Small Business Innovation Research (SBIR) Projects

SBIR PHASE I (OFFICE OF SCIENCE, BASIC ENERGY SCIENCES)

General Techniques for Increasing Packing Density of Metal-Organic Frameworks for Enhanced Volumetric Storage of Hydrogen

NuMat Technologies
8025 Lamon Avenue, Skokie, IL 60077

Metal-organic frameworks are porous materials with great potential in several adsorption-based applications. For metal-organic frameworks to realize their potential in gas storage applications, including in fuel cell electric vehicles, these materials must be densified. This SBIR grant will focus on the densification and commercialization of metal-organic frameworks for onboard hydrogen storage in fuel cell electric vehicles.

High-Density Hydrogen Storage in Space-Filling Polyhedral Sorbents

NextGen Battery Technologies
1901 N. Moore St. Suite 1200, Arlington, VA 22209

NextGen will develop space-filling polyhedral adsorbent microliths that allow for high material packing densities in conventionally manufactured gas cylinders due to their small size (<0.5 cm), while retaining high porosities for rapid filling and discharge of the tank, and improved thermal conductivity. NextGen will demonstrate the hydrogen storage capabilities of this readily scalable technology on three classes of sorbent materials: activated carbons, metal-organic framework materials, and porous polymers, showing that it truly is a “materials-agnostic” solution.

Development of Novel Compaction Regimes for Hydrogen Storage Materials

E&G Associates, Inc.
100 Cherokee Blvd. Suite 332, Chattanooga, TN 37405

Current technology for hydrogen storage requires high-pressure systems that are too large and costly to be viable for transportation. This Phase I SBIR project’s objective is to develop a compact material-based solution, which allows high-volume hydrogen storage in a small footprint, making hydrogen-powered vehicles more feasible.

New Fluorinated Ionomers for Enhanced Oxygen Transport in Fuel Cell Cathodes

Compact Membrane Systems
335 Water Street, Newport, DE 19804

Compact Membrane Systems, Inc. has identified a family of ionomer materials that have very high oxygen permeability and are anticipated to have improved polymer electrolyte membrane fuel cell performance compared to industry standards. The Phase I program will focus on synthesizing and characterizing varied compositions (equivalent weights) of these ionomer materials and formulation into ionomer dispersions. Thin membranes will be fabricated from the dispersions and their oxygen permeances will be measured. Selected ionomers will be tested in membrane electrode assemblies and compared to industry standards.

Novel Fluorinated Ionomer for Polymer Electrolyte Membrane Fuel Cells

Giner, Inc.
89 Rumford Avenue, Newton, MA 02466-1311

Novel ionomers can lower catalyst layer transport resistances. This leads to improved fuel cell performance, especially under low-platinum and high-current-density operating conditions. The overall objective of this Phase I project is to design, synthesize, and characterize novel fluorinated ionomer for polymer electrolyte membrane fuel cell cathodes. The ionomers will demonstrate higher permeability to gases (oxygen and hydrogen) and low or no anion adsorption on platinum. Also, electrode morphology and structures will be correlated with fuel cell performance.

New Approaches to Improved Polymer Electrolyte Membrane Fuel Cell Catalyst Layers

Tetramer
657 South Mechanic Street, Pendleton, SC 29670

A viable solution to reduce the transport resistances in the catalyst layers is to create new ionomers that can provide good ion and oxygen transport needed to accomplish high-performing fuel cell catalysts. Characterization of transport properties of ionomers for various molecular architectures is the key step in the effort to create and identify the optimized polymer structure. Using this approach, we propose to develop, optimize, and demonstrate improved fuel cell catalyst ionomers based on new molecular architectures that will have dramatic improvements in performance and durability compared to current ionomers such as perfluorosulfonic acid materials.

Development of Innovative Gas Diffusion Layers for Polymer Electrolyte Membrane Fuel Cells

AvCarb Material Solutions, LLC
2 Industrial Avenue, Lowell, MA 01851

In this program AvCarb Material Solutions takes a multi-faceted approach to cost-effectively alter state-of-the-art fuel cell gas diffusion layer designs in a manner consistent with mass production, specifically focusing on improved water management and thermal/electrical properties.

High-Performance Gas Diffusion Layer

pH Matter, LLC
655 Singletree Drive, Columbus, OH 43229

In the proposed project, pH Matter, LLC will demonstrate a surface treatment approach that creates super-hydrophobic gas diffusion layers without compromising other important properties; the Phase I project will demonstrate gas diffusion layers with better hydrophobicity and gas transfer properties, acceptable corrosion resistance, and improved electrical conductivity that can be made cost effectively.

Gas Diffusion Layer Media Development for Improved Polymer Electrolyte Membrane Fuel Cell Performance

Techverse, Inc.
124 Goldenthal Court, Cary, NC 27519

In the proposed project, Techverse, Inc., collaborating with ElectroChem, Inc., will continue the development of a novel Teflon impregnation technique for hydrophobic treatment of fuel cell gas diffusion layers leading to its commercialization.

Advanced Manufacturing of Gas Diffusion Layers with Highly Engineered Porosity

Glacigen Materials, Inc.
288 Pronghorn Trail, Suite 2, Bozeman, MT 59718-7064

Glacigen Materials, in collaboration with Montana State University, proposes a Phase I SBIR project that will employ a proprietary embodiment of an advanced manufacturing technique to produce an exceptionally high-performance gas diffusion layer for polymer electrolyte membrane fuel cells. In the Phase I effort, Glacigen will create a gas diffusion layer with continuously graded and aligned porosity in a polytetrafluorethylene (Teflon)-treated titanium foam through scalable casting-based methods.

Controlled Porosity and Surface Coatings for Advanced Gas Diffusion Layers

Physical Sciences Inc.
20 New England Business Center, Andover, MA 01810-1077

This Phase I effort relies on two well-known ceramic processing technologies to produce novel gas diffusion layer structures. Physical Sciences Inc. will adapt the ice-templating and tape-casting method to produce gas diffusion layers with controlled, low tortuosity pores for enhanced water transport for better fuel cell performance. A pre-ceramic polymer approach will be used to deposit the SiC coatings on carbon surfaces for improved corrosion resistance and fuel cell durability.

Nanostructured Carbon-Based Gas Diffusion Layers for Enhanced Fuel Cell Performance

TDA Research, Inc.
12345 W. 52nd Avenue, Wheat Ridge, CO 80033-1916

Gas diffusion layers will be made from inexpensive precursors. We will optimize the physical properties (e.g., hydrophobicity/hydrophilicity and pore size distribution) of the new materials. They will be characterized ex situ (for corrosion, electrical and thermal conductivity, and surface morphology) and in situ by preparing membrane electrode assemblies from the most promising materials and testing their electrochemical performance under representative conditions. Based on the experimental results, we will carry out an engineering analysis to estimate cost of the new materials and compare their performance to that of current gas diffusion layers used in polymer electrolyte membrane fuel cells.

Innovative Bilayer Microporous Layer for Polymer Electrolyte Membrane Fuel Cells

Giner, Inc.
89 Rumford Avenue, Newton, MA 02466-1311

Giner proposes to create a new bilayer microporous layer-based design with combined pore size gradient and hydrophilic/hydrophobic gradient to control the water transport more effectively at both high and low humidity conditions. The introduction of a hydrophilic sublayer on top of a hydrophobic microporous layer will strengthen the driving force of water removal with minimized risk of dehydration in the catalyst layer and membrane.

Novel Membranes for Electrochemical Hydrogen Compression Enabling Increased Pressure Capability and Higher Pumping Efficiency

Xergy, Inc.
299 Cluckey Drive, Ste. A, Harrington, DE 19952

Xergy/Rochester Polytechnic Institute are developing membranes for high-pressure (875 bar) electrochemical hydrogen compression. Research and development efforts will include synthesis of novel ionomer and membrane chemistries followed by experimental evaluation to assess their mechanical strength under high pressure differentials.

Novel Sulfonated Block Copolymers for Efficient Electrochemical Hydrogen Compression

Sustainable Innovations
111 Roberts Street, Suite J, East Hartford, CT 06108

Sustainable Innovations Inc. and Rensselaer Polytechnic Institute are teaming to evaluate new ionic polymer membranes developed at Rensselaer Polytechnic Institute in Sustainable Innovations' electrochemical hydrogen separation and compression concepts. Gaia Energy Research Institute will provide techno-economic analysis of the new membrane manufacturing costs. The overall goal of this project is to enhance the reliability of electrochemical hydrogen compression by improving the durability of membranes.

SBIR PHASE II (OFFICE OF SCIENCE, BASIC ENERGY SCIENCES)

Multi-Functional Catalyst Support

PH Matter, LLC
6655 Singletree Dr., Columbus, OH 43229-1120

Hydrogen fuel cells are of interest for automotive applications because they produce zero emissions. However, fuel cells currently suffer from the high cost associated with precious metal electrode materials and long-term durability issues associated with voltage transients. In the proposed project, pH Matter will synthesize and demonstrate the performance of next-generation fuel cell electrode catalysts. The materials will outperform current precious metal catalysts in terms of cost, efficiency, and durability during operation. The unique properties of these materials allow them to be chemically resistant to degradation mechanisms suffered by traditional catalysts.

Novel Hydrocarbon Ionomers for Durable Proton Exchange Membranes

NanoSonic, Inc.
158 Wheatland Drive, Pembroke, VA 24136-3645

The objective of this project is to develop and demonstrate high-temperature hydrocarbon-based membranes that meet the chemical, thermal, and mechanical properties necessary for the demanding environments within a fuel cell vehicle. The approach involves the synthesis of novel, high-molecular-weight aromatic hydrocarbon membranes that possess polar moieties along the polymer backbone and pendant quaternary ammonium groups. During Phase I of this SBIR program, NanoSonic has manufactured a new class of durable, free-standing high-temperature hydrocarbon-based polymer electrolyte membranes as a low-cost alternative to expensive perfluorosulfonic acid ionomer-based membranes. The ionomers are mechanically tough and display high dimensional stability and low swelling. These innovative, structurally robust membranes exhibit fuel cell performance at 120°C with zero humidification. During the Phase II program, a series of novel phosphoric acid-imbibed poly (thioether benzonitrile) copolymers shall be evaluated per DOE's 2020 technical targets for membranes for transportation applications.

New Approaches to Improved Polymer Electrolyte Membrane Electrolyzer Ion Exchange Membranes

Tetramer Technologies, LLC
657 South Mechanic Street, Pendleton, SC 29670-1808

Electrolyzer systems produce high-value hydrogen on demand and on site via electrochemically splitting water. This Phase IIB project is directed at lowering electrolyzer cell costs while improving performance of the membrane. Tetramer Technologies, LLC has developed a new membrane molecular architecture, which during Phase II demonstrated equivalent or better performance to the current Nafion materials at 50% lower cost. These attributes directly address the DOE electrolyzer cost and performance targets. Key attributes of Tetramer's technology vs. the current Nafion electrolyzer membranes are improved physical performance properties, 50% lower hydrogen permeability, and equal or higher conductivity. This technology will provide thinner membranes that can lower costs and increase performance directly through decreased ionic resistance and indirectly through the reduction of the overall cell potential. The Phase IIB activities are focused on optimizing membrane performance, further lowering costs, scaling up manufacturing of the down-selected polymer membrane material, and initializing commercialization, culminating in the demonstration of the Tetramer membranes in stacks in prototype electrolyzer system units.

Flexible Barrier Coatings for Harsh Environments

GVD Corporation
45 Spinelli Place, Cambridge, MA 02138-1046

Many reliability problems stem from plastic and elastomer seals employed in hydrogen systems that leak and degrade because of the extreme-temperature, high-pressure, and high-wear hydrogen environments. There is a critical need for improved materials that can enable seals to operate reliably at both extreme temperatures ($-40°C \leq T \geq 200°C$) and high hydrogen pressures (>875 bar). Materials also need to withstand harsh environmental wear from repeated use. GVD Corporation proposes to utilize hydrogen gas barrier coatings deposited on such seals to shield them from hydrogen permeation and enable reliable, long-term operation. These barrier coatings are based on GVD's novel thin film vapor deposition technology. In GVD's process, an inorganic-organic multilayer barrier coating is fabricated from the vapor phase and grown directly on the surface of the elastomer seal. The coating deposits uniformly and conformally over three-dimensional seals and gaskets. Furthermore, these coatings are highly flexible and stable at 200°C. In Phase I and II, GVD demonstrated technical feasibility of the concept by depositing flexible, well-adhered barrier and lubricious coating stacks on elastomeric and rigid substrates. These coatings survived temperatures up to 200°C while reducing permeability to helium by >60% (equivalent to a 70%–90% reduction in hydrogen permeability). During Phase IIA, GVD will optimize these materials for large-scale manufacturing and for use in hydrogen dispensers.

Diode Laser Sensor for Contaminants in Hydrogen Fuel

Southwest Sciences, Inc.,
1570 Pacheco St, Suite E-11, Santa Fe, NM 87505-3993

Low concentrations of contaminants in hydrogen fuel can foul or damage fuel cells in hydrogen fuel cell vehicles. Currently there is little monitoring of hydrogen quality at filling stations as there is no instrumentation available to continuously perform this function at the station. In this project, a portable diode laser sensor is being developed that will be able to perform these measurements at filling stations. The sensor will provide fast measurements so that each vehicle fill can be monitored. In the Phase I project, the feasibility of measuring hydrogen contaminants at desired levels and with a fast time response was demonstrated. Measurements were performed on low levels of carbon monoxide, carbon dioxide, and methane in hydrogen. In Phase II, the number of gases detected will be expanded to include ammonia, hydrogen sulfide, and water vapor, among others identified as critical by stakeholders. A prototype instrument will be developed and tested at a state quality assurance laboratory and a hydrogen fuel station. A contaminant detector for hydrogen fuel is needed to prevent fouling of hydrogen fuel cell vehicle engines. A laser instrument for the detection of hydrogen contaminants at fuel stations will be developed in this project.

SBIR PHASE I (OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY)

Detection of Micron-Scale Flaws through Nonlinear Wave Mixing

Luna Innovations
301 1st Street, SW, Suite 200, Roanoke, VA 24011

Luna is developing an approach to detect micrometer-scale flaws in pressure vessels for hydrogen storage. Luna's approach will rely on nonlinear interactions between mixed acoustic waves to detect flaws. The approach focuses on electromagnetic acoustic transducer technology to allow non-contact inspections and rapid surface scanning. During Phase I, Luna focused on assessing the feasibility of identifying micrometer-scale flaws in steel alloys using non-collinear wave mixing through a breadboard system.

Highly Efficient Smart Tanks for Hydrogen Storage

TDA Research, Inc.
12345 W. 52nd Ave., Wheat Ridge, CO 80033

The commercial success of fuel cell electric vehicles requires significant reductions in the cost of hydrogen fueling. Current fueling stations require precooling equipment that chills the hydrogen to -40°C; this is needed to offset the temperature rise caused by compression during fueling to keep the compressed tank's operating temperature below its maximum operating temperature of 85°C. Reducing or eliminating the precooling requirement will reduce the cost of delivered hydrogen significantly. TDA Research proposes to develop a smart hydrogen storage tank that incorporates novel cooling schemes to quickly dissipate/absorb the heat of compression and keep the hydrogen gas temperature well below the hydrogen tank design temperature of 85°C with minimal impact on the cost, weight, volume, fill time, and well-to-powerplant efficiency. TDA's design maximizes the heat transfer area and the heat transfer coefficients to quickly dissipate the heat throughout the refueling process. TDA will design and carry out sub-scale proof-of-concept tests of the smart tank design at the bench scale to demonstrate that we can carry out refueling from any charge state and ambient temperature conditions, eliminating the precooling requirements at the station. We will also complete a preliminary design of the smart hydrogen storage tank for fuel cell electric vehicles and compare it against the DOE baseline 700-bar system.

Phase Change Material Subsystem for Temperature Reduction during Fast Fill

Strategic Analysis, Inc.
4075 Wilson Blvd, Suite 200, Arlington, VA 22203

Growth in the fuel cell electric vehicle market beyond early adopters will require significant reductions in the cost of hydrogen fueling. During fueling, hydrogen is precooled to -40°C to reduce the peak temperature rise in the tank to <85°C. About 15% of the station cost is due to the precooling equipment. Precooling to these temperatures also increases performance requirements of the hydrogen dispensers, which account for 14% of station cost and increased maintenance frequency. A materials-based solution that takes advantage of the latent heat of changing phase from solid to liquid along with engineered high-surface-area heat transfer supports will be developed. Previous approaches to phase change material heat mitigation prevented the tank walls from exceeding 85°C but did not provide adequate surface area to prevent the gas temperature from exceeding 85°C. The current project will address this shortcoming by developing low-cost, high-surface-area, in-tank supports integrated with a phase change material to efficiently couple the excess gas thermal energy to the phase change material to limit the total gas temperature to <85°C. The resulting product will be a tank insert that absorbs excess heat during refueling such that no precooling equipment at the station is required.

Thermally Conductive 700-bar Composite Tank for Hydrogen Storage

ADA Technologies, Inc.
11149 Bradford Road, Littleton, CO 80127

Precooling equipment accounts for about 15% of the cost of hydrogen fueling stations. Precooling is needed to maintain the tank's temperature under 85°C as heat is generated during the quick fill-up. ADA proposes to incorporate advanced materials into the design and fabrication of thermally conductive smart hydrogen tanks and reduce or eliminate the need for hydrogen precooling. In Phase I, the thermally conductive liner material will be manufactured and tested for strength, thermal conductivity, and hydrogen permeability at the coupon level. A thermally conductive overwrap will also be defined theoretically based on the existing carbon fiber-based products.

SBIR PHASE II (OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY)

Emergency Hydrogen Refueler for Individual Consumer Fuel Cell Vehicles

Skyhaven Systems, LLC
2 Park Drive, Unit 4, Westford, MA 01886

Skyhaven Systems, LLC is developing an emergency hydrogen refueler that can be stored in the vehicle trunk and used by the consumer to refill the vehicle if they run out of hydrogen fuel away from a hydrogen fueling station. A chemical hydride and water conduit system was developed and demonstrated in a Phase I program to safely react producing hydrogen gas with the requisite purity for a fuel cell vehicle. Material and refueler optimization focused on reacting 100% of the chemical hydride to hydrogen in a refueling period on the order of 15 minutes. Operational prototype hydrogen refuelers will be developed in the Phase II project that can produce 750 g of hydrogen gas to refill a fuel cell vehicle for a 50-mile driving range. The Phase II project will focus on material optimization, refueler design, codes and standards, hazardous materials and reliability assessment, manufacturing of the refueler, and prototype testing.

Cross-Polarized Near-Ultraviolet/Visible Detector for In-Line Quality Control of Polymer Electrolyte Membrane Materials

Mainstream Engineering Corporation
200 Yellow Place, Rockledge, FL 32955-5327

Mainstream is developing a commercializable, in-line quality control device with a single detector and two cross polarizers to identify defects and log defect location in membrane materials manufactured for polymer electrolyte membrane fuel cells. The experimental approach uses near-ultraviolet/visible light transmission techniques.

Ionomer Dispersion Impact on Advanced Fuel Cell and Electrolyzer Performance and Durability

Giner, Inc.
89 Rumford Avenue, Newton, MA 02466-1311

Previous work at Los Alamos National Laboratory has demonstrated improved fuel cell performance and durability using nonaqueous ionomer dispersions in the electrode. In this project Giner will translate this work to industrially relevant processes and materials, including new lower-equivalent-weight ionomers. Giner will develop low-cost roll-to-roll processes for membrane casting and electrode coating using these nonaqueous ionomer dispersions and validate these technologies for commercial applications in advanced fuel cell and electrolyzer systems.

Cryogenically Flexible, Low Permeability Thoreau's Rubber Hydrogen Dispenser Hose

NanoSonic, Inc.
158 Wheatland Drive, Pembroke, VA 24136-3645

Innovations in high-pressure (875-bar) hydrogen dispensing hoses are needed to improve reliability and reduce cost. Current dispensing hoses commonly fail multiple times a year and cost around $2,000 each. Causes of premature failure include the stresses that they experience from pressure cycling, temperature cycling (ambient to -40°C), and hydrogen embrittlement. NanoSonic is engineering a new class D hydrogen dispensing hose to survive 51,240 fills (70 fills/day, 2 years). This metal-free state-of-the-art hose is based on a unique fiber-reinforced, high-performance, cryogenically flexible polymer to resist hydrogen embrittlement, survive thermal cycles, perform consistently at pressures greater than 875 bar (H70 service, 700 bar and safety overpressure), and endure mechanical wear and fatigue at the pump. During Phase I and II, a superior class of non-electrically conductive, low-glass-transition-temperature polymer hose cores were developed that exhibit ultra-low hydrogen permeation after 180° bending in a -50°C chamber and offer an innovative path to dissipate static electricity. A novel ceramer coupling agent was also developed to enhance the strength of adhesion between the fitting and hose, and it resulted in significantly enhanced hose burst strengths. During the Phase IIB program, a down-selected hose design will be joined with a new fitting, such that is ready for commercialization.

Low-Cost Alloys for Magnetocaloric Refrigeration

General Engineering & Research, LLC
10459 Roselle St. Ste. A, San Diego, CA 92121-1527

An emerging technology for hydrogen cooling and liquefaction is magnetic refrigeration due to its high efficiency. Magnetic refrigeration utilizes the magnetocaloric effect (MCE), which refers to the temperature change in magnetic materials after they are exposed to magnetic fields. A critical challenge of developing low-cost magnetic refrigerators is the cost and availability of materials that exhibit the MCE; such materials are typically rare-earth elements. During the Phase I effort, promising low-cost, high-performance MCE materials were discovered that function at temperatures below 50 K. For reference, the temperature for hydrogen liquefaction is 20 K. Phase II will involve a simultaneous effort of optimizing processing of the sub-50 K materials to reduce cost and continuing to identify promising MCE alloys for >50 K applications. The proposed research has the potential to contribute to a fundamental understanding of MCE within nanoscience and advance the state-of-the-art in refrigeration technologies. Ultimately, materials developed will be viable for a range of applications, including hydrogen liquefaction (20 K), nitrogen liquefaction (80 K), space applications (100–200 K), and room-temperature refrigeration and air conditioning.

Hydrogen Contaminations Detection

Sustainable Innovations, LLC
111 Roberts Street, Suite J, East Hartford, CT 06108-3653

The purity requirements outlined in SAE J7219, ISO 14687-2, and ISO 14687 standards establish a three-orders-of-magnitude accuracy for the instrumentation that is necessary to detect these extremely low levels of several critical contaminants. The design and verification of the conceptual approach of a cost-effective and reliable instrument that can sample the hydrogen at the nozzle of a delivery pump, and either certify acceptability or provide a signal to shut off the fuel distribution system, is critical for enabling this technology. In addition to the extremely low levels of contaminants that need to be measured, this instrument must be robust and stable over a very large range of temperatures and pressures. Sustainable Innovations, LLC has teamed with the University of Connecticut Center for Clean Energy Engineering to develop a unique and innovative multi-channel hydrogen fuel quality monitor to detect impurities in hydrogen. The proposed design will operate on stored hydrogen and will consist of an array of sensors, each tuned to respond to critical concentrations of a specific contaminant as defined in SAE J2719. These sensors will each be calibrated at selected impurity concentration values, and the real time measurements will be compared to the "fingerprint" of these responses. Models, using algorithms verified during this program, will complete an analysis of this data and provide a "go/no-go" signal to proceed with vehicular fueling. The technical objective of this program is to define, design, fabricate, and verify operation of a hydrogen contaminant detector for use as a "go/no go" sensor at the nozzle of a high-pressure hydrogen storage/dispensing system.

Phase I focused on alloy/composite catalyst selection for each contaminant; fabrication processes; selection and verification of cell electrolyte; generating a library of electrochemical data; and development and verification of the algorithms. Phase I efforts have shown that the concept will be able to detect the contaminants. Phase II efforts will focus on furthering the concept by testing with a larger list of contaminants, identifying and developing materials for improved selectivity and response times, and developing a fieldable prototype. The essential areas of development are selection of the catalyst material; design and fabrication of miniature electrodes; electrolyte selection; electrochemical data library for each contaminant; and algorithms to compare the measured current of the test samples to baseline. Successful development of a low-cost hydrogen contaminant sensor will prove critically important in expanding markets for hydrogen used in industrial and fueling applications.