From: NYCSEF@CUNY.EDU noreply+139baab18c1b1880@formstack.com
Subject: NYCSEF Project Information - PRINT & MAIL TO NYCSEF
Date: December 8, 2019 at 10:58 PM
To: jkim11@stuy.edu

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Formstack Submission For: NYCSEF Project Information 2020
Submitted at 12/08/19 10:58 PM

ProjectID:	562458213
Project Title::	Highly Mesoporous Carbon Aerogel as Catalyst Support in Proton Exchange Membrane Fuel Cells
Your Name:	Eric Kim
NYCSEF Project Category:	EN
Your Email Address::	jkim11@stuy.edu
Is your project an INDIVIDUAL or TEAM project?:	Team
Did you conduct your study at a Registered Research Institution?:	Yes
Provide the name of the institution in which you worked.:	Stony Brook University
Your sponsoring teacher's name.:	Mee Kyung Han
Provide the name of your mentor.:	Miriam Rafailovich
Your sponsoring teacher's email address.:	hanmk89@gmail.com
Provide your mentor's email address.:	miriam.rafailovich@stonybrook.edu
Does your project display require electricity at the fair?:	Yes
Provide a brief description of your project below.:	We synthesized a novel mesoporous, high surface area aerogel, as a low cost & high efficiency alternative to existing catalyst support in PEMFC.
Where does your interest conducting this study come from?:	Make hydrogen cars cheaper to reduce number of gasoline cars and reduce pollution.

Below describe the rationale of your project in 750 words or less. Italics, super & subscripts, and special characters are not available on this form. Please exclude them for the entry below and feel free to include a properly formatted document as part of your hard copy, mail-in application.:	Proton exchange membrane fuel cells (PEMFC) have recently seen interest as a prospective new energy conversion system [1]. The development of alternative energy sources has been of focus to decrease the emission of greenhouse gases from the burning of fossil fuels [2-4]. The fuel cell's applications are diverse, ranging from transport, stationery, medical, and more [5-6]. PEMFCs can be utilized as efficient chemical converters especially in transport vehicles, which is largely attributed to their high efficiency, high power density, and low operating temperature [7-10]. The cell's primary component is the MEA, which includes a membrane and electrodes, which facilitates the chemical process of the oxygen reduction reaction (ORR) and the hydrogen oxidation reaction (HOR) [11]. Some challenges need to be addressed to further enhance the fuel cell's potential in the scientific community, though, including its lower durability and higher cost compared to their combustion engine counterparts. One method of mitigating these issues is to utilize supported catalysts with lower noble metal loadings. Carbon materials possess unique structural and electrical properties which make it suitable for use as a catalyst support in PEMFC. A high mesopore volume is desirable in catalyst support to ensure contact between the catalyst metal and the electrolyte. A number of carbon supports have been investigated, such as carbon black, carbon nanotubes, graphenes, and carbon aerogels. Carbon black, in particular, is a widely used catalyst support due to its cheap cost of production and wide availability. However, its high micropore volume, disorganized mechanical structure, and low conductivity all contribute to poor performance in PEMFC by limiting the diffusion of reactants and products. Thus, carbon black does not make efficient use of the precious metal catalyst and negates its cheaper price. Carbon nanotubes and graphenes have better electrical conductivity but are not suitable for commercialization due to their high manufacturing costs. Difficulty in platinum impregnation has also been observed in these materials. Carbon aerogels have been proposed as efficient catalyst supports due to its high electrical conductivity, high surface area, and tunable mechanical structure. One of the challenges with commercializing hydrogen fuel cell cars is the price. On average, a fuel cell car costs $60,000, and within the fuel cell, 50% of the cost is dedicated to the platinum catalyst material. High performance and low-cost PEMFC that reduces the use of platinum will bring down the price of the hydrogen car dramatically, making it more accessible to the public. According to the United States Environmental Protection Agency, motor vehicles cause 75% of carbon monoxide pollution and 27% of greenhouse gas emissions in the US. In contrast to a normal gasoline car that creates pollution, a hydrogen car simply outputs water. By bringing down the price of hydrogen cars and making it more accessible to the public, hydrogen cars will replace gasoline cars, ultimately removing a major source of pollution and moving us a step towards a greener earth.
Below describe how your research question(s), hypothesis(es) and/or goal(s) build on the research described in your project rationale in 250 words or less. Italics, super & subscripts and special characters are not available on this form. Please	Activated carbon aerogel based catalysts are novel methods used in applications in hydrogen fuel cells. Several papers have documented its use in supercapacitors and microbial fuel cells. However, the microporous properties of the activated carbon aerogels make them unsuitable for use in PEMFC. A new synthesis method was thus engineered to help further increase mesopore volume and surface area, two parameters deemed significant for PEMFC catalyst improvement supported by previous research. Synthesis of carbon aerogel has four major steps: gelation, aging, drying, and carbonization. The conventional drying method utilizes supercritical fluid drying to maintain the pore structure and mesoporosity while removing the solvent. However, supercritical drying requires the use of several expensive components which drives up the cost of production. Alternative drying methods have been observed such as freeze-drying and template-based method. Yet, these methods

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involve numerous chemical processing techniques and result in high density, microporous carbon aerogels. Furthermore, previous research has shown that these methods also yield low electrochemically active surface areas, resulting in low support conductivity and fuel cell performance.
In this research, an efficient yet inexpensive synthesis method of carbon aerogel and activated carbon aerogel as catalyst support for PEMFC was devised using ambient drying to reduce the costs as an alternative to the traditional supercritical-drying process.

Part A: Below describe in detail your research methods, data analysis and conclusions. Please refer to page 31a of the NYCSEF Rules for further

3.08 g of resorcinol and 0.016 g of sodium carbonate were dissolved in 50.4 mL of water. The mixture was magnetically stirred for 20 minutes. 0.51 mL of 37% wt formaldehyde solution was added to the mixture and stirred for an additional 5 minutes. The mixture was heated in a sealed container at 50 °C for 24 h and 85 °C for 48 h. The R-F gel was washed with excess amounts of acetone, solvent exchanging every 24 h. The gel was then dried in a vacuum oven at 100 °C. The organic gel was carbonized and activated in a Lindberg Blue M Tube Furnace. Equal amounts of organic R-F aerogel were loaded into two ceramic boats. Both boats were carbonized under an N2 atmosphere at 800 °C for 2 h at a heating ramp of 10 °C/min. After pyrolysis, the furnace was allowed to cool to 300 °C. One boat was taken out to cool to room temperature and the other was activated under CO2 atmosphere at 900 °C for 2 h at a heating ramp of 10 °C/min. The carbon was ground to obtain a fine powder. 100 mg of carbon powder was dispersed into 80 mL of DI water. The mixture was then stirred for 20 minutes and further sonicated for another 20 minutes. 2.6 mL of 0.1 M H2PtCl6 was added to the solution drop by drop under continuous magnetic stirring. The mixture was sonicated for 20 minutes. A stoichiometric excess of 0.6 M NaBH4 was dispersed drop-wise as the reducing agent and sonicated for 1 h. The solution was finally filtered using a Buüchner funnel and washed

Does your project involve vertebrate animals?: No

Does your project involve human subjects?: No

Does your project involve potentially hazardous biological agents?: No

Does your project involve hazardous chemicals, activities or devices?: Yes

The risk assessment of the project was done with a Qualified Scientist, Dr. Miriam Rafailovich, by filling out the Risk Assessment Form before experimentation. The form was reviewed and approved by the same Qualified Scientist.
Resorcinol can cause acute toxicity, skin irritation, and serious eye damage. Chloroplatinic acid hexahydrate can cause severe skin burns & eye damage and may cause allergy or asthma symptoms if inhaled. Formaldehyde is flammable, carcinogenic; it can cause skin irritation and serious eye damage. Sodium Carbonate causes serious eye irritation. Sodium borohydride is toxic; it can ignite spontaneously in contact with water, cause severe skin burns & eye damage, and damage fertility or the unborn child. Prolonged contact with the 5% Nafion solution can cause skin irritation. IPA is flammable and can cause eye irritation. Keep away from heat, and keep the container closed. Due to the high voltages

information. Do not insert tables or graphs, formatting will not be retained. Italics, super & subscripts and special characters are not available on this form. Please exclude them for the entry below and feel free to include a properly formatted document as part of your hard copy, mail-in application.:

several times with DI water. Desired Pt powder was obtained after heating at 80 °C overnight. 50 mg of catalyst powder was mixed with 222 mg of 15% Nafion solution, 0.53 mL of DI water, and 2.5 mL of IPA. The solution was mixed overnight to form the catalyst ink. The ink was applied onto the 5 cm2 papers of Sigracet 29 BC carbon paper using a spray gun. The papers were placed onto a heating plate to keep the surface temperature of the paper at 85 °C to evaporate the excess liquid. Finally, electrodes with the desired Pt loading of 0.1 mg/cm2 were obtained for both cathode and anode sides. The membrane electrode assembly was prepared by putting the current collector, electrodes, and a 5 cm2 Nafion 117 membrane together. Nitrogen adsorption and desorption measurements were carried out with the NOVAtouch LX2. EDXRF elemental analysis was conducted using a Rigaku NEX DE. The analysis was conducted in a helium atmosphere. TEM imaging was conducted using a JEOL JEM 1400 Transmission Electron Microscope. The prepared MEA was tested in a fuel cell test station from Fuel Cell Technologies, Inc. Electrochemical tests were conducted in four different environments: 60 °C H2/air, 60 °C H2/O2, 80 °C H2/air, and 80 °C H2/O2. A standard accelerated stress test was conducted on all the MEAs for 10,000 cycles to assess the durability of the MEA: H2 atmosphere for the anode and N2 atmosphere for the cathode at 80 °C. The protocol consists in jumping between two potentials, 2 seconds at 0.6 V and 2 seconds at 0.96 V. The nitrogen adsorption data was analyzed using NLDFT modelling on SAEIUS. The data was then plotted using MATLAB to see the visual characteristics of the graph. The EDXRF data was plotted using the Rigaku NEX DE software, then extrapolated. The pore sizes of the TEM imaging was extracted using ImageJ, and the data from ImageJ was plotted on a histogram using MATLAB. The fuel cell results and accelerated stress test data were graphed using MATLAB.

Enter you answers below. Refer to pages 18-20 of the NYCSEF Rules for Hazardous Chemicals, Activities or Devices.:

in the tube furnace to generate high temperatures, there is a risk of electrocution, fire, and severe burns.
To reduce risks, when using resorcinol, chloroplatinic acid, formaldehyde, sodium carbonate, sodium borohydride, Nafion solution, or IPA, wear personal protective equipment such as gloves, goggles, and lab coats, avoid eating or drinking when using chemicals, and wash skin thoroughly after use of the chemical. Chemicals will be kept in safe temperature conditions. Operations on all chemicals will be performed in a fume hood. It is important that Sodium borohydride is handled under inert gas, protected from moisture, and prevented from contacting water. The tube furnace must be grounded with no loose wires, and protective clothing is required. During fuel cell testing, H2 and CO detectors will be used to monitor the levels of gas. In the case of hazardous H2 and CO concentrations, alarms will sound, and occupants will leave the room until it is deemed to be safe to return.
Sharps will be disposed of in a cardboard container to prevent possible damage and risk. General hazardous chemicals will be sent to a licensed professional waste disposal service or burned in a chemical incinerator with an afterburner and scrubber. Materials related to nanoparticles will be put into plastic bags for disposal to prevent contamination and inhalation of toxic chemicals.

[1] Shimpalee, S., Lilavivat, V., Van Zee, J. W., McCrabb, H., & Lozano-Morales, A. (2011). Understanding the effect of channel tolerances on performance of PEMFCs. International Journal of Hydrogen Energy, 36(19), 12512–12523. https://doi.org/10.1016/j.ijhydene.2011.06.146
[2] Meinshausen, M., Meinshausen, N., Hare, W., Raper, S. C. B., Frieler, K., Knutti, R., … Allen, M. R. (2009). Greenhouse-gas emission targets for limiting global warming to 2 °C. Nature, 458(7242), 1158–1162. https://doi.org/10.1038/nature08017
[3] McCarthy, R., & Yang, C. (2010).

List at least 5 major references below. Italics, super & subscripts are not available on this form. Please exclude them for the entry below and feel free to include a properly formatted document as part of your hard copy, mail-in application.:

Determining marginal electricity for near-term plug-in and fuel cell vehicle demands in California: Impacts on vehicle greenhouse gas emissions. Journal of Power Sources, 195(7), 2099–2109. https://doi.org/10.1016/j.jpowsour.2009.10.024
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[6] Staffell, I., Scamman, D., Velazquez Abad, A., Balcombe, P., Dodds, P. E., Ekins, P., … Ward, K. R. (2019). The role of hydrogen and fuel cells in the global energy system. Energy & Environmental Science, 12(2), 463–491. https://doi.org/10.1039/C8EE01157E
[7] Peighambardoust, S. J., Rowshanzamir, S., & Amjadi, M. (2010). Review of the proton exchange membranes for fuel cell applications. International Journal of Hydrogen Energy, 35(17), 9349–9384. https://doi.org/10.1016/j.ijhydene.2010.05.017
[8] Rosli, R. E., Sulong, A. B., Daud, W. R. W., Zulkifley, M. A., Husaini, T., Rosli, M. I., … Haque, M. A. (2017). A review of high-temperature proton exchange membrane fuel cell (Ht-pemfc) system. International Journal of Hydrogen Energy, 42(14), 9293–9314. https://doi.org/10.1016/j.ijhydene.2016.06.211
[9] Staffell, I., Scamman, D., Velazquez Abad, A., Balcombe, P., Dodds, P. E., Ekins, P., … Ward, K. R. (2019). The role of hydrogen and fuel cells in the global energy system. Energy & Environmental Science, 12(2), 463–491. https://doi.org/10.1039/C8EE01157E
[10] Zhang, T., Wang, P., Chen, H., & Pei, P. (2018). A review of automotive proton exchange membrane fuel cell degradation under start-stop operating condition. Applied Energy, 223, 249–262. https://doi.org/10.1016/j.apenergy.2018.04.049
[11] de Bruijn, F. A., Dam, V. A. T., & Janssen, G. J. M. (2008). Review: Durability and degradation issues of pem fuel cell components. Fuel Cells, 8(1), 3–22. https://doi.org/10.1002/fuce.200700053

Provide your abstract below. Italics, super & subscripts are not available on this form. Please exclude them for the entry below and feel free to include a properly formatted document as part of your hard copy, mail-in application.:

Carbon aerogel possesses unique structural and electrical properties, such as high mesopore volume, large specific surface area, and high electrical conductivity, which make it suitable for use as catalyst support in Proton Exchange Membrane Fuel Cell (PEMFC). In this study, we present a novel synthesis of highly mesoporous carbon aerogel via ambient-drying and investigate its application in the fuel cell. The structural effects of activation on carbon aerogel will also be discussed. The TEM and XRF, NLDFT and BJH analysis were carried out to observe the morphology and pore structure. Pt on carbon aerogel and activated carbon aerogel show efficient activity in both ORR and HOR reactions compared to Pt on Vulcan XC-72, with increases up to 715% and 195% in specific power density, respectively. The enhanced performance of carbon aerogel is attributed to its large specific surface area and high mesopore to micropore ratio. Accelerated stress tests show that carbon aerogel has comparable durability with Vulcan XC-72, while activated carbon aerogel is less durable than both materials. Thus, this mesoporous carbon aerogel provides an efficient, cost-reduced alternative to existing microporous carbon material as catalyst support in PEMFC.

Have you reviewed all of your responses?:

Yes

Do you understand that by clicking submit, you will not be able to revise or edit your application?:

Yes