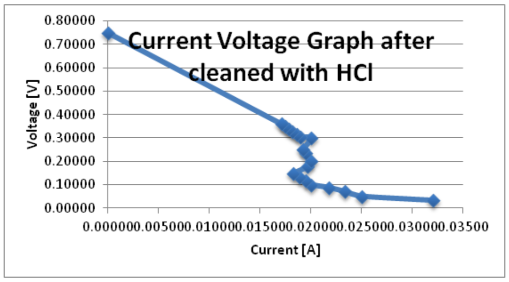

Figure 6 Results after electrodes cleaning

Figure 7: Fuel cell current testing set-up

The figure 7 also shows the set-up that most closely resembles the design for the system with tubes from fuel cell going directly to fuel and oxidant tubes and a single syringe pump drawing the fluids.

As it can be easily inferred, students applied several concepts learned throughout the curriculum from basic science courses to microfabrication, electrical design and applied chemistry to engineering systems. They also used their energy conversion and sustainability knowledge into play in this complex project.

Case Design

As presented above, the micro-fluidic fuel cells are at the proof-of-concept level up to now and the innovative approach of our students was to find a way to “pack’ the lab-based fuel cell into a marketable product. In this respect, students designed a generic case structure trying to keep the size as small as possible while fitting the necessary components. They also designed a manifold system that would drastically decrease the amount of tubes required during manufacturing. They also designed and build the canisters and design a system that would get the fuel and oxidant from the canisters to the manifolds. Figure 8 below shows an exploded view of the finalized case design.

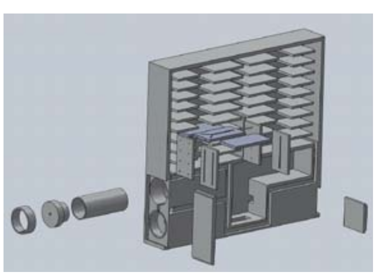

Figure 8: Exploded view of case design

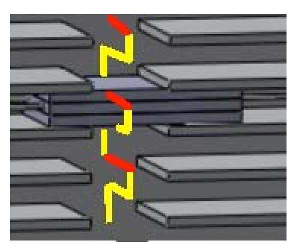

Figure 9: Stacking Design, yellow wires depicting wire connecting each fuel cell in series, the red wires depict the power generated by the fuel cell.

Stacking the fuel cells

Through stacking, each fuel cell would work as a battery, the more batteries that are in series together the more power output. In order to accomplish this they created “trays” for each individual cell. Figure 9 above is how the stack design will work in the system, the yellow wires depict the copper wire used to connect each cell in series, and the red wires depict power generated by the cell.

Manifold Design

The manifold designed will allow the stacked fuel cells to be fed at the same time with the fuel and oxidant, in parallel. The flow rate, similar to current in an electrical system, is the same when the flow is in parallel. Students designed a single pump system; all of the fuel cells will be pulled though the center manifold which will be connected to the pump. This manifold is known as the collecting manifold, it does just as the name says collects the chemicals as they exit the fuel cell, there is no need for separate channels since the chemicals have reacted with each other. As the fluid exits the chip, it will enter the first layer of the collecting manifold through connected Teflon tubing connected to the holes, as seen in Figure 10-A. The fluid from both stacks is directed into the single channel of this manifold. This differs from the feeding manifolds as it does not have a blank back.

Students used two feeding manifolds, as seen in Figure 10-B, each consisting of three layers of acrylic (similar to the collecting manifold). This first layer of the manifold (facing the fuel cell) is for feeding the cells the fuel and oxidant, it has sets of two holes that will connect directly to the fuel cells with Teflon tubing. Then, behind this first layer will be the channels that will provide the separated fuel and oxidant to the holes described in the first layer. The final layer (facing the case of the fuel cell) will simply be a solid piece of acrylic to enclose the channels in the middle layer. This differs from the collecting manifold since it is only feeding a single stack, while the collecting manifold is collecting the reactants from both stacks.

Figure 10 A and Figure 10 B show simplified four-chip manifolds, they were created for testing purposes. This version allows for four fuel cell chips to be connected and tested to verify and demonstrate the flow process of the manifold.

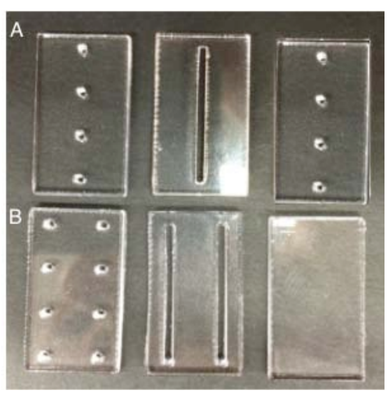

Figure 10: Two Parts of manifold system. A) Collecting Manifold: holes on each side to allow each stack to connect to the pump, only one channel is needed because the reaction has occurred. B) Feeding Manifold: each stack will have a feeding manifold; two channels are needed for the fuel and for the oxidant.

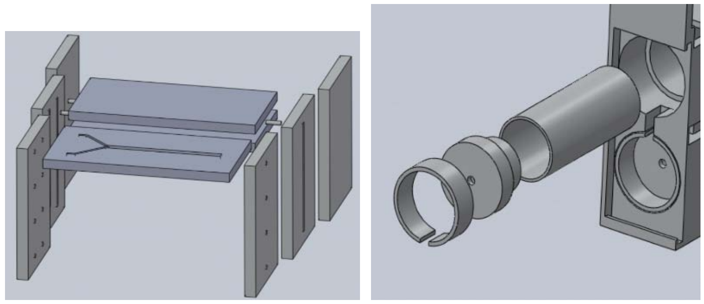

Figure 11: The manifold with connect to one stack of fuel cells (left) and Canister and collar connection

Canister Design and Connections to Manifold

According to the National Electric Code only metal canisters of 200 mL are allowed in order for the device to be approved for air travel. The canisters size is a mere 2.6 mL for each the fuel and for the oxidant. The canister is made out of Type 316 stainless steel for resistance to the sulfuric acid. Canisters needed to be designed to allow the tubing to exit. This can be seen clearly in Figure 11. Also in the figure 12, it is shown the entire plumbing schematic, including a small pump that will help the reactants to flow through the chips.

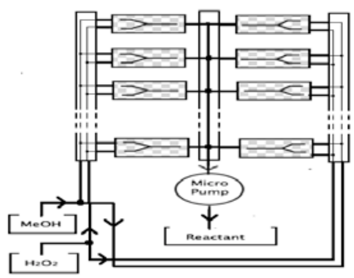

Figure 12: Plumbing schematic

Electrical Design

The OEM board is a small sized driving circuit. Developed by Bartels Microtechnik, the circuit board is specifically developed for the MP-6 piezoelectric pump. In order to control the flow rate of the micro pump you can either adjust the frequency of the OEM board, or the voltage output. The OEM board can generate up to a 235 V peak to peak voltage from a 3 to 5 V voltage supply. With no resistor value attached to the OEM board it will output a full 235 V and 100 Hz to the micro pump. In order to modify the frequency or voltage it is used a potentiometer. To operate the micro pump with a flow rate of 0-1 ml/min the micro pump and OEM board manual requires a voltage output of 80-90 volts. This was accomplished this by following the circuit diagram found in Figure 13.

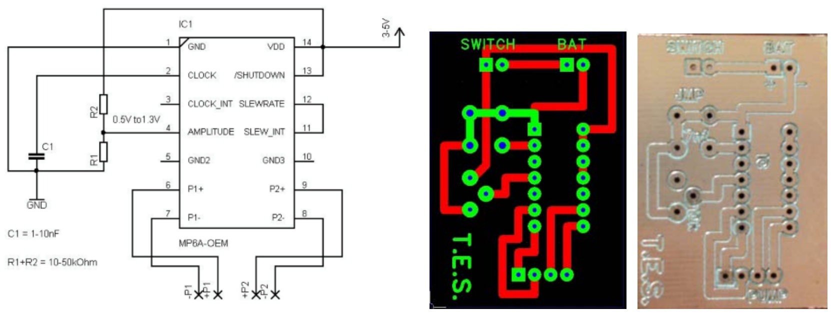

Figure 13: OEM Board with amplitude and frequency set and external components; PCB layout and milled PCB

As you can see from Figure 13, we needed to place a capacitor between the clock and ground to set the pumps frequency. Since a fuel cell needs such a small flow rate it was chosen a 10nF capacitor, actual value 7nF. The pump was attached to the control board via its four-pin connector manufactured by Molex. Having the potentiometer instead of a microcontroller was very beneficial, because by controlling the voltage going to the pump, the flow rate may be easily controlled.

The overall electrical system can be seen below in Figure 14. The power from the fuel cell stack will recharge the battery as well as power the load. The resistor R1 is used to create the voltage required to keep the battery charged. The resistor R2 is simulating the device being charged (such as a mobile phone battery) and will be a variable based on the device type (laptop battery, phone battery and so on). The diode is in place so that the battery is only feeding the OEM board. The switch will disconnect the pump when fuel cell stack is not in use.

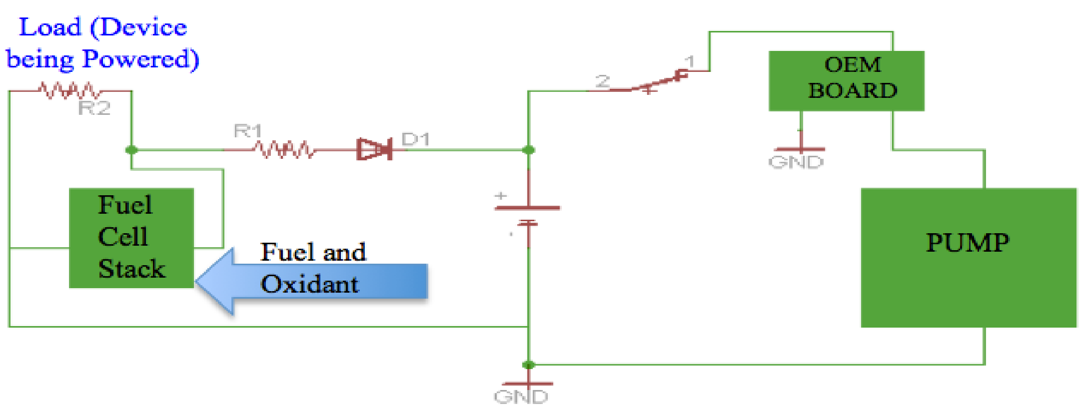

Figure 14: Electrical schematic for system

The system that was tested by the senior design team last AY, will be re-housed using a new and improved design for both the micro-chips and the overall encasing. This AY the new senior design team developed and they are in progress of developing the working prototype. The new design is depicted in the figures below. The novelty of the system consists in a “click-tight” type of micro-chips that eliminated the need of thermal bonding of the two sides of the chips a new manifold system that better feeds the chips with reactants and a new casing. Also, the new chips will incorporate the ladder design for a better efficiency.

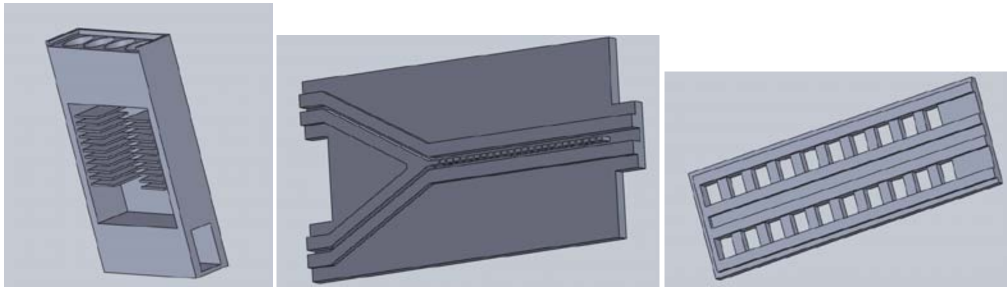

Figure 15: New system design

Future recommendations regarding the project success
The walls of channels are ten times thicker then suggested by proof of concepts in the literature, due to prototyping constraints, i.e., use of a laser cutter rather than photolithography to pattern the chips Also, using photolithography would also allow to create a ladder design developed by Weiwei Huo et al, this could increase the overall power density of the stack by 30%. This design adapted is attempted by a new team of students during this current AY 2014-2015. Another improvement could be done by using as fuel and oxidant pair a Vanadium redox compound rather than the methanol and hydrogen peroxide as currently is used (E. N. Kjeang 2009). Formulation of the vanadium solution is difficult; however the process is outlined in a paper by Kjeang et al. The use of vanadium would eliminate worry about poisoning of electrodes or using electrolysis because Toray Carbon Paper (Kjeang 2007) is used for the electrodes. The use of vanadium redox could provide increased power densities of 20%.

Third students recommended using spectrometry to determine to fuel utilization rate at the reaction site. It is possible that since the channel is too thick then the fuel is not being utilized as efficiently. Also it is possible using a ladder design to increase reaction surface area thus utilizing the fuel very efficiently. The next step may be to design a way to recycle any fuel that is not utilized. Having a recycling system in place would lengthen the amount of time the device can be used between fill ups.

The fourth recommendation is to have a pressurized canister, and to increase the size of the canister. A pressurized system would allow all of the fuel and oxidant in the canister to be used. Fifth recommendation consists in using an injection mold machine to create the case and to allow all of the tubing, and manifolds to be integrated into the system.

Other recommendation were related to more testing using different lengths of electrodes (to determine the exact amount of wire needed to create the greatest power output), and to study the influence of flow rates, and pressures on power density of the fuel cell stack. Long term testing needs to be done to ensure that the fuel cells are capable of replacing the use of batteries.

From educational standpoint, this project was an example of translational research at undergraduate level. Students went above and beyond their regular curricula and developed a highly complex research project.

Conclusions

The development and implementation of a project of this scale and also creating a working prototype in our senior project design course is described in detail. During this endeavor, students learn, verify, and reinforce theoretical concepts by performing experiments through the project experience. In our approach we adopted the principles of the problem-learning methodology. The design experience develops the students' lifelong learning skills, self-evaluations, self-discovery, and peer instruction in the design's creation, critique, and justification. Students learn to understand the manufacturer data sheets, application notes, and technical manuals. The experience, which would be difficult to complete individually, gives the students a sense of satisfaction and the accomplishment that is often lacking in many engineering courses, using traditional teaching approaches. Furthermore, the design experience motivates student learning and develops skills required in industry. The project is used to allow students to apply fundamental engineering concepts as well as principles of engineering design. The societal impact of the project also makes students more aware of what engineering can do to address current renewable energy and sustainability issues worldwide.

This project ranked the third among the nine senior design teams of our program during last AY, while the first place in Drexel University Engineering Technology department was taken by the capstone project that ranked second on the national SME senior design competition. From the complexity and depth of the research performed this project was ranked second at tie with another microfluidic device project. While our capstone project vary in topics approached, ranging from renewable energy devices (wind turbines integrated systems, micro –power point tracker and self-powered micro weather stations) to micro-combined heat and energy storage systems, and to microfluidic devices as lab-on-a-chip for medical testing, this project stands-out as along with other research based capstone projects for their uniqueness, novelty and innovative approaches. While all our projects must have some degree of novelty incorporated, this project is based on theoretical research, and its aim being to create what is called "translational research", bridging the gap between lab research and market needs.

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