XI. Small Business Innovative Research (SBIR) Hydrogen Program New Projects Awarded in FY 2007

The Small Business Innovation Research (SBIR) Program provides small businesses with opportunities to participate in DOE research activities by exploring new and innovative approaches to achieve R&D objectives. The funds set aside for SBIR projects are used to support an annual competition for Phase I awards of up to $100,000 each for about nine months to explore the feasibility of innovative concepts. Phase II is the principal research or R&D effort, and these awards are up to $750,000 over a two-year period. Small Business Technology Transfer (STTR) projects include substantial (at least 30%) cooperative research collaboration between the small business and a non-profit research institution. For more information about the SBIR Program, including all current and recent awards, go to http://www.science.doe.gov/sbir/.

Table 1 lists the SBIR projects awarded in FY 2007 related to the Hydrogen Program. On the following pages are brief descriptions of each.

TABLE 1. FY 2007 SBIR Projects Related to the Hydrogen Program

Title		Company	City, State
XI.1	Development of a Highly Efficient Solid State Electrochemical Hydrogen Compressor (Phase I Project)	FuelCell Energy, Inc.	Danbury, CT
XI.2	Nanocrystalline Photocatalysts for Hydrogen Production from Splitting of Water by Visible Light (Phase I Project)	Materials Modification, Inc.	Fairfax, VA
XI.3	Advanced Sealing Technology for Hydrogen Compressors (Phase I Project)	Mohawk Innovative Technology, Inc.	Albany, NY
XI.4	Photoelectrochemical System for Hydrogen Generation (Phase I Project)	Physical Optics Corporation	Torrance, CA
XI.5	Active Magnetic Regenerative Liquefier (Phase I Project)	Prometheus Energy	Seattle, WA
XI.6	Nanorod Array Photoelectrochemical Hydrogen Production (Phase I Project)	Synkera Technologies, Inc.	Longmont, CO
XI.7	Hydrogen Delivery and Production; Off-Board Hydrogen Bulk Storage (Phase I Project)	TIAX, LLC	Cambridge, MA
XI.8	Nanofiber Paper for Fuel Cells and Catalyst Supports (Phase I Project)	Inorganic Specialists, Inc.	Miamisburg, OH
XI.9	Development of Fuel Cell Cathodic Catalysts: Multimetallic Alloy Nanoparticles (Phase I Project)	NSC Technology	Vestal, NY
XI.10	Catalysis - Reactive Separations: Ceramic Proton-Conducting Membrane Reactor for Steam Methane Reforming (Phase I Project)	NexTech Materials, Ltd.	Columbus, OH
XI.11	Advanced Coal Research, Hydrogen Production from Coal (Phase I Project)	H2 Pump LLC	Latham, NY
XI.12	Hydrogen Production from Coal (Phase I Project)	Materials and Systems Research, Inc.	Salt Lake City, UT
XI.13	Separation Membrane Structures for Hydrogen (Phase II Project)	Genesis Fueltech, Inc.	Spokane, WA
XI.14	High-Volume Fabrication of Hydrogen Sensor Using Intrinsically Safe Optical Sensor Platform (Phase II Project)	InnoSense, LLC	Torrance, CA
XI.15	Low-Cost Manufacturing of Sheet Molding Compound Bipolar Plates for PEM Fuel Cells (Phase II Project)	Nanotek Instruments, Inc.	Dayton, OH
XI.16	Fuel Cell Membrane Measurement System for Manufacturing (Phase I Project)	Scribner Associates Incorporated	Southern Pines, NC

PHASE I PROJECTS

XI.1 Development of a Highly Efficient Solid State Electrochemical Hydrogen Compressor

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DOE Grant No. DE-FG02-07ER84772

With the depletion of fossil fuel reserves and a global requirement to develop a sustainable economy, hydrogen-based energy is becoming increasingly important. In the transportation sector, on-board storage of pure hydrogen may be required at pressures up to 10,000 psi, with compression of the hydrogen fuel ranging from 12,000 psi or even higher. However, the level of maturity of current hydrogen compressor technology is not adequate to meet these requirements. Existing compressors are inefficient and have many moving parts, resulting in significant component wear and therefore excessive maintenance. This project will develop an efficient, low-cost, solid-state electrochemical hydrogen compressor based on polymer electrolyte membrane (PEM) technology. Phase I will design, fabricate, and demonstrate an advanced, low-cost, solid-state, PEM hydrogen compressor cell capable of compressing hydrogen from 50 psi to 2,000 psi. In Phase II, the effort will be extended to develop electrochemical cell architectures capable of compressing hydrogen up to 12,000 psi.

XI.2 Nanocrystalline Photocatalysts for Hydrogen Production from Splitting of Water by Visible Light

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DOE Grant No. DE-FG02-07ER84778

Hydrogen has been widely considered as a clean and renewable energy alternative to coal, natural gas, and other fossil fuels. A potential method for the large-scale production of hydrogen involves the photoelectrochemical splitting of water, using solar energy. Research during the last two decades has shown that metal oxide photocatalysts are effective for overall water splitting; however, most of the metal-oxide photocatalysts developed to date only function in the ultraviolet region, due to their large band gaps (>3 eV). Although a number of photocatalysts driven by visible light have been proposed as potential candidates for this purpose, a satisfactory material has yet to be devised. A successful material would need band edge positions suitable for overall water splitting, a band gap energy smaller than 2.2 eV, and stability in an aqueous solution. This project will prepare nanocrystalline, non-oxide semiconductor materials and evaluate their photoelectrochemical efficiency in the splitting of water using solar energy. In Phase I, a proprietary microwave plasma-assisted synthetic process will be used to synthesize nanopowders. A photoelectrochemical cell will be built for the reliable measurement of the efficiency of the photocatalysts. In Phase II, an efficient photocatalyst will be selected from Phase I results for further development.

XI.3 Advanced Sealing Technology for Hydrogen Compressors

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DOE Grant No. DE-FG02-07ER84779

To successfully develop the hydrogen economy, the significant cost, energy inefficiencies, and difficulties in transportation and storage must be overcome. For example, current hydrogen compression technology is not reliable and can contaminate hydrogen, both of which result in high costs. This project will develop oil-free centrifugal hydrogen compressors capable of transporting up to 1,000,000 kg/day and compressing the hydrogen from 300 to 1,000-2,000 psi, through the use of non-contacting low leakage foil seal technology. The approach includes analytical trade studies to establish design requirements, followed by an experimental program to demonstrate the ability of the oil-free foil seal technology to meet the machine requirements. Phase I will apply an existing foil seal analysis capability to enhance the foil seal design needed for use with hydrogen. Then, a sub-scale version of the enhanced seal design will be fabricated, and preliminary static testing will be conducted to verify performance. Phase II will fabricate the full-scale seal and demonstrate low leakage over a wide range of operating conditions, up to and including expected compressor pressures, surface speeds, and temperatures.

XI.4 Photoelectrochemical System for Hydrogen Generation

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DOE Grant No. DE-FG02-07ER84869

Photoelectrochemical systems produce hydrogen from water by means of special semiconductors using energy from sunlight, but they are still in the early stage of development. New materials are needed in order for these systems to take full advantage of their ability to directly generate hydrogen at low temperatures, without the use of carbon-rich materials such as natural gas or biomass. This project will develop a new photoelectrochemical system for hydrogen generation, based on proven semiconductor technology. In this approach, an electrochemically deposited A2B6 semiconductor electrode will provide an energy bandgap of 2-2.3 eV, satisfying the requirements for hydrogen-generation efficiency under solar illumination (>10%) and durability (>1,000 hr). In Phase I, the optimal structure of the semiconductor electrode and the method of electrochemical deposition will be developed. Then, the electrode will be fabricated, characterized (including evaluation of its lifetime in electrolyte), and demonstrated for the generation of the hydrogen.

XI.5 Active Magnetic Regenerative Liquefier

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DOE Grant No. DE-FG02-07ER84783

The use of cryogenic liquid hydrogen is integral to the storage, transport, distribution and use of hydrogen for the transportation sector. The power required to liquefy such cryogens is a major impediment to the production of LH_2, especially if the power for the liquefaction is supplied from the hydrogen feedstock for the liquefier. This project offers a breakthrough toward liquefier technology that can reduce capital cost by ~1/3 and increase thermodynamic efficiency by a factor of two over conventional technology.

XI.6 Nanorod Array Photoelectrochemical Hydrogen Production

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DOE Grant No. DE-FG02-07ER84871

One of the most promising sources of hydrogen, photoelectrochemical hydrogen production, or water-splitting via sunlight, is currently rendered impractical by a number of technical and economic drawbacks related to materials properties. This project will develop novel nanomaterials that will address the problems associated with the currently available materials used in photoelectrochemical hydrogen production. These novel materials will be based on a unique, three-dimensional nanostructured architecture that will enable DOE's targets for band gap, lifetime, and chemical conversion to be met or exceeded.

XI.7 Hydrogen Delivery and Production; Off-Board Hydrogen Bulk Storage

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DOE Grant No. DE-FG02-07ER84789

The use of hydrogen as a fuel for transportation and stationary power applications has been identified as a clear path toward achieving two DOE goals: reducing the nation's dependence on imported petroleum and improving the environment through the reduction of fossil-fuel-related emissions. Although a safe, efficient, and low-cost hydrogen fuel infrastructure will be needed to promote widespread hydrogen use, the low density of compressed hydrogen gas and the high energy requirements for liquefaction are major roadblocks to implementing this infrastructure. This project will develop technology for the cost-effective storage and delivery of low temperature, high pressure (LTHP) hydrogen. The approach will take advantage of the density benefits of cold, compressed hydrogen without the high energy requirements of liquefied hydrogen. Additionally, the delivery of LTHP hydrogen to a hydrogen forecourt station (i.e., "fueling station") would mitigate problems associated with heat of compression during vehicle fills and thereby enable fast, safe, and cost-effective dispensing. Phase I will investigate such issues as multistage compression, low temperature refrigeration, insulated pressure tubes for a LTHP trailer, and vehicle filling compressor requirements. Then in Phase II, the cold hydrogen will be integrated with a sub-scale forecourt compression system and tested.

XI.8 Nanofiber Paper for Fuel Cells and Catalyst Supports

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DOE Grant No. DE-FG02-07ER84799

A dramatic improvement in hydrogen fuel cell cathode performance will be needed before the technology can be considered viable and used to create a hydrogen economy. The use of carbon nanotubes as catalyst supports could produce outstanding leaps in performance and catalyst utilization, but three problems are associated with their use: (1) cost and availability, (2) no simple manufacturing method for making a practical product, and (3) its smooth basal plane surface (which provides few anchoring points for binding catalyst particles). The latter problem requires that the nanotubes be pitted or abraded using strong oxidants, in order to generate features that foster a well-dispersed catalyst distribution). This project will solve all three problems with an inexpensive ($100/lb) nanofiber that is well-suited for catalyst binding. The nanofiber will be processed into a catalyst support using a straightforward, wet-laid papermaking procedure that is ideal for continuous manufacturing. In previous work, the nanofiber was modified with special surface chemistry that promotes catalyst activity. In initial testing, a cathode made with a thin nanofiber layer exhibited over three times the catalyst utilization compared to state-of-the-art procecures. Phase I will concentrate on the cathode only, defining the best combination of nanofiber layer thickness, composition, and ionomer content. Phase II will involve both electrodes and continuous manufacturing.

XI.9 Development of Fuel Cell Cathodic Catalysts: Multimetallic Alloy Nanoparticles

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DOE Grant No. DE-FG02-07ER84843

Currently, the low activity, poor durability, and high cost of the cathode catalysts in proton exchange membrane fuel cells and direct methanol fuel cells constitute some of the major barriers to the commercialization of fuel cells. In particular, the durability of Pt-based catalysts can be compromised by sintering and dissolution, especially at high electrode potentials or under load-cycling. This project will nano-engineer multi-metallic-alloy nanoparticle catalysts with a combination of properties that will enhance activity, optimize stability, and reduce cost. Phase I work will demonstrate the feasibility of scaling-up a patented process for the production of low-cost, active, and robust catalysts for the fuel cell market.

XI.10 Catalysis - Reactive Separations: Ceramic Proton-Conducting Membrane Reactor for Steam Methane Reforming

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DOE Grant No. DE-FG02-07ER84801

Hydrogen is one of the most important reactants in the petroleum and chemical industries. The United States produces around 41 million metric tons of hydrogen annually, and the demand for hydrogen is expected to increase significantly with the building of the hydrogen economy. About 80% of hydrogen is produced through steam methane reforming of natural gas, in conjunction with the water-gas shift reaction. Consequently, distributed hydrogen production from natural gas will be an important stepping stone for the hydrogen economy, since a natural gas infrastructure is already in place. This project will develop an electrochemically-driven, ceramic membrane reactor that will combine the steps of methane reforming, the water-gas shift reaction, hydrogen separation, and hydrogen pressurization.

XI.11 Advanced Coal Research, Hydrogen Production from Coal

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DOE Grant No. DE-FG02-07ER84880

The production of hydrogen from coal will require efficient and cost effective methods to separate and purify hydrogen, while enabling the capture and, ultimately, the sequestration of carbon dioxide. Advanced membrane technologies are needed that can separate hydrogen from mixed gas streams containing impurities and that can operate over a wide range of gas compositions. This project will develop technology for using electrochemical hydrogen pumps to separate hydrogen from coal-to-hydrogen production streams. Phase I will consist of a proof-of-principle demonstration that electrochemical pumping can separate hydrogen from gas mixtures typical of a gasified coal process. Also, the necessary operational parameters will be defined, prior to the design of large stacks in Phase II.

XI.12 Hydrogen Production from Coal

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DOE Grant No. DE-FG02-07ER84818

This project will develop a high temperature electrochemical device to produce hydrogen directly from a coal fuel. The device will build upon the concept of the coal-assisted steam electrolyzer (CASE), which is comprised of an anode mixed with solid carbon fuel, a solid oxygen ion-conducting electrolyte, and a solid cathode. Both the cathode and anode of the CASE will show good electronic and ionic conductivity, exhibit good electrocatalytic properties, and be chemically stable under a reducing atmosphere at temperatures above 800°C. Phase I will involve the design and construction of cathode-supported CASE tubes. In particular, the electrochemical reaction sites on the anode will be increased, in order to increase the effective anodic reaction rates. In Phase II, a hybrid fuel cell-electrolyzer bundle will be designed, constructed, and evaluated for hydrogen generation directly from coal fuel.

PHASE II PROJECTS

XI.13 Separation Membrane Structures for Hydrogen

Genesis Fueltech, Inc.
528 South Cannon
Spokane, WA 99204

This project will develop a cost-effective hydrogen purifier module for the manufacture of hydrogen-producing reformers used in remote power applications, military power generation, and fuel cell transportation (hydrogen refueling stations, on-vehicle reformers for public transportation buses). Secondary applications of the purifier itself should extend to industrial processes that require hydrogen with minimal contamination.

XI.14 High-Volume Fabrication of Hydrogen Sensor Using Intrinsically Safe Optical Sensor Platform

InnoSense, LLC
2531 West 237th Street
Suite 127
Torrance, CA 90505

This project will develop a manufacturing technology for high volume production of hydrogen sensors, to address safety concerns related to the hydrogen economy infrastructure.

XI.15 Low-Cost Manufacturing of Sheet Molding Compound Bipolar Plates for PEM Fuel Cells

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This project will develop advanced fuel cell component technology and related mass production processes for batteries, automobiles, and microelectronics.

XI.16 Fuel Cell Membrane Measurement System for Manufacturing

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150 E. Connecticut Avenue
Southern Pines, NC 28387-5528

Measurement technologies for fuel cell membrane manufacturing operations will improve quality control and reduce costs. These attributes are crucial not only to the adoption of proton exchange membrane fuel cells by the automotive industry, but also to the success of U.S. transition to a sustainable, secure hydrogen-based energy system.