U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Pathways to Success:

Innovations Enabled by the U.S. Department of Energy Fuel Cell Technologies Office

November 2018

Prepared by Pacific Northwest National Laboratory for the U.S. Department of Energy Fuel Cell Technologies Office

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Table of Contents

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Summary

The purpose of the project described in this annual report is to identify and document research and development (R&D) innovations and intellectual property that resulted from U.S. Department of Energy (DOE) support through the Fuel Cell Technologies Office (FCTO) in the Office of Energy Efficiency and Renewable Energy (EERE). Patent applications, issued patents and additional investment and commercialization by private industry are indicators that can demonstrate the benefit of DOE funding. As one indicator of innovation and knowledge generation, this report identifies, analyzes, and characterizes U.S. patent applications and patent awards related to FCTO-funded R&D. Patent application data span the years 2001 to 2017 while issued patents are tracked cumulatively starting from the inception of DOE activities in 1977 through 2017. FCTO directed Pacific Northwest National Laboratory (PNNL) to perform this analysis based on the lab's previous expertise, existing databases, and familiarity with the program. PNNL used information from FCTO program and annual progress reports, and examined grants made under the Small Business Innovation Research and Small Business Technology Transfer Programs that are related to hydrogen and fuel cells.

Since FY2008, PNNL has performed annual patent searches resulting from FCTO R&D project funding and analyzed the types of patents awarded, (i.e., related to fuel cells, hydrogen production and delivery, or hydrogen storage innovations); awardee organization type (private company, national laboratory, or university); and current patent status (still used in research, available for license, licensed, or no longer being pursued). Technologies commercialized by the private sector as a result of FCTO funding were also tracked in prior years. However, in FY2017, PNNL also began investigating patent applications related to hydrogen and fuel cell technologies and attributed to FCTO-funded R&D to further understand and quantify the technical innovation and intellectual property resulting from FCTO-funded R&D. While issued patents typically reflect innovations that may have occurred several years in the past, patent applications can provide insight into the most recent innovations that are not yet patented or commercialized.

The 2017 patent analysis identified 738 awarded patents associated with research supported by FCTO dating back to 1977, with 463 patents awarded over the past 10 years. These results show a substantial increase compared to data from the 2016 report of 650 total patents, including 330 in fuel cells, 235 in hydrogen production/delivery, and 85 in hydrogen storage.[1]

The 738 FCTO awarded patents include:
- 373 fuel cell patents (51%)
- 273 hydrogen production/delivery patents (37%), and
- 92 hydrogen storage patents (12%).

Three types of organizations received the patents:
- national laboratories (268 patents, or 36%)
- private companies (346 patents, or 47%), and
- universities (124 patents, or 17%).

Private companies received the greatest number of patent awards in the fuel cell and hydrogen production/delivery areas, accounting for 50% of the fuel cell patent awards and 54% of the production/delivery patent award. The national laboratories had 60% of the awards in the hydrogen storage area. The patent award status-by-use analysis indicated that nearly half of the awarded patents (363) are currently used in ongoing R&D efforts with 165 patents available for license and a further 63 patents are currently licensed.

The PNNL patent application analysis examined all the available published application data in the United States Patent and Trademark Office online database, which covers the time period 2001 through 2017. The application analysis identified 893 patent applications related to FCTO-funded R&D. Preliminary analysis indicates that approximately 80% of these received patent awards, with an average patent lag (the time between filing and receiving a patent award) of approximately 3 years.[2] This report documents the methodology and results of both the patent and patent application analyses, and documents the specific patents and patent applications that resulted from FCTO-funded R&D.

[1] The increase in the number of patents reported from 2016 to 2017 can be attributed to both new patents awarded since the previous report was released and the introduction of new and improved patent searching methods that were developed for the patent applications analysis. Final 2016 data, presented in Chapter 3, reflects updates since the 2016 report's publication.

[2] Future analysis will further screen and characterize the patent awards identified in the 2017 patent application analysis to determine if additional patents should be added to the FCTO awarded-patent database.

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1.0 Introduction

This report documents the methodology and results of an effort to identify and characterize patent activity related to R&D funded by the U.S. Department of Energy's Fuel Cell Technologies Office (FCTO). The report includes an inventory of hydrogen and fuel cell related U.S. patents and patent applications from 1977 to 2017, providing an indicator of innovation and intellectual property development enabled by FCTO's applied R&D funding sustained over a number of years.[3] Pacific Northwest National Laboratory (PNNL) has been conducting similar analytical studies for other EERE offices for over two decades. The results presented in this report represent the findings from the PNNL effort and include the use of input and resources from FCTO. This chapter presents a brief overview of FCTO-funded R&D that is leading to innovations, and a summary of the contents of this report.

1.1 Overview of the DOE Fuel Cell Technologies Office

The Fuel Cell Technologies Office focuses on advancing a portfolio of hydrogen and fuel cell technologies through early stage applied research and technology development. Technology R&D includes hydrogen production (from diverse domestic resources including renewable, fossil, and nuclear resources), infrastructure development (including hydrogen delivery and storage), and fuel cells for transportation, stationary, and portable applications. Through the H2@Scale initiative, the office brings together stakeholders to advance affordable hydrogen utilization to increase revenue opportunities in multiple energy sectors. The program addresses key technical challenges for fuel cells and hydrogen production, delivery, and storage. While the focus is on early-stage R&D, past activities included activities to address other barriers to widespread adoption such as hydrogen codes and standards, market transformation, and manufacturing-related challenges. The research involved in solving critical technological barriers is often high risk, and can benefit from leveraging resources and skills. Therefore, FCTO encourages public-private partnerships, which include the supply chain industry, automotive and power equipment manufacturers, energy and chemical companies, electric and natural gas utilities, building designers, standards development organizations, other federal agencies, state government agencies, universities, national laboratories, and other national and international stakeholder organizations.

FCTO focuses primarily on transportation (fuel cell-powered vehicles and the associated fueling infrastructure) as well as cross-cutting R&D that can enable other applications such as stationary power generation (including primary, distributed, and backup or emergency power generation), as well as hydrogen production, delivery and storage for diverse domestic uses in manufacturing, chemical processing, or energy storage. The FCTO R&D focus areas that are relevant to technology development represented in this report include the following:

- Hydrogen Production
- Hydrogen Delivery
- Hydrogen Storage
- Fuel Cells

These four R&D focus areas are briefly summarized below.[4]

Hydrogen Production. The Hydrogen Production subprogram focuses on R&D for low-cost, highly efficient hydrogen production technologies from diverse domestic energy sources and feedstocks. FCTO is developing technologies that include advanced electrochemical water splitting (including high temperature/pressure operations and novel catalysts/membranes), direct solar water splitting (including thermochemical and photoelectrochemical processes), novel reforming processes of hydrocarbon and waste-stream feedstocks (including thermal, catalytic, and microbial-based processes), as well as hybrid systems and other innovative approaches to hydrogen production. In addition, work includes developing better catalysts and coordinating with the Office of Science on basic research, such as hydrogen production from algae and other biological systems. FCTO has also coordinated with the Office of Fossil Energy (FE) over the years on coal gasification (with sequestration) and separation processes, with the Office of Nuclear Energy (NE) on hydrogen production from thermochemical processes, and with the DOE's Joint Center for Artificial Photosynthesis (JCAP) funded

[3] Formerly the Hydrogen, Fuel Cells & Infrastructure Technologies Program, 2002-2009, and the Fuel Cell Technologies Program, 2009-2012.

[4] The particular sub-program names, objectives of, and R&D activities funded by, FCTO and its predecessor programs have changed over the years as the Office has become more focused on the goals described above and as advancements have been made in R&D. Because this report looks retrospectively at R&D innovations over the history of hydrogen and fuel cell research within EERE, the patents and the resultant and potential R&D innovations described in the remainder of this report may be broader than one would expect from examining the current FCTO efforts.

by DOE's Office of Science. More recently, FCTO has expanded its collaboration with NE to include work on hybrid nuclear systems and with the Advanced Research Projects Agency-Energy (ARPA-E).

Hydrogen Delivery. The Hydrogen Delivery subprogram focuses on R&D related to hydrogen delivery and infrastructure technologies that enable the introduction and long-term viability of hydrogen as an energy carrier for transportation and stationary power. Objectives include reducing the cost of compression, storage, and dispensing at refueling stations and stationary power facilities; reducing the cost of hydrogen transport from central and semi-central production facilities to the refueling stations and other end users; and reducing the cost of hydrogen delivery from the point of production to the point of use in vehicles or stationary power units. Efforts include applied materials research and early-stage component and process development to address technical challenges related to hydrogen embrittlement, developing new and improved materials for pipeline delivery of hydrogen, developing novel liquid and solid carrier technologies, improving compression and bulk storage technologies, and improving the efficiencies of hydrogen liquefaction. Hydrogen safety research and technical support for hydrogen codes and standards is also pursued.

Hydrogen Storage. Hydrogen Storage R&D focuses on materials and technologies for compact, lightweight, and inexpensive storage of hydrogen for automotive and stationary fuel cell applications. R&D efforts have included work to improve the performance and lower the cost of high-pressure (700 bar) compressed hydrogen storage systems for fuel cell electric vehicles (FCEVs) as well as advancing cold/cryo-compressed systems for greater volumetric energy density. Work is ongoing on materials-based hydrogen storage technologies for bulk and on-board hydrogen storage. Various research activities are being pursued, including high-capacity metal hydrides; adsorbent-based and nanostructured materials; chemical carriers; and other promising materials for low or medium pressure hydrogen storage. Coordination with the Office of Science is also noteworthy, particularly in developing a fundamental understanding of hydrogen-material interactions. FCTO also coordinates with ARPA-E, which has funded innovative materials and tank R&D for natural gas storage. Synergies between hydrogen and natural gas storage are being explored. Within the last couple of years, FCTO has coordinated efforts with EERE's Advanced Manufacturing Office (AMO) and Vehicle Technologies Office (VTO) on carbon fiber cost reduction.

Fuel Cells. Fuel Cells R&D focuses on enabling low-cost, durable, and high-performance fuel cells, primarily for transportation applications (though synergies exist with stationary applications). R&D efforts emphasize polymer electrolyte membrane or proton exchange membrane (PEM) fuel cells as replacements for internal combustion engines in light-duty vehicles as well as fuel cells for stationary power and auxiliary power applications. Research focus areas include membranes (PEM and alkaline), electrocatalysts and electrodes, membrane electrode assemblies, gas diffusion layers, bipolar plates, seals, and other aspects of fuel cell design including water management and balance-of-plant components. FCTO had included small-scale solid oxide fuel cell (SOFC) R&D for several years to complement FE's Solid Oxide Fuel Cells Program[5] on megawatt-scale SOFC power systems; however recently FCTO has shifted away from SOFC R&D. The FCTO portfolio includes diverse non-SOFC fuel-cell technology such as alkaline fuel cells, and only includes solid oxide approaches as they relate to hydrogen production/electrolysis. Work on fundamental catalysis is coordinated with the Office of Science. Coordination with ARPA-E has also been initiated, particularly in innovative areas such as alkaline exchange membranes. More recently, FCTO has initiated early-stage R&D on optimizing components (such as membranes, catalysts and electrodes) for unitized reversible fuel cells that store energy and generate power.

More information about FCTO's goals, objectives, research thrusts, and activities can be found in the FCTO Multi-Year Research, Development, and Demonstration Plan (https://energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development office-multi-year-research-development).

[5] The mission of FE's Solid Oxide Fuel Cells Program is to enable the generation of efficient, low-cost electricity with intrinsic carbon capture capabilities for (1) near-term natural gas-fueled distributed generation systems and modular coal-fueled systems and (2) long-term coal or natural gas-fueled central power systems with carbon capture and sequestration. Source: https://www.hydrogen.energy.gov/pdfs/review18/fe01_vora_2018_o.pdf.

1.2 Contents of this Report

The remaining chapters explain in more detail the methodology used for the patent awards and applications analyses and provide the results of the efforts in tables and charts. The appendices provide the list of patents and patent applications resulting from the R&D efforts undertaken by FCTO and its predecessor program.

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2.0 Approach

Two efforts have been undertaken by PNNL as part of this analysis. The first was a technology patent analysis project initiated in FY 2008 and updated annually, under FCTO's System Analysis sub-program. This effort identified hydrogen- and fuel-cell-related patents that are associated with FCTO-funded projects (or projects conducted by DOE-EERE predecessor programs) and determined the patents' current status. The original report from this effort, the August 2009 EERE report entitled *Pathways to Commercial Success: Technologies and Products Supported by the Hydrogen, Fuel Cells & Infrastructure Technologies Program,* has been updated annually from FY 2010 through FY 2017.[6] While prior-year reports included additional analysis to track patent use in emerging and commercial technologies, the current (FY2018) report focuses exclusively on patent analysis.

The second effort, initiated in December 2017, was a patent application analysis that employed a detailed search of the United States Patent and Trademark Office (USPTO) database to identify all hydrogen and fuel cell related patent applications (non-Federal and FCTO-funded). The approach taken for the patent analysis activity is summarized in Sections 2.1 and 2.2 below.

2.1 Patent Search

For the initial patent analysis conducted in FY2008, PNNL conducted several patent searches using the USPTO database. The searches included key words related to the hydrogen and fuel cell program and focused exclusively on patents for which DOE had a "Government Interest."[7,8] The resulting list contained fuel cell and hydrogen production, storage, and delivery patents dating back to 1977. The PNNL team then conducted an initial screening analysis to winnow the patent list to those likely to be associated with EERE research. (Other parts of DOE, including the Offices of Fossil Energy, Nuclear Energy, and Science, also conduct research on hydrogen and fuel cells, but those patents were not included in this study.) PNNL also worked with FCTO to incorporate the patents cited in the *DOE Hydrogen and Fuel Cells Program Annual Progress Reports* for 2002 – 2007.[9]

The next step was to obtain more information about the government's role in developing each patent and to determine its current status. The PNNL team contacted patent holders by phone or email. For large organizations (e.g., national laboratories, universities, and multinational corporations), PNNL team members were often referred to a central office within the organization, such as a technology transfer, commercialization, or legal affairs office. The PNNL team members asked the patent holders or central offices whether FCTO or EERE (or its predecessors) funded the research resulting in the patent. Patents not related to FCTO or EERE funding were removed from the list. If a patent had received such funding, the PNNL team attempted to determine the current status of the patent and place it in one of the following categories: (1) no longer being pursued for commercialization by industry nor used in research, (2) still being used in research, (3) used in a commercial product, or (4) licensed to another company.[10] As PNNL gathered technology data, additional patents associated with FCTO/EERE funding were identified and added to the list. Figure 2.1 depicts the initial patent analysis process for the hydrogen and fuel cell technologies.

[6] See https://www.energy.gov/eere/fuelcells/market-analysis-reports#mkt-pathways for prior-year reports.
[7] One search used the following search terms: "hydrogen" AND "storage" OR "transport" OR "delivery" OR "dispensing" AND "government/energy." The other search used the following search terms: "fuel cell" AND "PEM" OR "membrane" AND "government/energy."
[8] Note that the patent database has a separate field that designates whether there is a "Government Interest" in the patent. If DOE has an interest, that field says, for example, "The United States Government has rights in this invention pursuant to Contract No. […]between the United States Department of Energy and […a national laboratory or other party]." It is possible that not all of the parties with EERE-related patents correctly indicated that their patents had a "Government Interest."
[9] These reports can be found at http://www.hydrogen.energy.gov/annual_progress.html
[10] Prior-year analysis also included steps to determine whether patents used in research were part of an emerging technology or a commercial product.

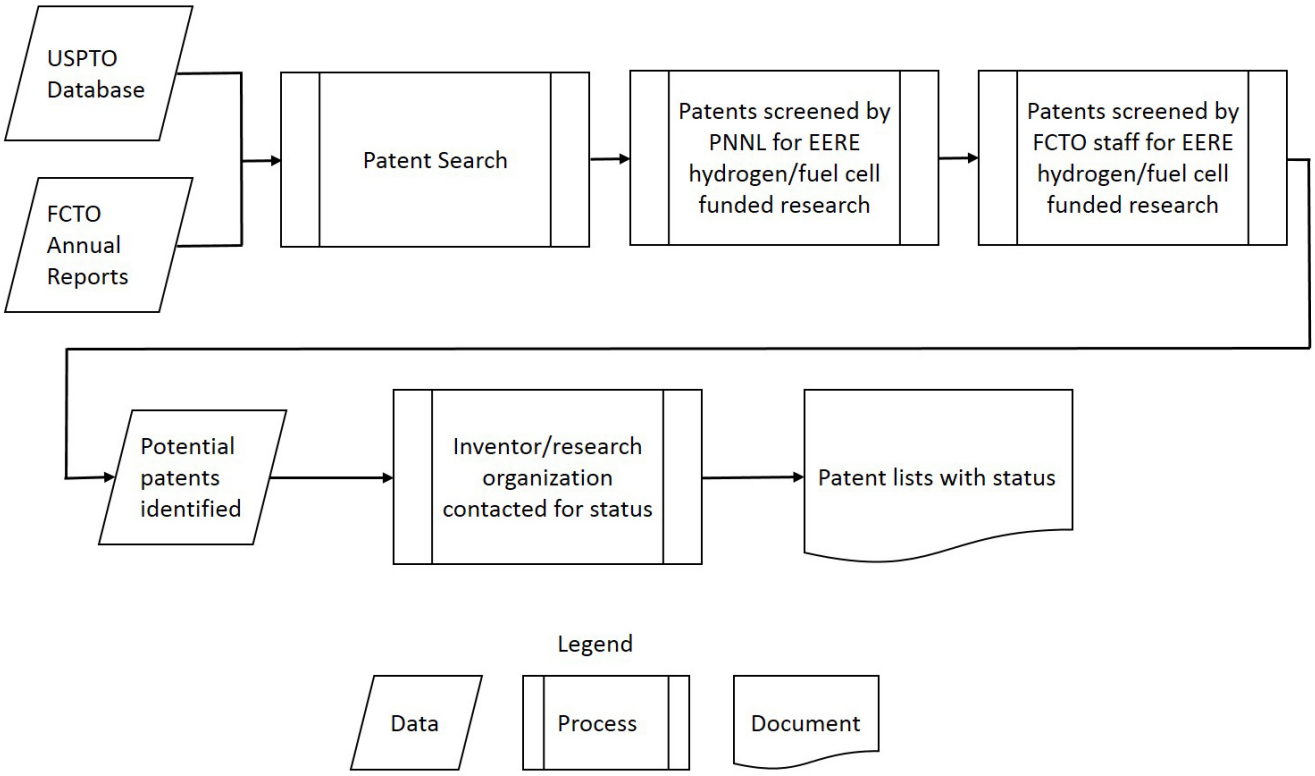

Figure 2.1 Initial Patent Analysis Process for Hydrogen and Fuel Cell Technologies

In FY 2010, PNNL updated the analysis and conducted a search through FY 2008 and 2009 Hydrogen and Fuel Cells Program Annual Progress Reports to identify any new patents issued during those years and contacted principal investigators for FCTO-funded emerging technologies and commercial products to determine if they had been awarded any new patents. In June 2010, EERE launched a Technology Commercialization Portal on its website (http://techportal.eere.energy.gov/), which features a portfolio of EERE-funded technologies available for licensing, including patents. Using the EERE Portal, the PNNL team conducted a search for patents that employed screening strategies similar to those used in the original USPTO database searches. The PNNL team contacted patent holders via phone and e-mail to determine whether or not the underlying research associated with a patent was FCTO-funded. If a patent had received such funding, its current status was obtained. In subsequent years, PNNL updated its patent search analysis using this same methodology.

The combined, cumulative results of all the patent searches are discussed in Section 3.2.

2.2 Patent Application Search

To further characterize patent activity as an indicator of innovation and knowledge generation resulting from FCTO R&D funding, PNNL conducted a U.S. patent application search in FY 2017. Results from the patent application analysis provide further insight into the amount innovation and knowledge arising from early stage R&D and the percentage of applications resulting in a patent award. The approach taken for the patent application search was similar to that used for the patent award search described in Section 2.1, with the addition of a customized, automated search of online patent resources.

To search for patent applications, PNNL used the USPTO patent and patent application online database[11], the WIPO (World Intellectual Property Organization) website and database[12], the European Patent Office (EPO) Espacenet online database[13], and other informative patent related websites and online resources. The USPTO online database contains

[11] USPTO online database http://appft.uspto.gov/netahtml/PTO/index.html
[12] WIPO website http://www.wipo.int/portal/en/
[13] European Patent Office website https://www.epo.org/index.html

published patent applications from March 2001 to the present day; applications prior to March 2001 are not available. In accordance with USPTO's pre-grant publication rules, non-provisional applications are published 18 months after the earliest effective filing date, unless non-publication is requested.[14] Therefore, patent applications filed within the last eighteen months are not available for analysis and neither are applications filed before September 1999 (i.e., not published by March 2001). Once a full non-provisional patent application[15] is filed, the USPTO examines the application against previous patents and prior art for originality and patentability. During this process, the "patent prosecution phase," the inventor will defend the application's claims against prior art. After a successful defense, a patent award is granted by the USPTO. The overall process of reviewing a non-provisional application until a patent award is granted can take several years.

During the application review process the USPTO uses a system known as the Cooperative Patent Classification (CPC) scheme to assign the application to the relevant subject or technology areas. The CPC scheme is a joint effort to harmonize the USPTO, EPO, and WIPO patent classification schemes and is updated regularly to reflect changes in technology. The CPC system arranges inventions and innovations in a hierarchal array of nine main sections that are each divided into classes, subclasses, and groups (main groups and subgroups),[16] and currently contain approximately 250,000 classifications. As an example, the CPC code for a PEM fuel is shown in Figure 2.2.[17]

"Proton Exchange Membrane Fuel Cell" CPC code = Y02E 60/521		
Section	Y	General Tagging of New Technological Developments; General Tagging of Cross-over technologies spanning over several sections of the IPC; technical subjects covered by former USPC cross reference art collections and digest
Class	02	Technologies or Applications for Mitigation or Adaptation against Climate
Subclass	E	Reduction of Greenhouse Gas [GHG} Emissions related to Energy Generation, Transmission or Distribution
Main Group (00)	60/00	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation
Subgroup	60/521	Proton Exchange Membrane Fuel Cells [PEMFC]

Figure 2.2 Example Cooperative Patent Classification (CPC) Code Levels Hierarchy

To search the USPTO and other on-line patent databases, PNNL first constructed a set of 16 CPC codes that captured every patent listed in the known FCTO patent portfolio. The USPTO patent application database was queried with these 16 FCTO patent portfolio CPC codes at the Section-Class-Subclass level so as not to eliminate relevant applications. To improve and further refine the results, PNNL developed an expanded set of full CPC codes related to hydrogen and fuel cell innovations and technologies (i.e., down to the subgroup level). The full CPC code list was compiled from numerous online CPC resources, and contained over 1500 codes in 159 subclasses and 536 groups.

The full CPC code query yielded a dataset of approximately 62,000 federal-funded and non-federal-funded patent applications. PNNL screened this dataset to remove applications not related to hydrogen or fuel cell technology or applications with a government interest other than DOE. The final dataset consisted of just over 40,000 applications, including 1,710 applications related to DOE-funded R&D. This dataset was further screened by PNNL to determine which applications were related to FCTO-funded R&D. The results of this analysis are discussed in Section 3.2.

[14] As dictated by the Code of Federal Regulations 35 U.S.C. 122. For more information visit the USPTO website https://www.uspto.gov/web/offices/pac/mpep/s1120.html

[15] "Provisional patent applications" allow an earlier filing date to be established, and a non-provisional application must then be filed within 12 months to benefit from the earlier filing date. Provisionally filed patent applications that have been abandoned are not published. The term *non-provisional* is implied hereafter.

[16] For more information visit USPTO website https://www.uspto.gov/web/offices/pac/mpep/s905.html

[17] For more details visit the USPTO website https://www.uspto.gov/web/patents/classification/cpc/html/cpc-Y02E.html#Y02E

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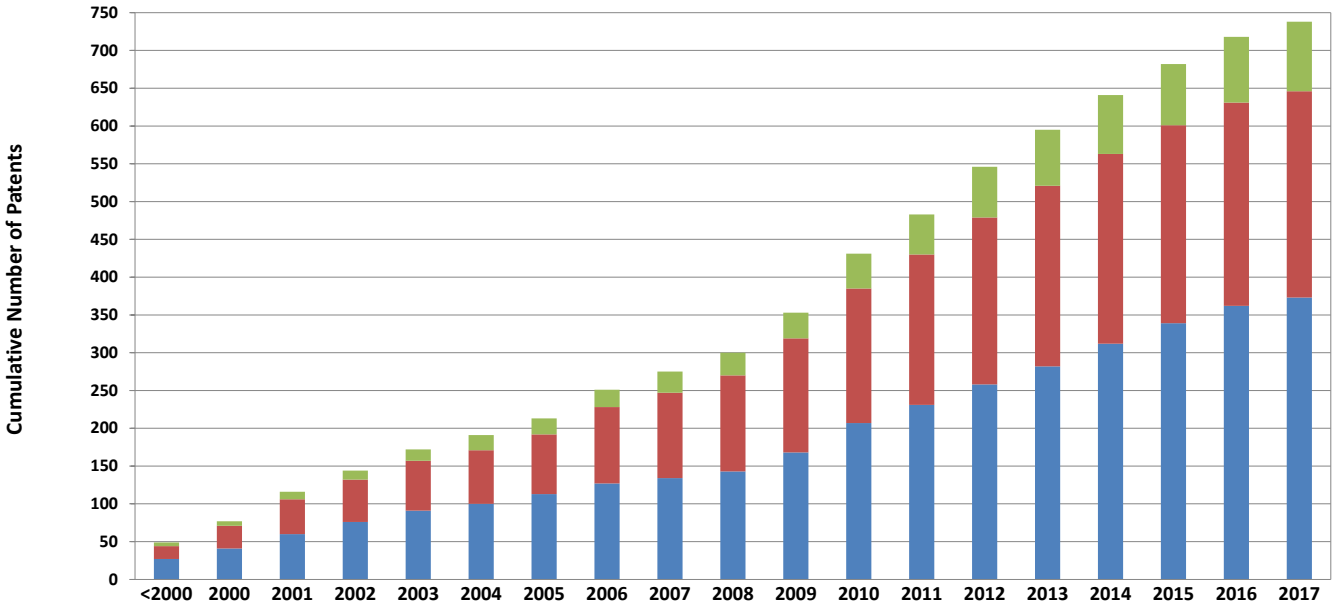
3.0 Results

The results of the efforts undertaken in the FCTO technology patent application and patent award tracking project are summarized in this chapter. Section 3.1 describes the patent search and analysis and Section 3.2 describes the patent applications search and analysis.

3.1 Patent Search and Analysis

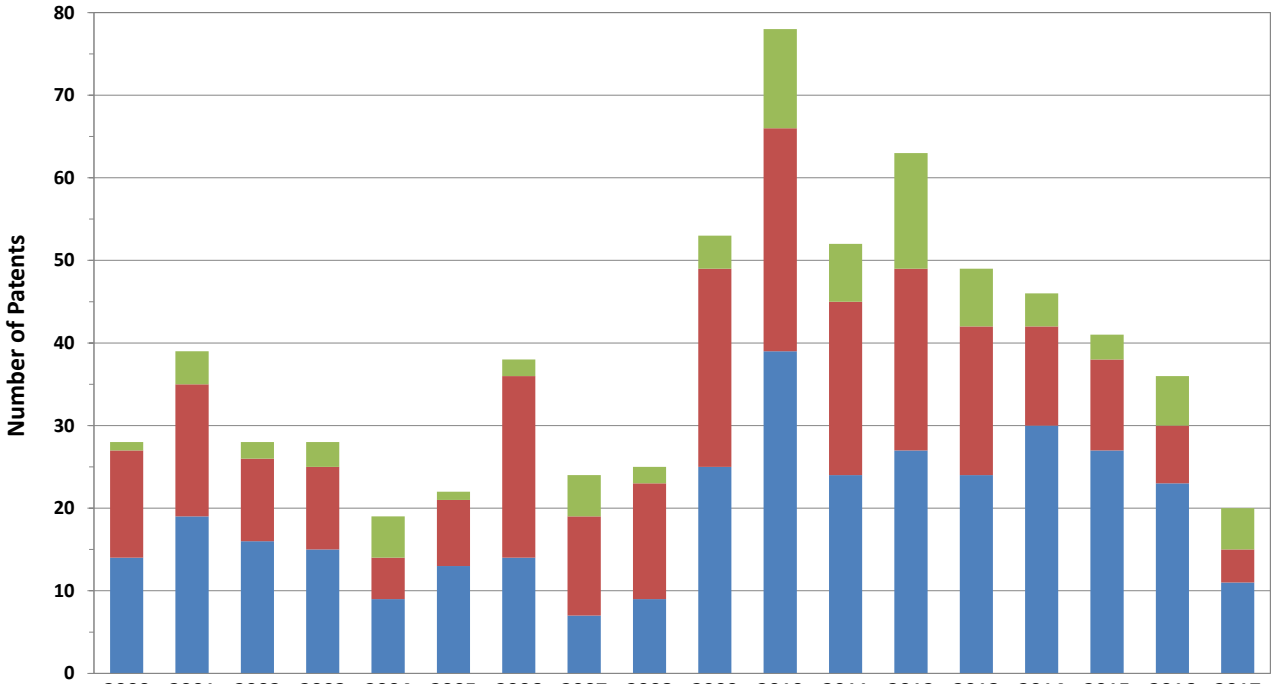
The results of the 2017 search for awarded patents related to FCTO-funded R&D are summarized below and detailed in Appendix A. Appendix A provides the full list of patents by technology area, including the patent number, award date, organization receiving the patent, patent title, description, and status. The patents are listed in chronological order from the most recent to the oldest patent for each group.

Figure 3.1 shows the cumulative number of patents awarded over time through 2017. The 738 FCTO awarded patents include 373 fuel cell patents, 273 hydrogen production/delivery patents, and 92 hydrogen storage patents. From 2007 through 2017, an average of 49 patents per year were awarded. During the same period, fuel cell, hydrogen production/delivery, and hydrogen storage patents were awarded at an average rate of 25, 17, and 7 patents per year, respectively. These average patent award rates are almost double those from the previous period of 2000 through 2007 (i.e., 28 patents per year: 13 fuel cell, 12 production/delivery, and 2 storage patents per year). The slope of the plot in Figure 3.1 shows that the number of patents awarded per year increased significantly from midway between 2008 and 2010 onwards. To date, 2010 had the largest number of patents awarded in an individual year: 39 fuel cell patents, 27 production/delivery patents, and 12 storage patents, as illustrated in Figure 3.2.



	<2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Storage	5	6	10	12	15	20	21	23	28	30	34	46	53	67	74	78	81	87	92
Production/Delivery	17	30	46	56	66	71	79	101	113	127	151	178	199	221	239	251	262	269	273
Fuel Cell	27	41	60	76	91	100	113	127	134	143	168	207	231	258	282	312	339	362	373
Total	49	77	116	144	172	191	213	251	275	300	353	431	483	546	595	641	682	718	738

Figure 3.1 Cumulative Number of Hydrogen and Fuel Cell Innovation Patents Awarded over Time (1977 - 2017)

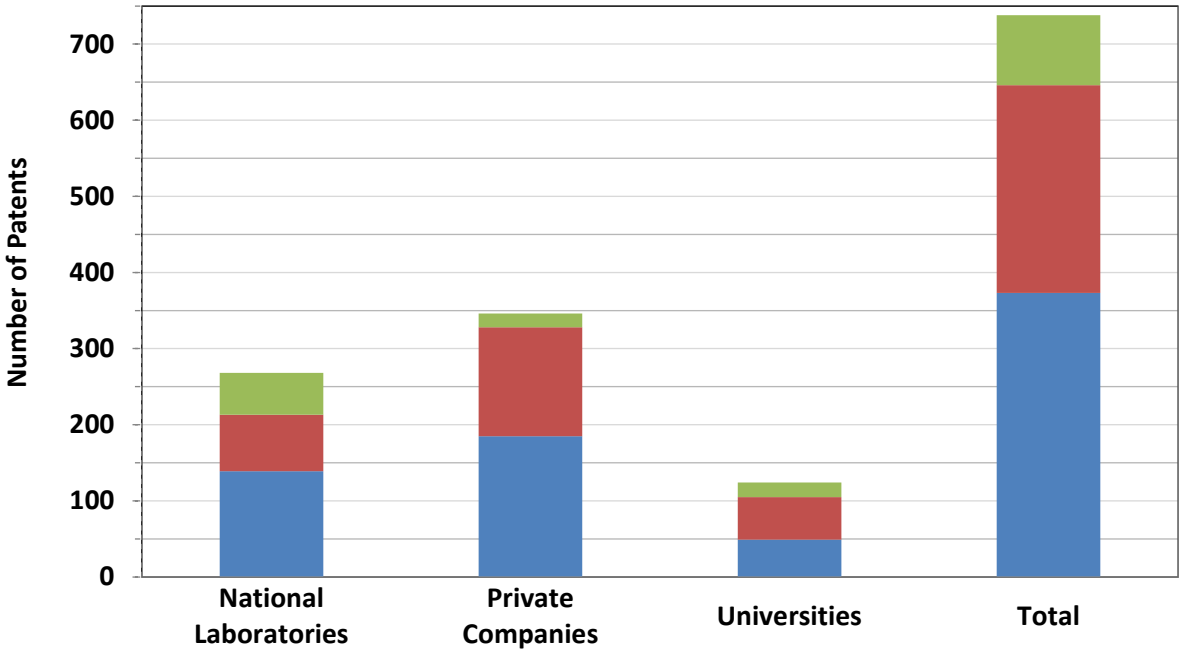


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Storage	1	4	2	3	5	1	2	5	2	4	12	7	14	7	4	3	6	5
Production/Delivery	13	16	10	10	5	8	22	12	14	24	27	21	22	18	12	11	7	4
Fuel Cell	14	19	16	15	9	13	14	7	9	25	39	24	27	24	30	27	23	11
Total	28	39	28	28	19	22	38	24	25	53	78	52	63	49	46	41	36	20

Figure 3.2 Number of Hydrogen and Fuel Cell Innovation Patents Awarded Per Year (2000 – 2017)

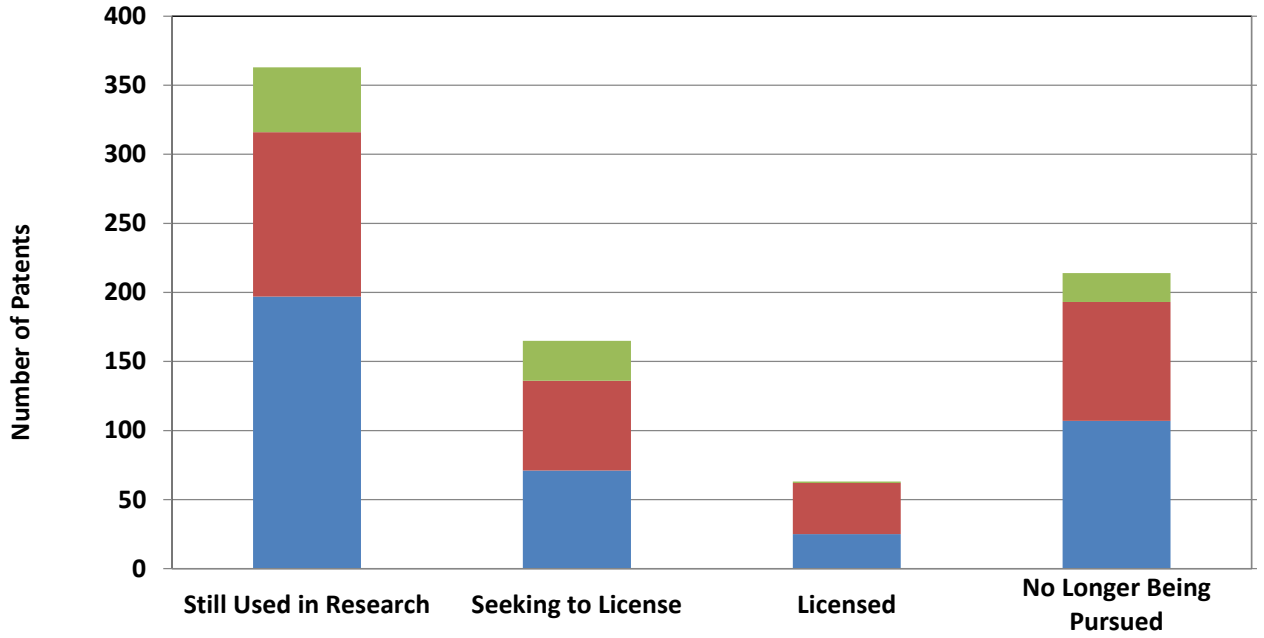
Another way to view the patent awards, shown in Figure 3.3, is by the type of organization that received the patent or the inventor's employer. Three types of organizations were identified: national laboratories 37% (268 patents), private companies 47% (346 patents), and universities 17% (124 patents). National laboratories and private companies account for 87% of all patents awarded for fuel cell technologies; private companies received 50% of the awards. In the hydrogen production/delivery area, private companies had the most patent awards (52%), followed by national laboratories (27%) and universities (21%). National laboratories account for 60% of the hydrogen storage patents, followed by universities and private companies each with 20%.

Figure 3.4 shows patent award status by use. Based on their usage status, the patents were grouped by PNNL into one or more of the following categories: used in ongoing research, seeking to license, licensed (exclusive and non-exclusive), or no longer being pursued. Nearly half of the patents (363) are still being used in research, over 20% (165) are available for license, approximately 10% (63) are licensed, and just less than 30% (214) of the awarded patents are no longer being pursued.



	National Laboratories	Private Companies	Universities	Total
Storage	55	18	19	92
Production/Delivery	74	143	56	273
Fuel Cell	139	185	49	373
Total	268	346	124	738

Figure 3.3 Type of Organization Receiving Patent Awards



	Still Used in Research	Seeking to License	Licensed	No Longer Being Pursued
Storage	47	29	1	21
Production/Delivery	119	65	37	86
Fuel Cell	197	71	25	107
Total	363	165	63	214

Figure 3.4 Status of Awarded Patents by Use

3.2 Patent Application Search and Analysis

The results of the 2017 patent application search related to FCTO-funded R&D are summarized below.

All hydrogen and fuel cell related patent applications, both non-Federal funded and FCTO funded, for the period 2001 through 2017 are shown in Figure 3.5. Overall, over 40,000 hydrogen or fuel cell-related patent applications were filed, with an average of approximately 2,400 applications filed per year.

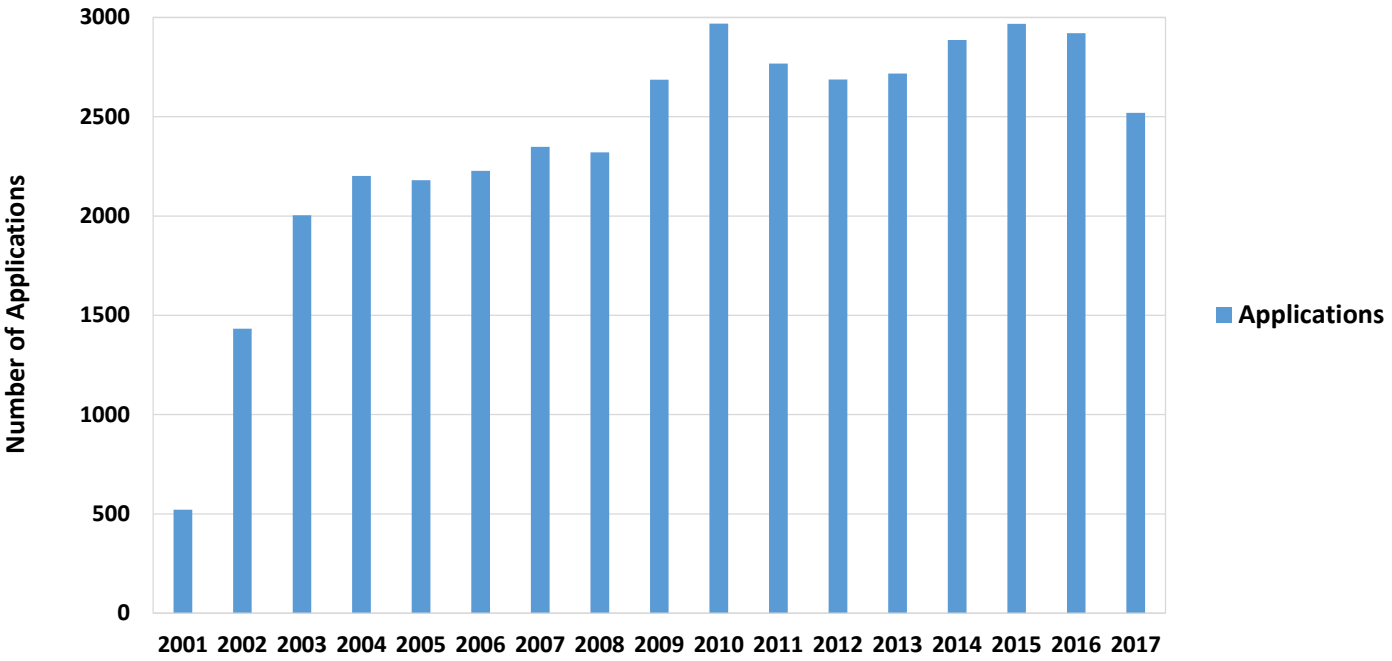
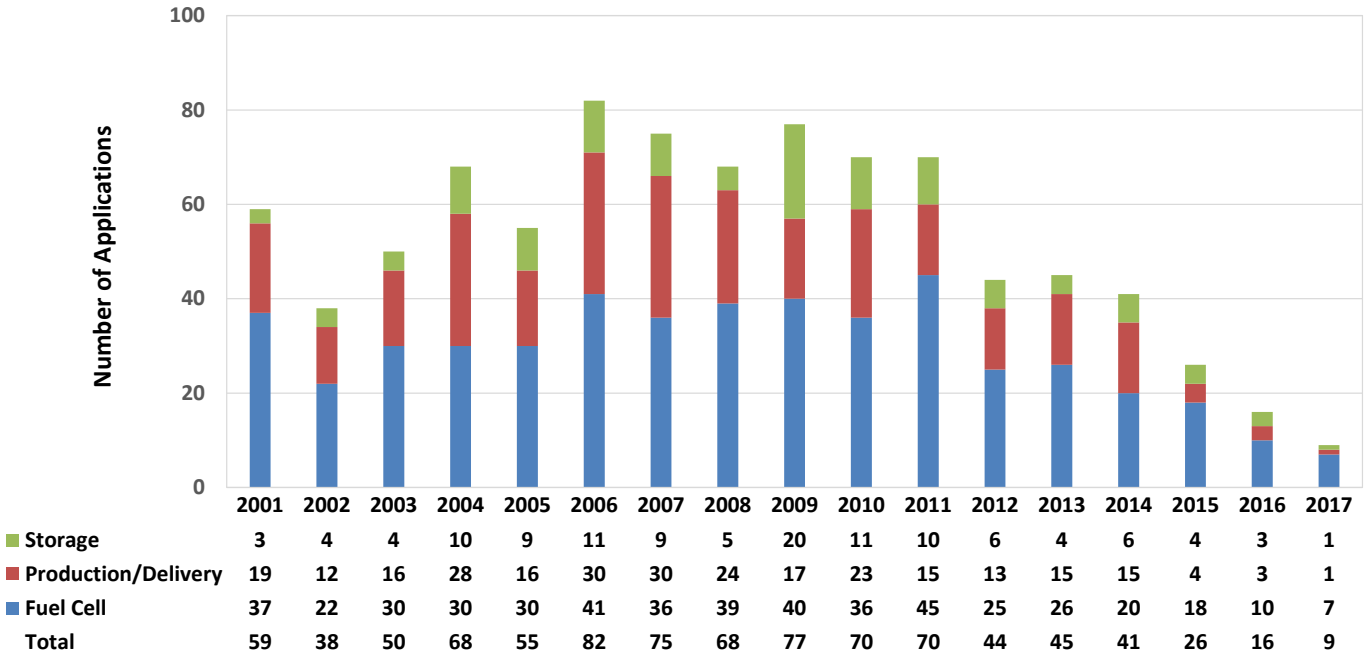


Fig 3.5 All Hydrogen and Fuel Cell Related Patent Applications, 2001 – 2017 (Non-Federal and FCTO-funded)

The annual number of patent applications related to FCTO-funded R&D for the period 2001-2017 is shown in Figure 3.6 grouped by sub-program. A total of 893 FCTO-related patent applications were filed, with 53 applications filed per year on average. The decline shown in the number of applications between 2016 and 2017 can be attributed to applications still being processed before they are published.

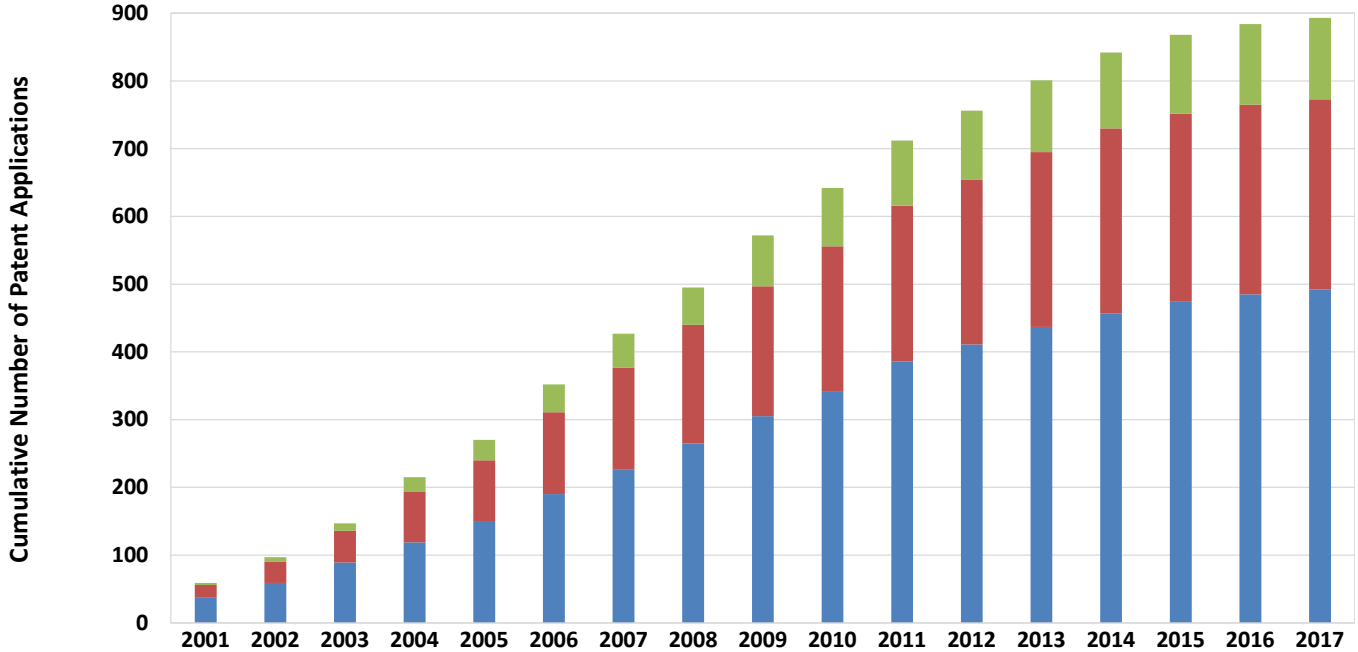
Figure 3.7 shows the cumulative plot of FCTO-related patent applications by sub-program. The 2017 total of 893 applications included 492 (55%) in the area of fuel cells, 281 (32%) for hydrogen production/delivery, and 120 (13%) for hydrogen storage. On average, 29 fuel cell, 17 production and delivery, and 7 storage applications were filed annually. The amount of intellectual property resulting from FCTO-funded R&D rapidly increases through 2012 before slowing down in recent years.

The FCTO-related applications filed by organization type are shown in Figure 3.8. Almost 55% of the applications are for fuel cell technology. Private companies and national laboratories account for almost 80% of the intellectual property, with universities accounting for just over 20% of all the patent applications.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Storage	3	4	4	10	9	11	9	5	20	11	10	6	4	6	4	3	1
Production/Delivery	19	12	16	28	16	30	30	24	17	23	15	13	15	15	4	3	1
Fuel Cell	37	22	30	30	30	41	36	39	40	36	45	25	26	20	18	10	7
Total	59	38	50	68	55	82	75	68	77	70	70	44	45	41	26	16	9

Fig 3.6 Patent Applications Related to FCTO-Funded R&D by Year (2001 – 2017)



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Storage	3	7	11	21	30	41	50	55	75	86	96	102	106	112	116	119	120
Production/Delivery	19	31	47	75	91	121	151	175	192	215	230	243	258	273	277	280	281
Fuel Cell	37	59	89	119	149	190	226	265	305	341	386	411	437	457	475	485	492
Total	59	97	147	215	270	352	427	495	572	642	712	756	801	842	868	884	893

Fig 3.7 Cumulative Patent Applications Related to FCTO-Funded R&D (2001 – 2017)

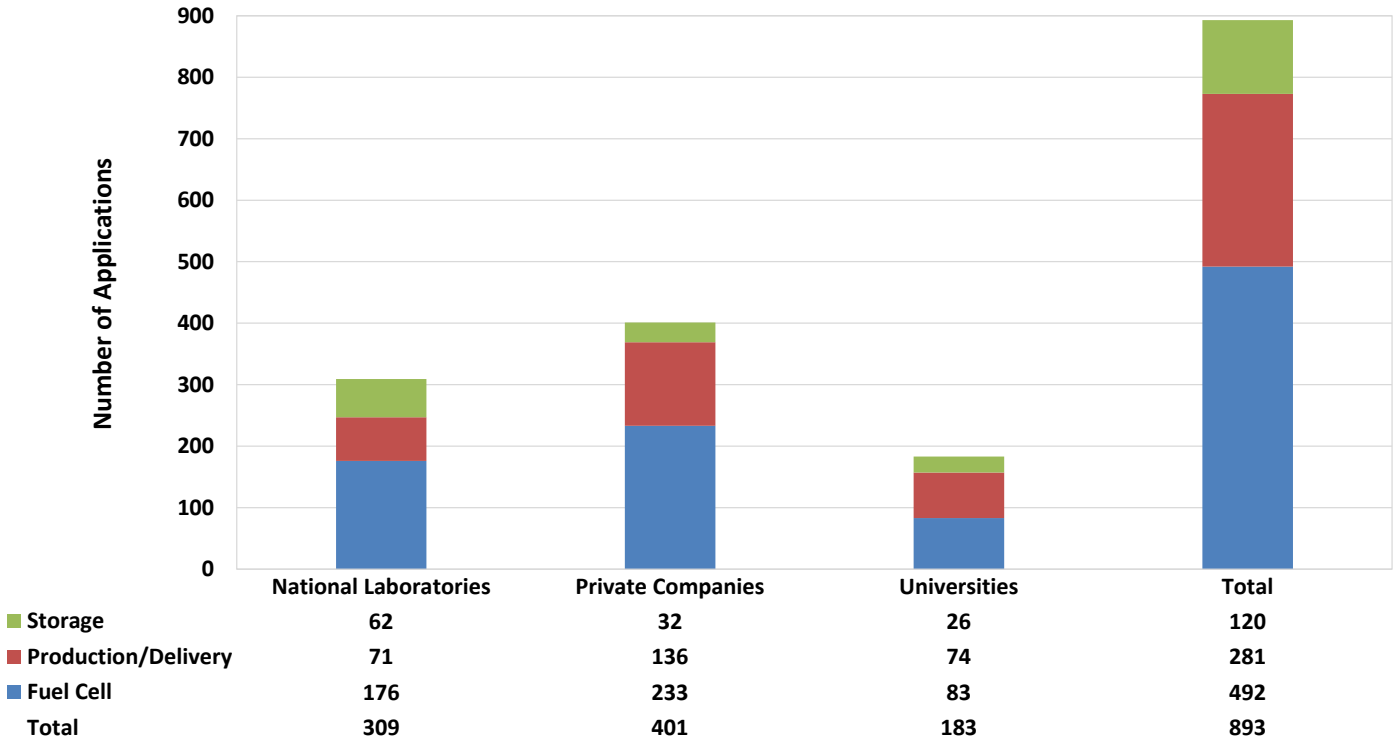


Fig 3.8 Patent Applications by Organization Type (2001 – 2017)

PNNL's patent application analysis also examined the number of applications receiving patent awards. Preliminary results indicate that for the time period 2001 – 2017, the average FCTO-related patent award percentage is approximately 80%, compared to 55% for non-federal funded applications.[18] This could be attributed to the hydrogen and fuel cell knowledge and experience of organizations and researchers who participate in FCTO-funded R&D programs and projects. Those organizations and individuals, through annual program review meetings and collaboration on projects, have a collective body of knowledge and understanding of the related technologies and innovations. This translates into thoroughly researched, well written patent applications for review by USPTO patent examiners. Similarly, patent lag time, the time between filing a patent application and receiving a patent award, is approximately 3.2 years on average for FCTO-related patent awards compared to approximately 4 years for non-federal funded patent awards. The shorter lag time for FCTO-related patents could be an indicator of the quality of the patent applications filed, i.e., well-presented and researched patents have a shorter patent prosecution process. Patent lag has also been used as an indicator of the relationship between R&D investment and innovation productivity. Long patent lag times can delay technology innovation and lengthen the time it takes to move a technology innovation into commercial use.

[18] Future analysis will further screen and characterize the patent awards identified in the 2017 patent application analysis to elaborate on these results and determine if additional patents should be added to the FCTO awarded-patent database.

Appendix A: Patent Status List[19]

[19] The status of certain patents refer to commercial and emerging technology innovations; it should be noted that FCTO has not tracked technology innovations resulting from FCTO R&D funding since FY2016.

A.1 Fuel Cell Patents Status

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,853,255	12/26/17	Brookhaven National Laboratory	Core-shell fuel cell electrodes	Membrane electrode assemblies that may include at least one gas-diffusion layer having a first side and a second side, and particle cores adhered to at least one of the first and second sides of at least one gas-diffusion layer. The particle cores include surfaces adhered to at least one of the first and second sides of at least one gas-diffusion layer and surfaces not in contact with at least one gas-diffusion layer. Furthermore, a thin layer of catalytically atoms may be adhered to the surfaces of the particle cores not in contact with at least one gas-diffusion layer.	Still being used in ongoing research.
9,825,308	11/21/17	Argonne National Laboratory	Low platinum catalyst and method of preparation	A low platinum catalyst and method for making same. The catalyst comprises platinum-transition metal bimetallic alloy microcrystallites over a transition metal-nitrogen-carbon composite. A method of making a catalyst comprises preparation of transition metal organic frameworks, infusion of platinum, thermal treatment, and reduction to form the microcrystallites and composite.	Still being used in ongoing research.
9,728,802	08/08/17	Giner Electrochemical Systems, LLC	Micromold methods for fabricating perforated substrates and for preparing solid polymer electrolyte composite membranes	In polymer electrolyte membrane (PEM) fuel cells and electrolyzers, attaining and maintaining high membrane conductivity and durability is crucial for performance and efficiency. The present invention provides novel methods using micromolds to fabricate the perforated polymer electrolyte membrane substrates. These novel methods using micromolds create uniform and well-defined pore structures. In addition, these novel methods using micromolds may be used in batch or continuous processing.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,716,279	07/25/17	Brookhaven National Laboratory	Core-shell fuel cell electrodes	Describes an electrocatalyst with at least one gas-diffusion layer having a first side and a second side, and particle cores adhered to at least one of the first and second sides of at least one gas-diffusion layer. The particle cores include surfaces adhered to at least one of the first and second sides of at least one gas-diffusion layer and surfaces not in contact with at least one gas-diffusion layer. Furthermore, a thin layer of catalytically atoms may be adhered to the surfaces of the particle cores not in contact with at least one gas-diffusion layer.	Still being used in ongoing research.
9,689,085	06/27/17	Brookhaven National Laboratory	Underpotential deposition-mediated layer-by-layer growth of thin films	A method of depositing contiguous, conformal submonolayer-to-multilayer thin films with atomic-level control is described. The process involves electrochemically exchanging a mediating element on a substrate with a noble metal film by cycling the applied voltage between the bulk deposition potential for the mediating element and the material to be deposited. Repeated desorption and adsorption of the mediating element during each potential cycle can be used to precisely control film growth on a layer-by-layer basis.	No longer being pursued.
9,669,098	06/06/17	Lawrence Berkeley National Laboratory	Metal-organic frameworks with exceptionally large pore apertures	The disclosure relates to metal organic frameworks or isoreticular metal organic frameworks, methods of production thereof, and methods of use thereof.	Still being used in ongoing research.
9,640,824	05/02/17	3M Company	Fuel cell electrodes with conduction networks	A fuel cell electrode layer may include a catalyst, an electronic conductor, and an ionic conductor. Within the electrode layer is a plurality of electronic conductor rich networks and a plurality of ionic conductor rich networks that are interspersed with the electronic conductor rich networks. A volume ratio of the ionic conductor to the electronic conductor is greater in the ionic conductor rich networks than in the electronic conductor rich networks. During operation of a fuel cell that includes the electrode layer, conduction of electrons occurs predominantly within the electronic conductor rich networks and conduction of ions occurs predominantly within the ionic conductor rich networks.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,598,769	03/21/17	Argonne National Laboratory	Method and system for continuous atomic layer deposition	A system and method for continuous atomic layer deposition. The system and method includes a housing, a moving bed which passes through the housing, a plurality of precursor gases and associated input ports. The amount of precursor gas, position of the input ports, and relative velocity of the moving bed and carrier gases enable exhaustion of the precursor gases at available reaction sites.	Licensed exclusively on 06/07/2017.
9,597,708	03/21/17	General Electric Company	Bond layer for a solid oxide fuel cell, and related processes and devices	An electrically conductive layer of material having a composition comprising lanthanum and strontium is described. The material is characterized by a microstructure having bimodal porosity. Another concept in this disclosure relates to a solid oxide fuel cell attached to at least one cathode interconnect by a cathode bond layer. The bond layer includes a microstructure having bimodal porosity. A fuel cell stack which incorporates at least one of the cathode bond layers is also described herein, along with related processes for forming the cathode bond layer.	Still being used in ongoing research.
9,570,756	02/14/17	3M Company	Fuel cell electrode with nanostructured catalyst and dispersed catalyst sublayer	Polymer electrolyte membrane (PEM) fuel cell membrane electrode assemblies (MEA's) are provided which have nanostructured thin film (NSTF) catalyst electrodes and a sublayer of dispersed catalyst situated between the NSTF catalyst and the PEM of the MEA.	Still being used in ongoing research.
9,564,643	02/07/17	Oak Ridge National Laboratory	Engineered glass seals for solid-oxide fuel cells	A seal for a solid oxide fuel cell includes a glass matrix having glass percolation therethrough and having a glass transition temperature below 650°C. A deformable second phase material is dispersed in the glass matrix.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,515,340	12/06/16	Sandia National Laboratory	Conductive polymer layers to limit transfer of fuel reactants to catalysts of fuel cells to reduce reactant crossover	A fuel cell catalyst layer is operable to catalyze a reaction involving a fuel reactant. A fuel cell gas diffusion layer is coupled with the fuel cell catalyst layer. The fuel cell gas diffusion layer includes a porous electrically conductive material that allows the fuel reactant to transfer through the fuel cell gas diffusion layer to reach the fuel cell catalyst layer. The porous electrically conductive material also conducts electrons associated with the reaction through the fuel cell gas diffusion layer. An electrically conductive polymer material is coupled with the fuel cell gas diffusion layer. The electrically conductive polymer material limits transfer of the fuel reactant to the fuel cell catalyst layer.	Still being used in ongoing research.
9,499,916	11/22/16	Lawrence Berkeley National Laboratory	Molecular molybdenum persulfide and related catalysts for generating hydrogen from water	New metal persulfido compositions of matter are described. In one embodiment the metal is molybdenum and the metal persulfido complex mimics the structure and function of the triangular active edge site fragments of MoS_2. This material is the current industry standard for petroleum hydro desulfurization, and a promising low-cost alternative to platinum for electrocatalytic hydrogen production. The molecular $[(PY5W_2)MoS_2]^{x+}$ containing catalyst can generate hydrogen from acidic-buffered water or even seawater at very low overpotential at a turnover frequency rate more than 500 moles H_2 per mole catalyst per second, with a turnover number (over a 20-hour period) of at least 19,000,000 moles H_2 per mole of catalyst.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,490,486	11/08/16	Brookhaven National Laboratory	Method for removing strongly adsorbed surfactants and capping agents from metal to facilitate their catalytic applications	A method of synthesizing activated electrocatalysts with a morphology of a nanostructure. The method includes safely and efficiently removing surfactants and capping agents from the surface of the metal structures. The method includes synthesis of nanoparticles in polar or non-polar solution with surfactants or capping agents and subsequent activation by CO-adsorption-induced surfactant and capping agent desorption and electrochemical oxidation. The method produces activated macroparticle or nanoparticle electrocatalysts without damaging the surface including breaking, increasing particle thickness or increasing the number of low coordination sites.	No longer being pursued.
9,468,923	10/18/16	Northwestern University	Porous polymer networks and ion-exchange media and metal-polymer composites made therefrom	Porous polymeric networks and composite materials comprising metal nanoparticles distributed in the polymeric networks are provided. Also provided are methods for using the polymeric networks and the composite materials in liquid-and vapor-phase waste remediation applications. The porous polymeric networks, are highly porous, three-dimensional structures characterized by high surface areas. The polymeric networks comprise polymers polymerized from aldehydes and phenolic molecules.	Research complete; seeking to license.
9,463,428	10/11/16	3M Company	Palladium-based catalyst and support systems	Described are catalyst compositions, oxidizable-gas burner systems, methods of oxidizing oxidizable gas, and methods of preparing catalyst compositions and oxidizable-gas burner systems.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,455,451	09/27/16	Lawrence Berkeley National Laboratory	Membrane-electrode structures for molecular catalysts for use in fuel cells and other electrochemical devices	Water soluble catalysts, (M) meso-tetra (N-Methyl-4-Pyridyl) Porphinepentachloride (M=Fe, Co, Mn & Cu), have been incorporated into the polymer binder of oxygen reduction cathodes in membrane electrode assemblies used in PEM fuel cells and found to support encouragingly high current densities. The voltages achieved are low compared to commercial platinum catalysts but entirely consistent with the behavior observed in electroanalytical measurements of the homogeneous catalysts. A model of the dynamics of the electrode action has been developed and validated, allowing the MEA electrodes to be optimized for any chemistry that has been demonstrated in solution. It has been shown that improvements to the performance will come from modifications to the structure of the catalyst combined with optimization of the electrode structure and a well-founded pathway to practical non-platinum group metal catalysts exists.	Research complete; seeking to license.
9,437,880	09/06/16	Pacific Northwest National Laboratory	Method of manufacturing a fuel cell stack having an electrically conductive interconnect	A method of manufacturing a solid oxide fuel cell stack having an electrically conductive interconnect, including the steps of: (a) providing a first fuel cell and a second fuel cell, (b) providing a substrate having an iron-chromium alloy, (c) depositing a layer of metallic cobalt over a portion of substrate surface, (d) subjecting the layer of metallic cobalt to reducing conditions, (e) then exposing the remaining portion of the layer of metallic cobalt to oxidizing conditions for a predetermined time and temperature, such that the surface portion of the layer of metallic cobalt is oxidized to cobalt oxide, forming the electrically conductive interconnect having a layer of metallic cobalt sandwiched between a surface layer of cobalt oxide and the layer of cobalt-iron-chromium alloy, and (f) sandwiching the substrate between the first and second fuel cells.	No longer being pursued.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,431,670	08/30/16	3M Company	High durability fuel cell components with cerium salt additives	A fuel cell membrane electrode assembly is provided comprising a polymer electrolyte membrane with bound anionic functional groups and cerium cations. Fuel cell membrane electrode assemblies can be comprised with polymer electrolyte membranes bound with anionic functional groups, a portion of which can be in acid form and neutralized by cerium cations.	No longer being pursued.
9,425,461	08/23/16	Los Alamos National Laboratory	Rejuvenation of automotive fuel cells	A process for rejuvenating fuel cells has been demonstrated to improve the performance of polymer exchange membrane fuel cells with platinum or ionomer electrodes. The process involves dehydrating a fuel cell and exposing at least the cathode of the fuel cell to dry gas (nitrogen, for example) at a temperature higher than the operating temperature of the fuel cell. The process may be used to prolong the operating lifetime of an automotive fuel cell.	Still being used in ongoing research.
9,421,521	08/23/16	Argonne National Laboratory	Nanosegregated bimetallic oxide anode catalyst for proton exchange membrane electrolyzer	A surface segregated bimetallic composition of the formula $Ru_{1-x}Ir_x$ wherein $0.1 \leq x \leq 0.75$, wherein a surface of the material has an Ir concentration that is greater than an Ir concentration of the material as a whole is provided. The surface segregated material can be produced by a method including heating a bimetallic composition of the formula $Ru_{1-x}Ir_x$, wherein $0.1 \leq x \leq 0.75$, at a first temperature in a reducing environment, and heating the composition at a second temperature in an oxidizing environment. The surface segregated material can be used in electrochemical devices.	Still being used in ongoing research.
9,419,300	08/16/16	3M Company	Proton conducting materials	These materials are useful for fuel cell applications such as the manufacture of fuel cell electrodes, proton exchange membranes (PEMs), catalyst additives or in tie layers designed to be thermally and chemically robust while operating within a fuel cell's harsh environment. At higher temperatures they conduct protons, with significantly higher levels of bound acidic groups, while in a low hydration state. Methods of making the materials are also described.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,406,943	08/02/16	Argonne National Laboratory	Electrocatalysts using porous polymers and method of preparation	A method of producing an electrocatalyst article using porous polymers. The method creates a porous polymer designed to receive transition metal groups disposed at ligation sites and activating the transition metals to form an electrocatalyst which can be used in a fuel cell. Electrocatalysts prepared by this method are also provided. A fuel cell which includes the electrocatalyst is also provided.	Still being used in ongoing research.
9,379,393	06/28/16	Nanotek Instruments, Inc.	Carbon cladded composite flow field plate, bipolar plate and fuel cell	A carbon-cladded composite composition for use as a fuel cell flow field plate or bipolar plate. The composition comprises a core composite layer sandwiched between two clad layers, a conductive carbon or graphite material (e.g., carbon nanotubes, nano-scaled graphene plates, graphitic nanofibers, and fine graphite particles) and the core composite layer comprising of a matrix resin and a conductive filler.	Research complete; seeking to license.
9,350,026	05/24/16	Argonne National Laboratory	Nanofibrous electrocatalysts	A nanofibrous catalyst and method of manufacture. A precursor solution of a transition metal-based material is formed into a plurality of interconnected nanofibers by electro-spinning the precursor solution with the nanofibers converted to a catalytically active material by a heat treatment. Selected subsequent treatments can enhance catalytic activity.	Still being used in ongoing research.
9,343,758	05/17/16	Protonex Technology Corporation	Solid oxide fuel cell systems with hot zones having improved reactant distribution	A Solid Oxide Fuel Cell (SOFC) system having a hot zone with a center cathode air feed tube for improved reactant distribution, a catalytic partial oxidation (CPOX) reactor attached at the anode feed end of the hot zone with a tail gas combustor at the opposing end for more uniform heat distribution, and a counter-flow heat exchanger for efficient heat retention.	Still being used in ongoing research.
9,287,568	03/15/16	3M Company	High performance, high durability non-precious metal fuel cell catalysts	This invention relates to non-precious metal fuel cell cathode catalysts, fuel cells that contain these catalysts, and methods of making the same. The fuel cell cathode catalysts are highly nitrogenated carbon materials that can contain a transition metal. The highly nitrogenated carbon materials can be supported on a nanoparticle substrate.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,276,273	03/01/16	3M Company	Fuel cell water management via reduced anode reactant pressure	A method is provided for operation of a fuel cell with improved water management by maintaining reduced anode pressure relative to cathode pressure, relative to atmospheric pressure, or both. Typically, the fuel cell comprises a membrane electrode assembly comprising nanostructured thin film cathode catalyst.	Research complete; seeking to license.
9,269,473	02/23/16	University of California -Berkeley	Conductive open frameworks	The disclosure relates to materials that comprise conductive covalent organic frameworks. The disclosure also relates to materials that are useful to store and separate gas molecules and sensors.	Still being used in ongoing research.
9,255,334	02/09/16	Argonne National Laboratory	Hydrogen evolution reaction catalyst	Systems and methods for a hydrogen evolution reaction catalyst are provided. Electrode material includes a plurality of clusters. The electrode exhibits bifunctionality with respect to the hydrogen evolution reaction. The electrode with clusters exhibits improved performance with respect to the intrinsic material of the electrode absent the clusters.	Still being used in ongoing research.
9,246,177	01/26/16	Argonne National Laboratory	Bimetallic alloy electrocatalysts with multilayered platinum-skin surfaces	Compositions and methods of preparing a bimetallic alloy having enhanced electrocatalytic properties are provided. The composition comprises a PtNi substrate having a surface layer, a near-surface layer, and an inner layer, where the surface layer comprises a nickel-depleted composition, such that the surface layer comprises a platinum skin having at least one atomic layer of platinum.	Still being used in ongoing research.
9,234,843	01/12/16	National Renewable Energy Laboratory	On-line, continuous monitoring in solar cell and fuel cell manufacturing using spectral reflectance imaging	A monitoring system comprising a material transport system providing for the transportation of a substantially planar material through a monitoring zone. A data processing system is also provided. The processing system is configured to receive data from the line camera and provides information relating to a quality parameter of the material.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,228,954	01/05/16	University of Central Florida	Method of detecting defects in ion exchange membranes of electrochemical cells by chemochromic sensors	A method of detecting defects in membranes such as ion exchange membranes of electrochemical cells. A chemochromic sensor is placed above the cathode and flow isolation hardware lateral to the ion exchange membrane being tested. The anode side is exposed to a first reactant fluid including hydrogen. The chemochromic sensor is examined for a color change after the exposure. A color change indicates that the ion exchange membrane has at least one defect that permits hydrogen transmission.	Licensed to HySense Technology LLC. Part of a commercial hydrogen production technology.
9,227,224	01/05/16	Stanford University	Method of forming macro-structured high surface area transparent conductive oxide electrodes	A method of forming a high surface area transparent conducting electrode including deposition of a transparent conducting thin film on a conductive substrate forming a transparent conducting electrode.	Research complete; seeking to license.
9,203,100	12/01/15	Intelligent Energy, Inc.	Fuel cell system	A fuel cell system comprising a fuel cell stack and an electrical control unit configured to adjust operating parameters for optimized operation using voltage deviations from the cells in the fuel cell stack.	Still being used in ongoing research.
9,203,094	12/01/15	University of Akron	Catalysts compositions for use in fuel cells	The present invention relates to the generation of electrical energy from a solid-state fuel. In one embodiment, the present invention relates to a solid oxide fuel cell for generating electrical energy from a carbon-based fuel, and to catalysts for use in a solid oxide fuel cell.	Research complete; seeking to license.
9,186,653	11/17/15	Northeastern University	Highly stable platinum alloy catalyst for methanol electrooxidation	A catalyst for use in the anode of direct methanol fuel cells. The material core is an alloy of platinum and gold and surrounded by coatings of ruthenium and a ternary alloy of platinum, gold, and ruthenium. The catalyst is made by a reverse-micelle method or by a single-phase scalable method. The catalyst is highly stable under conditions of use and resists dissolution of ruthenium or platinum.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,178,244	11/03/15	Intelligent Energy, Inc.	Fuel cells and fuel cell components having asymmetric architecture and methods thereof	A composite for a fuel cell layer with alternating layers of electron conducting components and ion conducting components. At least one of the ion conducting components or the electron conducting components is geometrically asymmetric in one or more dimensions.	Still being used in ongoing research.
9,169,140	10/27/15	Los Alamos National Laboratory	Non-precious metal catalysts prepared from precursor comprising cyanamide	A catalyst comprising of graphitic carbon and methods for fabrication. A catalyst for oxygen reduction reaction for an alkaline fuel cell is prepared by heating a mixture of cyanamide, carbon black, iron sulfate salt and an iron acetate salt at 700 to 1100°C under an inert atmosphere.	Still being used in ongoing research.
9,160,021	10/13/15	3M Company	Proton conducting materials	Materials that are useful as ionomers or polymer ionomers, and compounds including bi-sulfonyl imide groups that can be highly fluorinated polymers.	Still being used in ongoing research.
9,153,831	10/06/15	University of South Carolina	Electrode design for low temperature direct-hydrocarbon solid oxide fuel cells	In certain embodiments of the present disclosure, a solid oxide fuel cell is described. The solid oxide fuel cell includes a hierarchically porous cathode support having an impregnated cobaltite cathode deposited thereon, an electrolyte, and an anode support. The anode support includes hydrocarbon oxidation catalyst deposited thereon, wherein the cathode support, electrolyte, and anode support are joined and wherein the solid oxide fuel cell operates at a temperature of 600°C or less.	Research complete; seeking to license.
9,126,830	09/08/15	Bettergy Corporation	Metal doped zeolite membrane for gas separation	Inorganic membranes and methods for separating gases, vapors, and liquids using the same. The composite zeolite membrane is prepared by TS-1 zeolite membrane synthesis, and subsequent palladium doping.	Still being used in ongoing research. Part of an emerging technology.
9,093,685	07/28/15	Los Alamos National Laboratory	Methods of making membrane electrode assemblies	Membrane electrode assembly comprising of ink printed ionomer and catalyst layers to form a membrane assembly.	Still being used in ongoing research.
9,080,242	07/14/15	General Electric Company	Pressurized electrolysis stack with thermal expansion capability	Systems and methods for mounting an electrolyzer stack in an outer shell to allow for differential thermal expansion. The outer shell accommodates thermal expansion, preventing damage to the electrolyzer stack.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,065,142	06/23/15	Argonne National Laboratory	Fuel cell electrodes	A process for patterning the surface of a platinum group metal-based electrode by contacting the electrode with an adsorbate to form a patterned platinum group metal-based electrode with both absorbate blocked and unblocked platinum group metal sites.	Still being used in ongoing research.
9,051,431	06/09/15	Los Alamos National Laboratory	Poly(arylene)-based anion exchange polymer electrolytes	Poly(arylene) electrolytes including copolymers lacking ether groups in the polymer may be used as membranes and binders for electrocatalysts in preparation of anodes for electrochemical cells such as solid alkaline fuel cells.	Still being used in ongoing research.
9,048,480	06/02/15	Los Alamos National Laboratory	Anion exchange polymer electrolytes	Anion exchange polymer electrolytes that include guanidinium functionalized polymers may be used as membranes and binders for electrocatalysts in preparation of anodes for electrochemical cells such as solid alkaline fuel cells.	Still being used in ongoing research.
9,045,839	06/02/15	General Electric Company	Methods and systems for in-situ electroplating of electrodes	Electrochemical device having enhanced electrodes with surfaces that facilitate operation, such as formation of a porous nickel layer on an operative surface, e.g., a cathode. The device's enhanced electrode and its operation can be used in various electrochemical devices, in particular, electrodes in an electrolyzer useful for splitting water into hydrogen and oxygen.	Still being used in ongoing research.
9,034,165	05/19/15	Brookhaven National Laboratory	Underpotential deposition-mediated layer-by-layer growth of thin films	A method of depositing contiguous, conformal submonolayer-to-multilayer thin films with atomic-level control. This process is especially suitable for the formation of a catalytically active layer on core-shell particles for use in energy conversion devices such as fuel cells.	Research complete; seeking to license.
9,023,553	05/05/15	Chemsultants International	Multilayered composite proton exchange membrane and a process for manufacturing the same	A multilayered membrane for use with fuel cells and related applications. The multilayered membrane includes a carrier film, with alternating layers of undoped conductive polymer electrolyte material and conductive polymer electrolyte material, each layer of is doped with nanoparticles.	No longer being pursued.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,023,550	05/05/15	Savannah River National Laboratory	Nanocrystalline cerium oxide materials for solid fuel cell systems	Disclosed are solid fuel cells, including solid oxide fuel cells and PEM fuel cells that include nanocrystalline cerium oxide materials as a component of the fuel cells. A solid oxide fuel cell can include nanocrystalline cerium oxide as a cathode component and microcrystalline cerium oxide as an electrolyte component, which can prevent mechanical failure and interdiffusion common in other fuel cells.	Still being used in on-going research; seeking to license.
9,017,900	04/28/15	Lawrence Livermore National Laboratory	Fuel cell components and systems having carbon-containing electrically-conductive hollow fibers	Process for forming fuel cell structure using an ionically conductive, electrically resistive electrolyte/ separator layer which covers the inner or outer surface of a carbon-containing electrically conductive hollow fiber. The fiber contains provision for a catalyst, anode and cathode that extend along at least part of the length of the structure, the cathode being on an opposite side of the hollow fiber as the anode.	Research complete; seeking to license.
9,017,530	04/28/15	Brookhaven National Laboratory	Method and electrochemical cell for synthesis and treatment of metal monolayer electrocatalysts metal, carbon, and oxide nanoparticles ion batch, or in continuous fashion	An apparatus and method for synthesis and treatment of electrocatalyst particles using batch or continuous processing.	Licensee name withheld (Confidential).
9,012,344	04/21/15	Argonne National Laboratory	Electrocatalysts using porous polymers and method of preparation	A method of producing an electrocatalyst article using porous polymers that are designed to receive transition metal groups disposed at ligation sites and activate transition metals to form an electrocatalyst which can be used in a fuel cell.	Still being used in ongoing research.
9,005,331	04/14/15	Brookhaven National Laboratory	Platinum-coated non-noble metal-noble metal core-shell electrocatalysts	A process to encapsulate core-shell particles with a thin film of a catalytically active metal is described. The particles are preferably nanoparticles comprising a non-noble core with a noble metal shell which does not contain any Pt. The overall process is a robust and cost-efficient method for forming Pt-coated non-noble metal-noble metal core-shell nanoparticles that can be used as an electrocatalyst.	Licensee name withheld (Confidential).

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,974,578	03/10/15	Northwestern University	Porous polymer networks and ion-exchange media and metal-polymer composites made therefrom	Porous polymeric networks and composite materials comprising metal nanoparticles distributed in the polymeric networks are provided. Also provided are methods for using the polymeric networks and the composite materials in liquid-and vapor-phase waste remediation applications. The porous polymeric networks, are highly porous, three-dimensional structures characterized by high surface areas. The polymeric networks comprise polymers polymerized from aldehydes and phenolic molecules.	Research complete; seeking to license.
8,968,432	03/03/15	Pacific Northwest National Laboratory	Rapid start fuel reforming systems and techniques	An on-board fuel processor includes a microchannel steam reforming reactor, a water vaporizer in a cross-flow panel configuration is heated in series with a combustion gas. Fuel is directly injected into the steam, and during a rapid cold start which can be achieved in under 30 seconds with a manageable amount of electric power consumption.	Research complete; seeking to license.
8,962,132	02/24/15	Giner, Inc.	Solid polymer electrolyte composite membrane comprising a porous support and a solid polymer electrolyte including a dispersed reduced noble metal or noble metal oxide	Solid polymer electrolyte composite membrane and its manufacture. The composite membrane consists of a thin, rigid, dimensionally stable, non-electrically conducting support with cylindrical, straight-through pores between top and bottom surfaces of the support. The pores are filled with a solid polymer electrolyte including dispersed reduced noble metal or noble metal oxide.	Research complete; seeking to license.
8,944,437	02/03/15	Air Products & Chemicals, Inc.	Seal between metal and ceramic conduits	A seal between a ceramic conduit and a metal conduit of an ion transport membrane device consisting of a sealing surface of ceramic conduit, a single gasket body, and a single compliant interlayer.	Still being used in ongoing research.
8,939,293	01/27/15	Synkera Technologies, Inc.	Composite membrane with integral rim	Composite membranes that can be adapted for separation, purification, filtration, analysis, reaction and sensing. The membranes can include a porous support structure having elongate pore channels extending through the support structure.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,927,453	01/06/15	Brookhaven National Laboratory	Molybdenum and tungsten nanostructures and methods for making and using same	Process to form molybdenum and tungsten nanostructures, for example, nanosheets and nanoparticles. These formed nanostructures could be used as catalysts for hydrogen evolution reactions.	Still being used in ongoing research.
8,906,575	12/09/14	Los Alamos National Laboratory	Minimizing electrode contamination in an electrochemical cell	An electrochemical cell assembly that is expected to prevent or at least minimize electrode contamination includes one or more getters that trap a component or components leached from a first electrode and prevents or at least minimizes them from contaminating a second electrode.	Still being used in ongoing research.
8,906,270	12/09/14	Colorado School of Mines	Acidic ion exchange membrane and method for making and using the same	The invention relates to a polymeric composition and a method for making and using the polymeric composition, more specifically to a polymeric composition and a method for making and using the polymeric composition in the form of a membrane.	Research complete; seeking to license.
8,895,206	11/25/14	Johns Hopkins University	Porous platinum-based catalysts for oxygen reduction	A porous metal catalyst containing platinum with a specific surface area in the range 5–75 m^2/g is used to coat the electrodes of a fuel cell for oxygen reduction. The porous metal is produced by forming an alloy consisting of platinum and nickel and dealloying the alloy in a substantially pH neutral solution to reduce the amount of nickel in the alloy to produce the porous metal.	Research complete; seeking to license.
8,895,204	11/25/14	Intelligent Energy, Inc.	Water reactive hydrogen fuel cell power system	A water reactive hydrogen fueled power system including devices and methods to combine reactant fuel materials and aqueous solutions to generate hydrogen. The generated hydrogen is converted in a fuel cell to provide electricity. The water reactive hydrogen fueled power system includes a fuel cell, a water feed tray, and a fuel cartridge to generate power for portable power electronics.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,889,316	11/18/14	Arkema, Inc.	Organic/inorganic composite blend membrane compositions of polyelectrolyte blends with nanoparticles	Composite blend membranes formed from blends of one or more polyelectrolytes, and one or more types of nanoparticles. Preferably the blend also includes one or more fluoropolymers. The addition of the nanoparticles was found to enhance the conductivity and mechanical properties of the membranes.	Still being used in ongoing research.
8,865,441	10/21/14	Stanford University	Efficient cell-free hydrogen production	Cell-free synthesis of hydrogen from glucose and cellulosic hydrolysates is provided. Bacterial cells are modified to express high levels of (i) active [FeFe] hydrogenase; (ii) ferredoxin; and (iii) ferredoxin-NADP-reductase (FNR). The cells are then lysed and the lysate is combined with substrate during a production phase, where H_2 is produced.	Research complete; seeking to license.
8,865,359	10/21/14	General Motors Corporation	Fuel cell having improved thermal characteristics	One embodiment includes a fuel cell comprising a polymer electrolyte membrane sandwiched between an anode and a cathode, a gas diffusion layer disposed over each of the cathode and the anode, a gas flow distributor layer disposed over the gas diffusion layer on both the anode and cathode sides, and optionally a coolant plate disposed over the gas flow distributor layer. The thermal resistance of the combined gas diffusion layer and gas flow distributor layer on the anode or cathode side is sufficient to allow the cathode catalyst layer to operate at an elevated temperature to evaporate water produced at the cathode.	Still being used in ongoing research.
8,865,040	10/21/14	Nanotek Instruments, Inc.	Highly conductive composites for fuel cell flow field plates and bipolar plates	A fuel cell flow field plate or bipolar plate with flow channels on the faces of the plate which is made from an electrically conductive polymer composite. The composite is composed of mainly polymer binder material with conductive filler, weight reinforcement fibers, expanded graphite platelets, graphitic nanofibers, or carbon nanotubes.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,835,343	09/16/14	Argonne National Laboratory	Non-platinum group metal electrocatalysts using metal organic framework materials and method of preparation	A method of preparing a nitrogen containing electrode catalyst using a high surface area metal-organic framework (MOF) material free of platinum group metals to form catalytic active sites within the MOF using a high temperature thermal treatment. The electrode catalysts created in this manner may be used in various electrochemical systems, including a proton exchange membrane fuel cell.	Still being used in ongoing research.
8,835,003	09/16/14	University of South Carolina	Porous metal oxide particles and their methods of synthesis	Methods for synthesis of porous particles from a solution formed from a leaving agent, a surfactant, and a soluble metal salt in a solvent. The surfactant congregates to form a nanoparticle core such that the metal salt forms about the nanoparticle core to form a plurality of nanoparticles. The solution is heated such that the leaving agent forms gas bubbles in the solution, and the plurality of nanoparticles congregate about the gas bubbles to form a porous particle. The porous particles can include a particle shell formed about a core to define an average diameter 0.5–50 μm. The particle shell can be formed from a plurality of nanoparticles having an average diameter of 1–50 nm and defined by a metal salt formed about a surfactant core.	Research complete; seeking to license.
8,814,964	08/26/14	Argonne National Laboratory	Method for improving catalyst function in auto-thermal and partial oxidation reformer-based processors	Method for reforming fuel, using an oxidation catalyst to partially oxidize the fuel and generate heat to warm incoming fuel and the reforming catalyst while simultaneously reacting partially oxidized fuel with steam from the reforming catalyst.	No longer being pursued.
8,771,899	07/08/14	Lawrence Livermore National Laboratory	Fuel cell components and systems having carbon-containing electrically-conductive hollow fibers	Process for forming fuel cell structure using an ionically conductive, electrically resistive electrolyte/ separator layer which covers the inner or outer surface of a carbon-containing electrically conductive hollow fiber. The fiber contains provision for a catalyst, anode and cathode that extend along at least part of the length of the structure, the cathode being on an opposite side of the hollow fiber as the anode.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,765,327	07/01/14	3M Company	Fuel cell electrodes with conduction networks	A fuel cell electrode layer may include a catalyst, an electronic conductor, and an ionic conductor. The electrode layer is interspersed electronic and ionic conductor rich networks.	Still being used in ongoing research.
8,741,454	06/03/14	Case Western Reserve University	Proton exchange membrane for fuel cell	A proton exchange membrane (PEM) with an ion exchange capacity consisting of a polymer based on polyphosphazene polyaromatic chemistry. The polymer has excellent ionic conductivity and low water swelling which increases thermal, and chemical stability.	Still being used in ongoing research.
8,734,632	05/27/14	H2Pump, LLC	Hydrogen furnace system and method	Apparatus and operating methods for controlled atmosphere furnace systems. Hydrogen is injected and circulated within the enclosure from a gas inlet to a gas outlet. The temperature is raised to a predetermined threshold while the gas is pumped using an electrochemical hydrogen pump.	Still being used in ongoing research. Part of commercialized technology.
8,709,295	04/29/14	Los Alamos National Laboratory	Nitrogen-doped carbon-supported cobalt-iron oxygen reduction catalyst	A method for making a non-precious-metal catalyst for carrying out the oxygen reduction reaction in polymer electrolyte membrane fuel cells.	Still being used in ongoing research.
8,703,355	04/22/14	Florida State University	Catalytic electrode with gradient porosity and catalyst density for fuel cells	A membrane electrode assembly for a fuel cell comprising a gradient catalyst structure and a method of making the same.	Research complete; seeking to license.
8,699,207	04/15/14	Brookhaven National Laboratory	Electrodes synthesized from carbon nanostructures coated with a smooth and conformal metal adlayer	High-surface-area carbon nanostructures coated with a smooth and conformal submonolayer-to-multilayer thin metal films and their method of manufacture.	Part of an emerging fuel cell technology. Seeking to license.
8,691,177	04/08/14	University of Missouri	High surface area carbon and process for its production	The present invention provides a high surface area porous carbon material and a process for making this material. In particular, the carbon material is derived from biomass and has large mesopore and micropore surfaces that promote improved adsorption of materials and gas storage capabilities.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,663,448	03/04/14	H2Pump, LLC	Hydrogen furnace system and method	Apparatus and operating methods for controlled atmosphere furnace systems. Hydrogen is injected and circulated within the enclosure from a gas inlet to a gas outlet. The temperature is raised to a predetermined threshold while the gas is pumped from the gas outlet to the gas inlet using an electrochemical hydrogen pump.	Still being used in ongoing research. Part of commercialized technology.
8,658,329	02/25/14	Los Alamos National Laboratory	Advanced membrane electrode assemblies for fuel cells	A method for constructing membrane electrode assemblies for use in fuel cell applications.	Still being used in ongoing research.
8,652,709	02/18/14	Argonne National Laboratory	Method of sealing a bipolar plate supported solid oxide fuel cell with a sealed anode compartment	Methods for sealing a bipolar plate supported solid oxide fuel cell with a sealed anode compartment. A single-step high temperature sintering process is used to form gastight containment seals.	Research complete; seeking to license.
8,647,497	02/11/14	University of Central Florida	Method and system for hydrogen sulfide removal	A system for hydrogen sulfide removal from a sour gas mixture including hydrogen sulfide. The sour gas mixture is reacted with a transition metal compound in a scrubber. Sulfide from the hydrogen sulfide is oxidized to form elemental sulfur and the transition metal is reduced to form a reduced state transition metal compound.	Research complete; seeking to license.
8,642,308	02/04/14	University of New Mexico	Biofuel cell electrocatalysts utilizing enzyme-carbon nanotube adducts	Electrodes for fuel cells that contain enzymes (biological catalysts) bound to the walls of carbon nanotubes.	Still being used in ongoing research.
8,637,205	01/28/14	3M Company	Fuel cell subassemblies incorporating subgasketed thrifted membranes	A fuel cell roll subassembly is described that includes individual electrolyte membranes. Gaskets are attached to the individual electrolyte membranes to form a "grid" of the individual electrolyte membranes exposed through the apertures formed by the gaskets. Part of the gasket web that forms the "grid" may have little or no adhesive on the subgasket surface facing the electrolyte membrane.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,637,193	01/28/14	3M Company	Fuel cell nanocatalyst with voltage reversal tolerance	Fuel cell catalyst having a catalyst surface bearing a non-occluding layer of iridium or a surface bearing a sub-monolayer of iridium with a planar equivalent thickness of between 1 and 100 Angstroms. The catalyst has a nanostructure with microstructured support whiskers bearing a thin film of nanoscopic catalyst particles. The catalyst typically has no electrically conductive carbon material and at least a portion of the iridium in the zero oxidation state.	Still being used in ongoing research.
8,632,928	01/21/14	Signa Chemistry, Inc.	Water reactive hydrogen fuel cell power system	A water reactive hydrogen fueled power system including devices and methods to combine reactant fuel materials and aqueous solutions to generate hydrogen. The generated hydrogen is converted in a fuel cell to provide electricity. The water reactive hydrogen fueled power system includes a fuel cell, a water feed tray, and a fuel cartridge to generate power for portable power electronics.	Licensed to name withheld (Confidential). Part of a former commercial hydrogen production technology.
8,628,891	01/14/14	Acumentrics Corporation	Interconnection of bundled solid oxide fuel cells	A system and method for electrically interconnecting a plurality of fuel cells to provide dense packing of the fuel cells. Each fuel cell has discrete electrical connection points along the outer surface. Adjacent fuel cells electrical connections are interconnected to allow higher packing density. In tubular solid oxide fuel cells, the discrete electrical connection points are spaced along the length of the fuel cell.	Still being used in ongoing research. Part of a commercial fuel cell technology.
8,628,871	01/14/14	3M Company	High durability fuel cell components with cerium salt additives	Fuel cell membrane electrode assembly comprising of a polymer electrolyte membrane with bound anionic functional groups and cerium cations.	Still being used in ongoing research. Part of an emerging fuel cell technology.
8,624,105	01/07/14	Synkera Technologies, Inc.	Energy conversion device with support member having pore channels	Devices for energy conversion and storage and their manufacture. The devices comprise of a support with an array of pore channels. Material layers for energy conversion materials and conduction are coaxially disposed in the pore channels to form rods. The material structure can be varied in the pore channels to fabricate various energy devices, e.g., photovoltaic (PV) devices, radiation detectors, capacitors and batteries.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,617,765	12/31/13	E.I. du Pont de Nemours and Company	Chemically stabilized ionomers containing inorganic fillers	Ionomeric polymers that are chemically stabilized and contain inorganic fillers are prepared, and show reduced degradation. The ionomers are useful in membranes and electrochemical cells.	Research complete - company holding IP.
8,614,023	12/24/13	Protonex Technology Corporation	Solid oxide fuel cell systems with hot zones having improved reactant distribution	A Solid Oxide Fuel Cell (SOFC) system having a hot zone with a center cathode air feed tube for improved reactant distribution, a catalytic partial oxidation (CPOX) reactor attached at the anode feed end of the hot zone with a tail gas combustor at the opposing end for more uniform heat distribution, and a counter-flow heat exchanger for efficient heat retention.	Still being used in ongoing research.
8,586,252	11/19/13	Acumentrics Corporation	Integral reactor system and method for fuel cells	A reactor system is integrated internally within an anode-side cavity of a fuel cell. The reactor system is configured to convert higher hydrocarbons to smaller species while mitigating the lower production of solid carbon. The reactor system may incorporate one or more pre-reforming sections, an anode exhaust gas recirculation device, and a reforming section.	Still being used in ongoing research. Part of a commercial fuel cell technology.
8,585,807	11/19/13	Argonne National Laboratory	Low-cost method for fabricating palladium and palladium-alloy thin films on porous supports	A process for forming a palladium or palladium alloy membrane on a ceramic surface using a pre-colloid mixture of palladium powder, carrier fluid, dispersant, pore former and binder.	Research complete; seeking to license.
8,574,664	11/05/13	General Electric Company	Electrolyte membrane, methods of manufacture thereof and articles comprising the same	A method of forming an electrolyte membrane comprising of a mixture of polyhydroxy compound, aromatic polyhalide compound and an alkali metal hydroxide and depositing on a porous substrate.	Still being used in ongoing research.
8,557,480	10/15/13	Lawrence Livermore National Laboratory	High power density fuel cell comprising an array of microchannels	Fuel cell with a porous electrolyte support structure formed by an array of microchannels. The array could be formed using a combination of molding, stamping, extrusion, injection and electrodeposition processes.	Research complete; seeking to license.
8,545,657	10/01/13	Lawrence Livermore National Laboratory	Methods for tape fabrication of continuous filament composite parts and articles of manufacture thereof	Process for forming a composite structure using bonding material in the form of a tape. The tape comprises of fiber and a matrix, wherein the bonding material has a short curing time (< 1 second). The tape can be wrapped around a substrate to manufacture larger parts.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,530,109	09/10/13	Los Alamos National Laboratory	Anion exchange polymer electrolytes	Solid anion exchange polymer electrolytes that include chemical compounds consisting of a polymer backbone with side chains that include guanidinium cations.	Still being used in ongoing research.
8,518,608	08/27/13	Los Alamos National Laboratory	Preparation of supported electrocatalyst comprising multiwalled carbon nanotubes	A process for preparing a durable non-precious-metal oxygen reduction electrocatalyst that involves heat treatment of a ball-milled mixture of polyaniline and multiwalled carbon nanotubes in the presence of an iron species.	Still being used in ongoing research.
8,518,603	08/27/13	Nanotek Instruments, Inc.	Sheet molding compound flow field plate, bipolar plate and fuel cell	A highly electrically conductive sheet molding compound (SMC) composition to fabricate a fuel cell flow field plate or bipolar plate. The structure consists of top and bottom sheets with a resin mixture sandwiched in-between. At least one of the top or bottom sheets are made from flexible graphite sheet with a planar outer surface and formed fluid flow channels. The resin composition is a thermoset resin with conductive filler to provide sufficient flow field plate electrical conductivity. The assembled graphite sheets form a bipolar plate for use in proton exchange membrane fuel cell applications.	Research complete; seeking to license.
8,518,596	08/27/13	General Motors Corporation	Low cost fuel cell diffusion layer configured for optimized anode water management	A gas diffusion layer that enables passive fuel cell water balance by retaining some product water under dry operating conditions and removing excess product water during wet operating conditions.	Still being used in ongoing research.
8,501,307	08/06/13	Nanotek Instruments, Inc.	Recompressed exfoliated graphite articles	An electrically conductive, recompressed exfoliated graphite article made into thin foil or sheet form for use as bipolar plates in fuel cells.	Part of an emerging fuel cell technology.
8,492,049	07/23/13	Los Alamos National Laboratory	Anion exchange polymer electrolytes	Anion exchange polymer electrolytes consisting of a guanidine base and a cation-stabilizing spacer moiety between the base and the polymer.	Still being used in ongoing research.
8,481,227	07/09/13	3M Company	Proton conducting materials	Fuel cell membrane materials with an increased number of strong acid groups created in some embodiments by reaction of these acid-containing molecules with acid-containing organic molecules, metal oxide or phosphate particles, metal salts, heteropolyacids, and the like.	Part of a commercial fuel cell technology.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,465,858	06/18/13	University of South Carolina	Development of a novel method for preparation of PEMFC electrodes	A method for preparation of membrane electrode assemblies that is based on pulse electrodeposition.	Seeking to license. Part of an emerging fuel cell technology.
8,465,715	06/18/13	Sandia National Laboratory	Method for synthesizing metal bis(borano) hypophosphite complexes	The present invention describes the synthesis of a family of metal bis(borano) hypophosphite complexes. One procedure is the syntheses of complexes beginning from phosphorus trichloride and sodium borohydride. Temperature, solvent, concentration, and atmosphere are all critical to ensure product formation. In the case of sodium bis(borano) hypophosphite, hydrogen gas was evolved by heating at temperatures above 150°C. Included in this family of materials are the salts of the alkali metals Li, Na and K, and the alkaline earth metals Mg and Ca. Hydrogen storage materials are possible. In particular the lithium salt, $Li[PH_2(BH_3)_2]$, theoretically would contain nearly 12 wt.% hydrogen. Analytical data for product characterization and thermal properties are given.	Still being used in ongoing research.
8,455,152	06/04/13	Bing Energy International	Integrated PEM fuel cell	A process for integrating a membrane electrode assembly with a bipolar plate in a fuel cell.	No longer being pursued.
8,439,534	05/14/13	Sandia National Laboratory	Mobile lighting apparatus	A mobile lighting apparatus that includes a portable frame such as a moveable trailer or skid having a light tower thereon. A hydrogen-powered fuel cell on the portable frame provides electrical power to an array of energy-efficient lights on the light tower.	Still being used in ongoing research. Part of an emerging fuel cell technology.
8,420,271	04/16/13	General Motors Corporation	Method to improve reliability of a fuel cell system using low performance cell detection at low power operation	A system and method for detecting a low performing cell in a fuel cell stack using measured cell voltages. The method includes determining that the fuel cell stack is running, the stack coolant temperature is above a certain temperature and the stack current density is within a relatively low power range.	Licensed to Honda.
8,415,070	04/09/13	E.I. du Pont de Nemours and Company	Partially Fluorinated Cyclic Ionic Polymers and Membranes	Ionic polymers are made from selected partially fluorinated dienes, in which the repeat units are cycloaliphatic. The polymers are formed into membranes.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,415,012	04/09/13	Florida State University	Carbon nanotube and nanofiber film-based membrane electrode assemblies	A membrane electrode assembly for a fuel cell comprising a catalyst layer and a method of making the same. The catalyst layer can include a plurality of catalyst nanoparticles, such as platinum, positioned on the surface of a porous buckypaper film.	Research complete; seeking to license.
8,404,613	03/26/13	Brookhaven National Laboratory	Platinum-based electrocatalysts synthesized by depositing contiguous adlayers on carbon nanostructures	High-surface-area carbon nanostructures coated with a smooth and conformal submonolayer-to-multilayer thin metal films and their method of manufacture.	Part of an emerging fuel cell technology. Seeking to license.
8,394,352	03/12/13	University of South Carolina	Porous metal oxide particles and their methods of synthesis	Methods for the formation of metal oxide nanoparticles that can be used in solid oxide fuel cells.	Research complete; seeking to license.
8,394,298	03/12/13	Los Alamos National Laboratory	Non-aqueous liquid compositions comprising ion exchange polymers	Compositions useful for formation of uniformly dispersed electrodes, which in turn are useful as a component of membrane-electrode assemblies for, e.g., fuel cells, sensors and capacitors.	Still being used in ongoing research.
8,334,014	12/18/12	University of New Mexico	Microparticles with hierarchical porosity	Oxide microparticles with engineered hierarchical porosity that can be used as electrocatalyst support structures in fuel cells.	Still being used in ongoing research.
8,333,941	12/18/12	University of New Mexico	Spray pyrolysis synthesis of mesoporous $NbRu_yO_z$ as electrocatalyst supports in fuel cells	Mesoporous conductive niobium and niobium-ruthenium particles that can be used in fuel cell catalysts.	Still being used in ongoing research.
8,329,006	12/11/12	Faraday Technology, Inc.	Electroplating cell with hydrodynamics facilitating more uniform deposition across a workpiece during plating	An apparatus for establishing more uniform deposition across one or more faces of a workpiece in an electroplating process. The apparatus employs eductors with a flow dampener member and other measures to provide a more uniform current distribution and a more uniform metal deposit distribution as reflected in a coefficient of variability that is lower than conventional processes.	Being used in ongoing research. Part of a commercial fuel cell technology.
8,326,477	12/04/12	General Motors Corporation	Heel and toe driving on fuel cell vehicle	A system and method for providing nearly instantaneous power in a fuel cell vehicle.	Licensed to Honda.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,323,809	12/04/12	3M Company	Fuel cell electrolyte membrane with basic polymer	An electrolyte membrane comprising an acid and a basic polymer, where the acid is a low-volatile acid that is fluorinated and is either oligomeric or non-polymeric, and where the basic polymer is protonated by the acid and is stable to hydrolysis.	Still being used in ongoing research. Part of a commercial fuel cell technology.
8,308,989	11/13/12	Brookhaven National Laboratory	Electrocatalyst for oxygen reduction with reduced platinum oxidation and dissolution rates	Methods for preventing the oxidation of the platinum electrocatalyst in the cathodes of fuel cells by use of platinum-metal oxide composite particles.	Part of an emerging fuel cell technology. Seeking to license.
8,304,122	11/06/12	Protonex Technology Corporation	Solid oxide fuel cell systems with hot zones having improved reactant distribution	A solid oxide fuel cell system having a hot zone with a center cathode air feed tube for improved reactant distribution, a catalytic partial oxidation reactor attached at the anode feed end of the hot zone with a tail gas combustor at the opposing end for more uniform heat distribution, and a counter-flow heat exchanger for efficient heat retention.	Being used in ongoing research.
8,278,011	10/02/12	Nanosys, Inc.	Nanostructured catalyst supports	Silicon carbide nanostructures that can be used as catalyst supports in membrane electrode assemblies and in fuel cells.	Being used in ongoing research. Part of an emerging fuel cell technology.
8,273,495	09/25/12	General Electric Company	Electrochemical cell structure and method of making the same	An electrochemical cell structure that includes an anode, a cathode spaced apart from the anode, an electrolyte in ionic communication with the anode and the cathode, and a nonconductive frame.	Still being used in ongoing research.
8,252,711	08/28/12	University of New Mexico	Self supporting structurally engineered non-platinum electrocatalyst for oxygen reduction in fuel cells	A method for producing a highly dispersed, unsupported, non-platinum electrocatalyst for use in fuel cells.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,247,135	08/21/12	Case Western Reserve University	Light-weight, flexible edge collected fuel cells	The invention is a flexible, microfabricated fuel cell and fuel cell stack that can be helically wound or bend into cylindrical shapes. The electrolyte is a proton exchange membrane (PEM) upon which can be printed, by ink jet means, the anode and cathode electrodes and the current collectors that convey current to or from the edges of the PEM which has a thickness on the order of 0.001 to 0.010 inches. Pluralities of the series connected fuel cell stacks can be arranged in electrical and physical parallel with one another to form batteries of fuel cell stacks connected by manifolds to sources of fuel and oxidizer. The invention is directed to a thin, light-weight, flexible fuel cell assembly that can be produced in ambient conditions using standard microfabrication techniques, such as thick film printing and ink jet deposition. Thick film printing techniques, screen printing or ink jet printing, are used to deposit porous current collectors on either side of the membrane.	Research complete; seeking to license.
8,236,207	08/07/12	Los Alamos National Laboratory	Non-aqueous liquid compositions comprising ion exchange polymers reference to related application	Compositions useful for formation of uniformly dispersed electrodes, which in turn are useful as a component of membrane-electrode assemblies for, e.g., fuel cells, sensors and capacitors.	Still being used in ongoing research.
8,232,017	07/31/12	Delphi	Fuel cell stack including non-fuel cell cassette	A fuel cell stack with a non-fuel cell cassette having temperature sensing elements. The temperature sensing elements are in one or more void spaces in the non-fuel cell cassette and connected to openings in the side of the non-fuel cell cassette for lead wires to communicate information to components outside of the fuel cell stack.	Still being used in ongoing research.
8,227,147	07/24/12	Los Alamos National Laboratory	Advanced membrane electrode assemblies for fuel cells	Method for producing polymer electrolyte membranes with improved performance and durability for fuel cell use.	Still being used in ongoing research.
8,227,140	07/24/12	3M Company	Proton conducting materials	Fuel cell membrane materials with an increased number of strong acid groups created in some embodiments by reaction of these acid-containing molecules with acid-containing organic molecules, metal oxide or phosphate particles, metal salts, heteropolyacids, and the like.	Still being used in ongoing research. Part of a commercial fuel cell technology.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,227,135	07/24/12	Case Western Reserve University	Electrolytes to enhance oxygen reduction reaction (ORR) in the cathode layer of PEM fuel cell	Polymer-based materials for use as an electrode binder in a fuel cell. A fuel cell consisting of electrodes including a catalyst and an electrode binder with an electrolyte located between the electrodes. The electrolyte may be a proton-exchange membrane (PEM). The electrode binder includes one or more polymers, such as a polyphosphazene.	Still being used in ongoing research.
8,206,682	06/26/12	BASF Corporation	Method for recovering catalytic elements from fuel cell membrane electrode assemblies	A method for recovering catalytic elements from fuel cell membrane electrode assemblies. Recovery of the membrane electrode assembly materials is achieved by converting the membranes into particulate, forming a slurry and then dissolving catalytic elements into a soluble catalytic element salt.	Research complete – company holding IP. Part of an emerging fuel cell technology.
8,197,955	06/12/12	General Electric Company	Electrolyte membrane, methods of manufacture thereof and articles comprising the same	Method to form an electrolyte membrane comprising of polyhydroxy, aromatic polyhalide and alkali metal hydroxide compounds. The process forms a porous substrate; and a crosslinked proton conductor deposited onto the porous substrate.	Still being used in ongoing research.
8,178,463	05/15/12	Argonne National Laboratory	Highly durable nanoscale electrocatalyst based on core shell particles	A multimetallic nanoscale catalyst having a core portion enveloped by a shell portion and exhibiting high catalytic activity and improved catalytic durability	Still being used in ongoing research.
8,153,324	04/10/12	Nanotek Instruments, Inc.	Controlled-release vapor fuel cell	A controlled-release fuel cell that is useful for powering small vehicles and portable electronic devices.	Being used in ongoing research.
8,137,858	03/20/12	Argonne National Laboratory	Method of fabricating electrode catalyst layers with directionally oriented carbon support for proton exchange membrane fuel cell	A new method of preparing a membrane electrode assembly (MEA) for a PEMFC that reduces precious metal usage, eliminates the need for a gas diffusion electrode (GDE) and simplifies the design and fabrication of bipolar plates.	Still being used in ongoing research.
8,129,306	03/06/12	Argonne National Laboratory	Non-platinum bimetallic polymer electrolyte fuel cell catalysts	A polymetallic nanoparticle alloy having enhanced catalytic properties including at least one noble metal and at least one base metal, where the noble metal is preferentially dispersed near the surface of the nanoparticle and the base metal modifies the electronic properties of the surface disposed noble metal.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,124,261	02/28/12	BASF Corporation	Process for recycling components of a PEM fuel cell membrane electrode assembly	Process for recycling components of a PEM fuel cell membrane electrode assembly. The membrane electrode assembly of a PEM fuel cell can be recycled by dissolving the MEA with a lower alkyl alcohol solvent to separate the anode and cathode layers of the assembly. The solution contains both the polymer membrane and noble metal catalysts which can be heated to form particulates and then separated by filtration.	Research complete – company holding IP. Part of an emerging fuel cell technology.
8,114,547	02/14/12	Ford Motor Company	Fuel cell stack flow diversion	A control valve to affect the flow of compressed gas in a fuel cell system.	Being used in ongoing research.
8,101,317	01/24/12	3M Company	Durable fuel cell having polymer electrolyte membrane comprising manganese oxide	Fuel cell membrane electrode assemblies and fuel cell polymer electrolyte membranes are provided comprising manganese oxides which demonstrate increased durability.	Still be used in ongoing research; Part of an emerging fuel cell technology.
8,092,954	01/10/12	3M Company	Method of making a fuel cell polymer electrolyte membrane comprising manganese oxide	Fuel cell membrane electrode assemblies and fuel cell polymer electrolyte membranes are provided comprising manganese oxides which demonstrate increased durability. Methods of making the same are provided.	Still being used in ongoing research.
8,088,526	01/03/12	General Motors Corporation	Anode reactive bleed and injector shift control strategy	A system and method for correcting a large fuel cell voltage spread for a split sub-stack fuel cell system.	Licensed to Honda.
8,071,701	12/06/11	Symyx Technologies, Inc.	Polydentate heteroatom ligand containing metal complexes, catalysts and methods of making and using the same	Metal complexes comprising certain polydentate heteroatom containing ligands, catalysts, and coordination polymerization processes employing the same are suitably employed to prepare polymers having desirable physical properties.	Still being used in ongoing research.
8,062,552	11/22/11	Brookhaven National Laboratory	Electrocatalyst for oxygen reduction with reduced platinum oxidation and dissolution rates	Method for using platinum-metal oxide composite particles as electrocatalysts in oxygen-reducing cathodes in fuel cells. The method prevents oxidation of platinum electrocatalyst at the cathodes.	Part of an emerging fuel cell technology. Seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,058,383	11/15/11	E.I. du Pont de Nemours and Company	Arylene-fluorinated-sulfonimide ionomers and membranes for fuel cells	Method for preparation of aromatic sulfonimide polymers for membranes in electrochemical cells. The resulting polymers are useful as cation-exchange resins which can be used for producing proton-exchange membranes for fuel cells and can be used in any application wherein cation-exchange capacity is desired. The resins may also be used as electrolytes, electrode binders, in lithium batteries in lithium salt form, and in any application requiring charge-transfer phenomena, such as components of light-emitting displays.	Research complete – company holding IP.
8,057,949	11/15/11	Ford Motor Company	Fuel cell stack flow diversion	A control valve to affect the flow of compressed gas in a fuel cell system.	Being used in ongoing research.
8,048,548	01/11/11	Brookhaven National Laboratory	Electrocatalyst for alcohol oxidation at fuel cell anodes	An electrocatalyst is used in an anode for oxidizing alcohol in a fuel cell. The electrocatalyst consists of a noble metal particle with surface clusters of SnO_2 and Rh. The noble metal particles include platinum, palladium, ruthenium, iridium, gold, and combinations thereof. In some embodiments, the electrocatalyst particle cores are nanoparticles.	Part of an emerging fuel cell technology. Seeking to license.
8,039,160	10/18/11	Arkema, Inc.	Multi-layer polyelectrolyte membrane	Method to produce multi-layer polyelectrolyte membranes containing polymeric resins, specifically fluoropolymer and non-perfluorinated polymeric resins containing ionic or ionizable groups (also referred to as a "polyelectrolytes"). These membranes are useful in a variety of products such as fuel cells.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,029,942	10/04/11	Case Western Reserve University	Fuel cell system with flow field capable of removing liquid water from the high-pressure channels	Fuel cell system with flow fields capable of operating interdigitated flow fields and simultaneously allowing removal of liquid water collected in the high-pressure channels, throughout individual exhaust passages. Ideally the channels follow radial-circumferential trajectories, each channel being provided with individual exhaust passages. Alternatively, each channel could be provided with a valve control in both individual supply passages and individual exhaust passages allowing the system to operate alternatively as an interdigitated flow field and an open-channel flow field.	Still being used in ongoing research.
8,028,842	10/04/11	Virginia Polytechnic Institute	Chlorine resistant desalination membranes based on directly sulfonated poly(arylene ether sulfone) copolymers	A method of making a hydrophilic-hydrophobic random copolymer membrane that can be used in fuel cells.	Research complete; seeking to license.
8,021,795	09/20/11	General Electric Company	Method for manufacturing solid oxide electrochemical devices	Methods for connecting and sealing solid oxide fuel cells into a stack assembly.	Still being used in ongoing research.
8,011,598	09/06/11	Delphi Technologies, Inc.	SOFC power system with A/C system and heat pump for stationary and transportation applications	A combined heat and power system wherein the compressor motor of a heat pump is powered by a portion of the electricity generated by a solid oxide fuel cell (SOFC), and the thermal output of the heat pump, which is increased by abstraction of heat from the SOFC exhaust.	No longer being used.
7,981,319	07/19/11	Los Alamos National Laboratory	Non-aqueous liquid compositions comprising ion exchange polymers	Compositions for formation of uniformly dispersed electrodes, which can be used in membrane-electrode assemblies for, e.g., fuel cells, sensors and capacitors.	Still being used in ongoing research.
7,955,759	06/07/11	Oak Ridge National Laboratory	Metallization of bacterial cellulose for electrical and electronic device manufacture	Method for deposition of metals in bacterial cellulose and the utilization of the metallized bacterial cellulose in the construction of fuel cells and other electronic devices.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,943,675	05/17/11	Case Western Reserve University	Electrolytes for fuel cell electrodes	Improved polymer-based materials are described, for example for use as an electrode binder in a fuel cell. A fuel cell comprises a first electrode including a catalyst and an electrode binder, a second electrode, and an electrolyte located between the first electrode and the second electrode. The electrolyte may be a proton-exchange membrane (PEM). The electrode binder includes one or more polymers, such as a polyphosphazene.	Still being used in ongoing research.
7,943,266	05/17/11	General Electric Company	SOFC seal and cell thermal management	A solid oxide fuel cell module in which the cell and its peripheral gas-flow-directing components (e.g., manifold and seals) are cooled to reduce stress-inducing thermal gradients and prevent cell cracking.	Being used in continuing research at the company.
7,927,748	04/19/11	Argonne National Laboratory	Catalytic membranes for fuel cells	A fuel cell with one or both of the anode and the cathode including a catalyst comprising a bundle of longitudinally aligned graphitic carbon nanotubes including a catalytically active transition metal incorporated longitudinally and atomically distributed throughout the graphitic carbon walls of said nanotubes.	Still being used in ongoing research.
7,910,653	03/22/11	E.I. du Pont de Nemours and Company	Process for the preparation of arylene fluorinated sulfonimide polymers and membranes	Polymer electrolyte membrane fuel cells (PEMFC) are expected to provide higher efficiencies, fewer environmental pollutants, and reduced operating and maintenance costs than traditional power sources. Developments have been made in the use of sulfonic acid functionalized polymers, including membranes such as Nafion™ perfluorosulfonic acid membranes.	No longer being used.
7,906,251	03/15/11	3M Company	Oxygen-reducing catalyst layer	Process for thin film deposition of oxygen-reducing catalysts on a substrate using vapor deposition and thermal treatment. The catalytic material film includes a transition metal that is substantially free of platinum.	Still being used in ongoing research.
7,902,299	03/08/11	Lawrence Berkeley National Laboratory	Single ion conductor cross-linked polymeric networks	The invention relates to the synthesis, characterization, and electrochemical response of a new type of single-ion comb-branch polymer electrolyte that can be used as a proton exchange membrane in fuel cells.	Being used in research at LBNL and seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,901,940	03/08/11	BASF Corporation	Method for measuring recovery of catalytic elements from fuel cells	A method for measuring the concentration of a catalytic element in a fuel cell powder. The method includes depositing a powder mixture consisting of the fuel cell powder and an internal standard material on a porous substrate, ablating a sample of the powder mixture using a laser, and vaporizing the sample using an inductively coupled plasma.	No longer being used.
7,896,949	03/01/11	General Electric Company	Membranes for separation of carbon dioxide	Describes methods for separating carbon dioxide from a fluid stream at a temperature higher than 200 ºC with selectivity higher than Knudsen diffusion selectivity using a porous membrane in a fluid stream. The porous membrane includes a porous support and a continuous porous separation layer. The porous support comprises alumina, silica, zirconia, stabilized zirconia, stainless steel, titanium, nickel-based alloys, aluminum-based alloys, zirconium-based alloys or a combination thereof. Median pore size of the porous separation layer is less than about 10 nm.	No longer being pursued.
7,887,927	02/15/11	Nanotek Instruments, Inc.	Highly conductive, multi-layer composite precursor composition to fuel cell flow field plate or bipolar plate	A roll-to-roll method of producing a flexible graphite-based, highly electrically conductive sheet molding compound (SMC) and SMC-based flow field or bipolar plates for use in a proton exchange membrane fuel cell.	Part of an emerging fuel cell technology.
7,871,738	01/18/11	Argonne National Laboratory	Nanosegregated surfaces as catalysts for fuel cells	A method of preparing a nanosegregated Pt alloy having enhanced catalytic properties. The method includes providing a sample of Pt and one or more transition metals in a substantially inert environment, and annealing the sample in such an environment at a temperature profile to form a nanosegregated Pt alloy having a Pt-skin on a surface.	Still being used in ongoing research.
7,868,086	01/11/11	E.I. du Pont de Nemours and Company	Arylene fluorinated sulfonimide polymers and membranes	Aromatic sulfonimide polymers that are useful in making proton exchange membranes for fuel cells.	Being used in continuing research at the company.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,867,669	01/11/11	Giner Electrochemical Systems, LLC	Solid polymer electrolyte composite membrane comprising laser micromachined porous support	A solid polymer electrolyte composite membrane and methods of manufacturing the same.	Part of an emerging fuel cell technology.
7,855,021	12/21/10	Brookhaven National Laboratory	Electrocatalysts having platinum monolayers on palladium, palladium alloy, and gold alloy core-shell nanoparticles, and uses thereof	Platinum-coated particles used in fuel cell electrocatalysts. The particles consist of a noble metal or metal alloy core at least partially encapsulated by an atomically thin surface layer of platinum atoms. The process relates to such particles having a palladium, palladium alloy, gold alloy, or rhenium alloy core encapsulated by an atomic monolayer of platinum.	Part of an emerging fuel cell technology. Seeking to license.
7,851,399	12/14/10	Los Alamos National Laboratory	Method of making chalcogen catalysts for polymer electrolyte fuel cells	A method of making a catalyst material for use in fuel cell cathodes. The catalyst material includes a support comprising at least one transition metal and at least one chalcogen disposed on a surface of the transition metal.	No longer being used.
7,838,612	11/23/10	E.I. du Pont de Nemours and Company	Arylene fluorinated sulfonimide compositions	Aromatic sulfonimide compositions that can be used to prepare polymers useful as membranes in electrochemical cells.	Still being used in ongoing research.
7,838,138	11/23/10	3M Company	Fuel cell electrolyte membrane with basic polymer	A fuel cell electrolyte membrane that includes an acid and a basic polymer. The acid is a low-volatility acid that is fluorinated and is either oligomeric or non-polymeric. The basic polymer is protonated by the acid and is stable to hydrolysis. As a result, the electrolyte membrane may be used at high operating temperatures while preserving proton conductivity.	Part of a commercial fuel cell technology.
7,829,652	11/09/10	General Electric Company	Polyarylether composition and membrane	A polyarylether copolymer that can be used as a cation-conducting membrane in fuel cells.	Still being used in ongoing research.
7,829,603	11/09/10	E.I. du Pont de Nemours and Company	Stable trifluorostyrene containing compounds grafted to base polymers, and their use as polymer electrolyte membranes	Ion exchange polymers that are useful in preparing catalyst coated membranes and membrane electrode assemblies used in fuel cells.	No longer being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,829,194	11/09/10	Oak Ridge National Laboratory	Iron-based alloy and nitridation treatment for PEM fuel cell bipolar plates	A corrosion resistant electrically conductive component that can be used as a bipolar plate in a PEM fuel cell. The plates are composed of an alloy substrate (Fe base metal with 10–30 wt.% Cr and 0.57 wt.% V) and a continuous surface layer of chromium nitride and vanadium nitride.	Part of an emerging fuel cell technology.
7,824,651	11/02/10	Nanotek Instruments, Inc.	Method of producing exfoliated graphite, flexible graphite, and nano-scaled graphene platelets	A method of exfoliating a layered material (e.g., graphite and graphite oxide) to produce nano-scaled platelets having a thickness smaller than 100 nm and typically smaller than 10 nm. The invention can be used in the manufacturing of fuel cell bipolar plates.	Part of an emerging fuel cell technology.
7,815,986	10/19/10	Arkema, Inc.	Blend of ionic (co)polymer resins and matrix (co) polymers	A novel polymeric resin blend useful for forming durable and chemical-resistant films for fuel cell membranes.	No longer being used.
7,807,063	10/05/10	Giner Electrochemical Systems, LLC	Solid polymer electrolyte composite membrane comprising plasma etched porous support	A solid polymer electrolyte composite membrane and methods of manufacturing the same.	Part of an emerging fuel cell technology.
7,803,891	09/28/10	Arkema, Inc.	Blend of ionic (co)polymer resins and matrix (co)polymers	A novel polymeric resin blend useful for forming durable and chemical-resistant films for fuel cell membranes.	No longer being used.
7,803,493	09/28/10	General Electric Company	Fuel cell system with separating structure bonded to electrolyte	The invention relates to a fuel cell assembly that is sealed in an efficient way to keep the fuel and oxidant paths separated at high operating temperatures.	Being used in continuing research at the company.
7,803,477	09/28/10	Oak Ridge National Laboratory	Metallization of bacterial cellulose for electrical and electronic device manufacture	A method for the deposition of metals in bacterial cellulose and for the employment of the metallized bacterial cellulose in the construction of fuel cells and other electronic devices.	Being used in continuing research at ORNL.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,794,170	09/14/10	Pacific Northwest National Laboratory	Joint with application in electrochemical devices	A hermetic seal forming flexible joint for use in electrochemical devices, such as solid oxide fuel cells (SOFCs), oxygen separators, and hydrogen separators, at operating temperatures of greater than 600 ºC and other extreme operating conditions. The joint is comprised of metal and ceramic parts and a flexible gasket. The flexible gasket is metal, but is thinner and more flexible than the metal part.	Research complete; seeking to license.
7,790,837	09/07/10	Virginia Polytechnic Institute	Ion-conducting sulfonated polymeric materials	Sulfonated polymers that can be formed into membranes that may be used in proton exchange membrane fuel cells.	Licensed to Battelle Memorial Institute.
7,790,314	09/07/10	Virginia Polytechnic Institute	Sulfonated polymer composition for forming fuel cell electrodes	Materials for a fuel cell membrane electrode assembly that are formed from sulfonated polymers.	Licensed to Battelle Memorial Institute.
7,790,285	09/07/10	Nanotek Instruments, Inc.	Nano-scaled graphene platelets with a high length-to-width aspect ratio	A nano-scaled graphene platelet (NGP) having a thickness no greater than 100 nm and a length-to-width ratio no less than 3 (preferably greater than 10). The NGP is prepared by intercalating a carbon fiber or graphite fiber with an intercalate to form an intercalated fiber and then exfoliating the intercalated fiber to obtain graphene sheets or flakes. The graphene sheets or flakes are separated to obtain nano-scaled graphene platelets. An electrically conductive nanocomposite material can be fabricated which could be useful for shielding of sensitive electronic equipment against electromagnetic interference (EMI) or radio frequency interference (RFI), and for electrostatic charge dissipation.	Research complete; seeking to license.
7,785,454	08/31/10	BASF Corporation	Gas diffusion electrodes, membrane-electrode assemblies and method for the production thereof	The invention relates to the production of an improved gas diffusion electrode for fuel cells. The electrode consists of an electrically conductive web, a non-catalyzed gas diffusion layer, and a noble metal coating.	No longer being used.
7,781,529	08/24/10	Arkema, Inc.	Blend of ionic (co)polymer resins and matrix (co) polymers	A novel polymeric resin blend useful for forming durable and chemical-resistant films for fuel cell membranes.	No longer being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,781,364	08/24/10	Los Alamos National Laboratory	Chalcogen catalysts for polymer electrolyte fuel cell	A cathode catalyst comprising a metal support that includes at least one transition metal and at least one chalcogen, both in elemental form. The catalyst is intended for use in polymer electrolyte membrane fuel cells and direct methanol fuel cells.	No longer being used.
7,767,616	08/03/10	Argonne National Laboratory	Aligned carbon nanotube with electro-catalytic activity for oxygen reduction reaction	A catalyst for an electrochemical oxygen reduction reaction (ORR) of a bundle of longitudinally aligned carbon nanotubes having a catalytically active transition metal incorporated longitudinally in said nanotubes.	No longer being pursued.
7,767,610	08/03/10	Sandia National Laboratory	Metal nanoparticles as a conductive catalyst	A metal nanocluster composite material for use as a conductive catalyst in fuel cell electrodes. The material has noble metal nanoclusters on a carbon substrate formed within a porous zeolitic material.	Being used in continuing research at SNL.
7,758,921	07/20/10	Argonne National Laboratory	Method of fabricating electrode catalyst layers with directionally oriented carbon support for proton exchange membrane fuel cell	A method of making a membrane electrode assembly (MEA) having an anode and a cathode and a proton conductive membrane there between. A bundle of longitudinally aligned carbon nanotubes with a catalytically active transition metal incorporated in the nanotubes forms at least one portion of the MEA and is in contact with the membrane.	No longer being pursued.
7,758,783	07/20/10	Nanotek Instruments, Inc.	Continuous production of exfoliated graphite composite compositions and flow field plates	A process for continuously producing a composite composition that can be used to make fuel cell bipolar plates or flow field plates. The flow field plates have a high electrical conductivity in the plate thickness direction.	Part of an emerging fuel cell technology.
7,737,190	06/15/10	E.I. du Pont de Nemours and Company	Process to prepare stable trifluorostyrene containing compounds grafted to base polymers using a solvent/ water mixture	A process for preparing a fluorinated ion exchange polymer that involves grafting at least one monomer derived from trifluorostyrene onto at least one base polymer in an organic solvent and water mixture. These ion exchange polymers are useful in preparing catalyst coated membranes and membrane electrode assemblies used in fuel cells.	No longer being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,732,084	06/08/10	General Electric Company	Solid oxide fuel cell with internal reforming, catalyzed interconnect for use therewith, and methods	A catalyzed interconnect for placement between an anode and a current collector in a fuel cell. This interconnect improves the efficiency of internal reforming of hydrocarbon fuels in solid oxide fuel cells.	Being used in continuing research at the company.
7,709,135	05/04/10	BASF Corporation	Efficient process for precious metal recovery from cell membrane electrode assemblies	A method is provided for recovering a catalytic element from a fuel cell membrane electrode assembly. The method includes grinding the membrane electrode assembly into a powder, extracting the catalytic element by forming a slurry comprising the powder and an acid leachate adapted to dissolve the catalytic element into a soluble salt, and separating the slurry into a depleted powder and a supernatant containing the catalytic element salt.	No longer being pursued.
7,704,919	04/27/10	Brookhaven National Laboratory	Electrocatalysts having gold monolayers on platinum nanoparticle cores, and uses thereof	Gold-coated particles useful as fuel cell electrocatalysts. The particles are composed of a platinum or platinum alloy core at least partially encapsulated by an outer shell of gold or gold alloy.	Part of an emerging fuel cell technology. Seeking to license
7,704,918	04/27/10	Brookhaven National Laboratory	Synthesis of metal-metal oxide catalysts and electrocatalysts using a metal cation adsorption/reduction and adatom replacement by more noble ones	Platinum-metal oxide composite particles and their use as electrocatalysts in oxygen-reducing cathodes and fuel cells. The invention also relates to methods of making the metal-metal oxide composites.	Being used in continuing research at BNL and seeking to license.
7,700,072	04/20/10	Purdue University	Catalytic hydrogen production from hydrolytic oxidation of organosilanes	A novel application of a transition metal oxo complex, a cationic oxorhenium (V) oxazoline, in the production of molecular hydrogen (H_2) from the catalytic hydrolytic oxidation of organosilanes. The reaction is characterized by quantitative hydrogen yields, low catalyst loading, ambient conditions, high selectivity for silanols, water as the only co-reagent, and no solvent requirement. The amount of hydrogen produced is proportional to the water stoichiometry. For example, reaction mixtures of polysilyl organics such as $HC(SiH_3)_3$ and water contain potentially greater than 6 wt.% hydrogen. Kinetic and isotope labeling experiments reveal a new mechanistic paradigm for the activation of Si--H bonds by oxometalates.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,699,916	04/20/10	Argonne National Laboratory	Corrosion-resistant, electrically-conductive plate for use in a fuel cell stack	A corrosion resistant, electrically conductive, durable plate partially coated with an anchor coating and a corrosion resistant coating. The plate is used as a bipolar plate in a proton exchange membrane fuel cell stack.	Being used in continuing research efforts at ANL.
7,691,780	04/06/10	Brookhaven National Laboratory	Platinum- and platinum alloy-coated palladium and palladium alloy particles and uses thereof	Particle and nanoparticle composites useful as oxygen-reduction electrocatalysts. The particle composites are composed of a palladium or palladium-alloy particle or nanoparticle substrate coated with an atomic submonolayer, monolayer, bilayer, or trilayer of zerovalent platinum atoms.	Part of an emerging fuel cell technology. Non-exclusive license to N.E. Chemcat Corporation.
7,691,770	04/06/10	General Electric Company	Electrode structure and methods of making same	The invention relates to a new electrode structure that improves the performance of solid oxide fuel cells.	Being used in continuing research at the company.
7,678,728	03/06/10	University of New Mexico	Self-supporting structurally engineered non-platinum electrocatalyst for oxygen reduction in fuel cells	A method for producing a highly dispersed, unsupported, non-platinum electrocatalyst for use in fuel cells.	Still being used in ongoing research.
7,670,988	03/02/10	University of New Mexico	Nanostructured anode PT-RU electrocatalysts for direct methanol fuel cells	An aerosol-assisted method for synthesis of nanostructured metallic electrocatalysts for direct methanol fuel cells. The resulting unsupported electrocatalysts are homogenous and highly dispersed.	Still being used in ongoing research.
7,659,026	02/09/10	E.I. du Pont de Nemours and Company	Fluorinated Sulfonamide Compounds and Polymer Electrolyte Membranes Prepared Therefrom For Use In Electrochemical Cells	A fluorinated sulfonamide small molecule containing an aromatic heterocyclic group modified by fluorinated sulfonamide groups and linear or branched perfluoroalkylene groups. The resulting particles and molecules can be used in polymer electrode membranes, membrane electrode assemblies, and fuel cells.	No longer being used.
7,652,479	01/26/10	Scribner Associates, Inc.	Electrolyte measurement device and measurement procedure	A novel electrode design and measurement system that allows rapid assessment of the through-thickness resistance of bare, non-catalyzed thin electrolytes such as those used in PEM fuel cells.	Part of an emerging fuel cell technology.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,648,784	01/19/10	Delphi Technologies, Inc.	Method and apparatus for controlling a fuel cell system having a variable number of parallel-connected modules	A fuel cell auxiliary power unit (APU) system comprising a plurality of fuel cell modules connected in parallel. Each module includes a local controller connected to a master controller that coordinates the modules to achieve a desired power output at any given time. Each module is operated within an output range to maximize efficiency of the system.	No longer being used.
7,645,535	01/12/10	General Electric Company	Method and materials for bonding electrodes to interconnect layers in solid oxide fuel cell stacks	A method and related bonding compositions for use in assembling a solid oxide fuel cell stack having thermally and chemically stable and electrically conductive bonds between alternating fuel cells and interconnect components in the stack.	Still being used in ongoing research.
7,635,534	12/22/09	BASF Corporation	Simplified process for leaching precious metals from fuel cell membrane electrode assemblies	An improved process for recovering precious metal catalysts from recycled fuel cell membrane electrode assemblies.	No longer being pursued.
7,633,267	12/15/09	Farasis Energy, Inc.	Apparatus for combinatorial screening of electrochemical materials	A high throughput combinatorial screening method and apparatus for the evaluation of electrochemical materials using a single voltage source.	No longer being used.
7,632,601	12/15/09	Brookhaven National Laboratory	Palladium-cobalt particles as oxygen-reduction electrocatalysts	An electrocatalyst is provided for oxygen-reducing cathodes and fuel cells containing palladium-cobalt particles.	Part of an emerging fuel cell technology project. Seeking to license
7,632,595	12/15/09	General Electric Company	Compliant fuel cell system	A fuel cell assembly comprising at least one metallic component, at least one ceramic component, and a structure disposed between the metallic component and the ceramic component. The assembly is designed to withstand strain during thermal cycles.	Being used in continuing research at the company.
7,632,593	12/15/09	Argonne National Laboratory	Bipolar plate supported solid oxide fuel cell with a sealed anode compartment	A bipolar plate supported solid oxide fuel cell with a sealed anode compartment. An improved method of sealing is provided by extending the metal seal around the entire perimeter of the cell between an electrolyte and the bipolar plate to form the anode compartment.	No longer being pursued.
7,629,426	12/08/09	Arkema, Inc.	Blend of ionic (co)polymer resins and matrix (co) polymers	A novel polymeric resin blend useful for forming durable and chemical-resistant films for fuel cell membranes.	No longer being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,629,285	12/08/09	University of South Carolina	Carbon-based composite electrocatalysts for low temperature fuel cells	A process for synthesis of a low-cost, easily manufactured carbon-based composite catalyst for use in proton exchange membrane (PEM) fuel cells is provided.	Research complete; seeking to license.
7,618,915	11/17/09	University of South Carolina	Composite catalysts supported on modified carbon substrates and methods of making the same	A method of producing a low-cost, easily manufactured carbon-based composite catalyst for use in proton exchange membrane (PEM) fuel cells is disclosed.	Research complete; seeking to license.
7,601,216	10/13/09	BASF Corporation	Gas diffusion electrodes, membrane-electrode assemblies and method for the production thereof	The invention relates to the production of an improved gas diffusion electrode for fuel cells. A method for forming a patterned noble metal coating on a gas diffusion medium is provided.	No longer being used.
7,589,047	09/15/09	Los Alamos National Laboratory	Composite materials and method of making	A method of depositing noble metals on a metal hexaboride support. The method permits the deposition of metallic films of controlled thickness and particle size at room temperature without using separate reducing agents. Composite materials comprising noble metal films deposited on such metal hexaborides may be used as catalysts and electrodes in fuel cells.	Being used in continuing research at Los Alamos National Laboratory.
7,588,857	09/15/09	Los Alamos National Laboratory	Chalcogen catalysts for polymer electrolyte fuel cell	A methanol-tolerant cathode catalyst and a membrane electrode assembly for fuel cells that includes such a cathode catalyst. The cathode catalyst includes a support having at least one transition metal in elemental form and a chalcogen disposed on the support. Methods of making the cathode catalyst and membrane electrode assembly are also described.	Research complete; seeking to license.
7,588,849	09/15/09	Delphi Technologies, Inc.	Solid-oxide fuel cell system having tempering of fuel cell stacks by exhaust gas	A fuel cell system which enhances stack performance via heat exchange with exhaust gas and use of a tempering jacket space surrounding the stack.	No longer being used.
7,575,824	08/18/09	Los Alamos National Laboratory	Method of improving fuel cell performance by removing at least one metal oxide contaminant from a fuel cell electrode	A method of removing contaminants from a fuel cell electrode. The method includes providing a getter electrode and a fuel cell catalyst electrode having at least one contaminant to a bath and applying a voltage sufficient to drive the contaminant from the fuel cell catalyst electrode to the getter electrode.	Being used in continuing research at LANL and seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,572,534	08/11/09	3M Company	Fuel cell membrane electrode assembly	A highly durable fuel cell membrane electrode assembly and methods of manufacturing are provided.	Part of a commercial fuel cell technology project.
7,563,532	07/21/09	E.I. du Pont de Nemours and Company	Trifluorostyrene containing compounds, and their use in polymer electrolyte membranes	A method for preparing a fluorinated ion exchange polymer by grafting a monomer onto a base polymer. These ion exchange polymers are useful in preparing catalyst coated membranes and membrane electrode assemblies for fuel cells.	No longer being used.
7,562,588	07/21/09	Delphi Technologies, Inc.	Method and apparatus for controlling mass flow rate of recycled anode tail gas in solid oxide fuel cell system	A system for controlling the mass flow rate of anode tail gas being recycled in a solid oxide fuel cell system.	No longer being used.
7,550,223	06/23/09	Los Alamos National Laboratory	Method of making metal-polymer composite catalysts	A metal-polymer-carbon composite catalyst for use as a cathode electrocatalyst in fuel cells. The catalyst includes a heteroatomic polymer, a transition metal linked to the heteroatomic polymer by one of nitrogen, sulfur, and phosphorus, and a recast ionomer dispersed throughout the heteroatomic polymer-carbon composite.	Being used in continuing research at LANL.
7,550,216	06/23/09	Foster-Miller, Inc.	Composite solid polymer electrolyte membranes	Composite solid polymer electrolyte membranes which include a porous polymer substrate interpenetrated with a water soluble ion-conducting material. These membranes are useful in electrochemical applications, including fuel cells and electrodialysis.	Still being used in ongoing research.
7,544,764	06/09/09	Virginia Polytechnic Institute	Sulfonated polymer composition for forming fuel cell electrodes	Materials for a fuel cell membrane electrode assembly that are formed from sulfonated polymers.	Licensed to Battelle Memorial Institute.
7,534,296	05/19/09	Michigan State	Electrically conductive diamond electrodes	An electrically conductive diamond electrode and process for preparation thereof is described. The electrode comprises diamond particles coated with electrically conductive doped diamond preferably by chemical vapor deposition which is held together with a binder. The electrodes are useful for oxidation reduction in gas, such as hydrogen generation by electrolysis.	Still being used in ongoing research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,518,886	04/14/09	Virginia Polytechnic Institute	Multiphase soft switched DC/DC converter and active control technique for fuel cell ripple current elimination	A fuel cell having an n-phase transformer isolated phase shift DC/DC converter, a three-phase transformer isolated phase shift DC/DC converter, or an active current ripple control.	Research complete; seeking to license.
7,517,604	04/14/09	3M Company	Fuel cell electrolyte membrane with acidic polymer	A fuel cell electrolyte membrane for use at high operating temperatures while preserving proton conductivity.	Part of a commercial fuel cell technology.
7,507,495	03/24/09	Brookhaven National Laboratory	Hydrogen absorption induced metal deposition on palladium and palladium-alloy particles	Methods for producing metal-coated palladium or palladium-alloy particles, and for producing catalysts using the particles.	Part of an emerging fuel cell technology. Non-exclusive license to N.E. Chemcat Corporation.
7,482,083	01/27/09	General Electric Company	Corrosion resistant coated fuel cell bipolar plate with filled-in fine scale porosities	A corrosion resistant coated fuel cell plate and method of making the same are embodied in a metal plate provided with a multilayered conductive coating and an overcoat which fills in fine scale porosities in the coating. In one preferred embodiment, the overcoating is amorphous graphite applied through a deposition process. In another preferred embodiment, overcoating is a thin layer of oxide created by chemical anodization process.	Still being used in ongoing research.
7,473,714	01/06/09	Virginia Polytechnic Institute	Materials for use as proton conducting membranes for fuel cells	A family of polymers having pendent sulfonate moieties connected to polymeric main chain phenyl groups. These polymers can be used in proton exchange membranes for fuel cells.	Licensed to Battelle Memorial Institute.
7,456,314	11/25/08	E.I. du Pont de Nemours and Company	Partially fluorinated ionic compounds	Cation-exchange resins that are useful in making proton-exchange membranes for electrochemical cells such as fuel cells.	Still being used in ongoing research.
7,449,111	11/11/08	Arkema, Inc.	Resins containing ionic or ionizable groups with small domain sizes and improved conductivity	A polymer that contains at least one acrylic resin or vinyl resin having at least one ionic or ionizable group. The polymer has improved conductivity when formed into a film and can be used in fuel cell membranes.	No longer being used.
7,419,546	09/02/08	BASF Corporation	Gas diffusion electrodes, membrane-electrode assemblies and method for the production thereof	The invention relates to the production of an improved gas diffusion electrode for fuel cells. A method for forming a noble metal coating on a gas diffusion medium is provided.	No longer being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,396,880	07/08/08	Arkema, Inc.	Blend of ionic (co)polymer resins and matrix (co) polymers	A novel polymeric resin blend useful for forming durable and chemical-resistant films for fuel cell membranes.	No longer being used.
7,375,176	05/20/08	Case Western Reserve University	Liquid crystal poly(phenylene sulfonic acids)	A rigid, rod liquid crystal polymer includes a poly (phenylene sulfonic acid).	Still being used in ongoing research.
7,373,819	05/20/08	Honeywell International, Inc.	Stress sensitive humidity sensor based on a MEMS structure	A humidity sensing apparatus and method include a substrate and a MEMS structure. The MEMS structure comprises a humidity-sensitive material in association with a movable member. Changes in humidity cause movement in the MEMS structure providing an indication of humidity based on a stress within the MEMS structure.	No longer being used.
7,365,121	04/29/08	Virginia Polytechnic Institute	Highly conductive thermoplastic composites for rapid production of fuel cell bipolar plates	A low-cost method of fabricating bipolar plates for use in fuel cells that use a wet lay process for combining graphite particles, thermoplastic fibers, and reinforcing fibers to produce a plurality of formable sheets.	Research complete; seeking to license.
7,361,729	04/22/08	Virginia Polytechnic Institute	Ion-conducting sulfonated polymeric materials	Sulfonated polymers that can be formed into membranes that may be used in proton exchange membrane fuel cells.	No longer licensed to Battelle Memorial Institute. No longer being pursued.
7,323,159	01/29/08	Argonne National Laboratory	Method for fast start of a fuel processor	An improved fuel processor for fuel cells is provided whereby the startup time of the processor is less than 60 seconds and can be as low as 30 seconds, if not less.	Not licensed and not being used in research at ANL.
7,270,906	09/18/07	Delphi Technologies, Inc.	Solid-oxide fuel cell module for a fuel cell stack	A novel fuel cell module having four sheet metal parts stamped from flat stock. The parts do not require any forming operations such as folding or dishing, and each part may have a different thickness to suit its function.	No longer being used.
7,264,778	09/04/07	Sandia National Laboratory	Carbon monoxide sensor and method of use	Carbon monoxide sensors suitable for use in hydrogen feed streams and methods of use. The sensors are palladium metal/insulator/semiconductor sensors. The methods and sensors are suitable for use in proton exchange membrane fuel cells.	Not licensed and not being used in research at SNL.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,255,798	08/14/07	Ion Power, Inc.	Recycling of used perfluorosulfonic acid membranes	A method for recovering and recycling catalyst-coated fuel cell membranes includes dissolving the used membranes in water and solvent, heating the dissolved membranes under pressure, and separating the components.	Used in Ion Power's emerging technology.
7,247,403	07/24/07	Oak Ridge National Laboratory	Surface modified stainless steels for PEM fuel cell bipolar plates	A nitridation treated stainless steel article (such as a bipolar plate for a proton exchange membrane fuel cell) having lower interfacial contact electrical resistance and better corrosion resistance than an untreated stainless steel article.	Still being used in ongoing research. Part of an emerging fuel cell technology.
7,214,442	05/08/07	Los Alamos National Laboratory	High specific power, direct methanol fuel cell stack	A fuel cell stack including at least one direct methanol fuel cell. A cathode manifold is used to convey ambient air to each fuel cell, and an anode manifold is used to convey liquid methanol fuel to each fuel cell.	Being used in continuing research at LANL.
7,211,346	05/01/07	Oak Ridge National Laboratory	Corrosion-resistant metallic bipolar plate	An electrically conductive component such as a bipolar plate for a PEM fuel cell. The component has an external, continuous layer of chromium nitride.	Still being used in ongoing research. Part of an emerging fuel cell technology.
7,195,835	03/27/07	Argonne National Laboratory	Proton conducting membrane for fuel cells	An ion conducting membrane comprising dendrimeric polymers covalently linked into a network structure.	No licensee and no further development of this technology at ANL.
7,144,753	12/05/06	Michigan State	Boron-doped nanocrystalline diamond	A conductive boron doped nanocrystalline diamond is described. The boron doped diamond conductivity is derived from the boron in the crystals acting as charge carriers. The diamond is useful for electrochemical electrodes in oxidation-reduction reactions and decontamination of aqueous solutions.	Still being used in ongoing research.
7,138,199	11/21/06	Dynalene, Inc.	Fuel cell and fuel cell coolant compositions	Directed to coolant compositions useful in fuel cells, and to fuel cells containing such coolant compositions.	Part of a commercial fuel cell technology.
7,135,537	11/14/06	E.I. du Pont de Nemours and Company	Sulfonimide-containing poly(arylene ether)s and poly(arylene ether sulfone)s, methods for producing the same, and their uses	Directed to sulfonimide-containing polymers, for use in conductive membranes and fuel cells.	No longer being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,101,643	09/05/06	Lawrence Berkeley National Laboratory	Polymeric electrolytes based on hydrosilyation reactions	New polymer electrolytes prepared by in situ cross-linking of allyl functional polymers based on a hydrosilation reaction using a multifunctional silane cross-linker and an organoplatinum catalyst. The electrolyte membranes are insoluble in organic solvents and have high mechanical strength.	Being used in research at LBNL and seeking to license.
7,101,635	09/05/06	Los Alamos National Laboratory	Methanol-tolerant cathode catalyst composite for direct methanol fuel cells	Direct methanol fuel cell having a methanol fuel supply, oxidant supply, and membrane electrode assembly.	Not licensed and not being used at LANL for research.
7,101,527	09/05/06	Iowa State University	Mixed anion materials and compounds for novel proton conducting membranes	Amorphous or partially crystalline mixed anion chalcogenide compounds for use in proton exchange membranes which can operate over a wide variety of temperature ranges, including in the intermediate temperature range 100 to 300 °C, and new uses for crystalline mixed anion chalcogenide compounds in such proton exchange membranes.	Being used in research at Iowa State University and seeking to license.
7,052,793	05/30/06	Foster-Miller, Inc.	Composite solid polymer electrolyte membranes	Composite solid polymer electrolyte membranes (SPEMs), which include a porous polymer substrate interpenetrated with an ion-conducting material. These SPEMs are useful in electrochemical applications, including fuel cells and electrodialysis.	Being used in continuing research at the company.
7,022,810	04/04/06	Sandia National Laboratory	Proton exchange membrane materials for the advancement of direct methanol fuel-cell technology	A new class of hybrid organic-inorganic materials, and methods of synthesis, which can be used as a proton exchange membrane in a direct methanol fuel cell.	Not licensed and not being used in research at SNL.
7,018,604	03/28/06	Iowa State University	Compounds for novel proton conducting membranes and methods of making same	A new set of compounds for use in polymer electrolyte membranes which are able to operate in a wide variety of temperature ranges, including in the intermediate temperature range of about 100 °C to 700 °C.	Being used in research at Iowa State University and seeking to license.
7,014,931	03/21/06	Los Alamos National Laboratory	Methanol-tolerant cathode catalyst composite for direct methanol fuel cells	A direct methanol fuel cell having a methanol fuel supply, oxidant supply, and its membrane electrode assembly.	Not licensed and not being used at LANL for research.
6,995,114	02/07/06	Symyx Technologies, Inc.	Platinum-ruthenium-palladium fuel cell electrocatalyst	A catalyst for use in electrochemical reactor devices, the catalyst containing platinum, ruthenium, and palladium.	Not licensed and no research being done with this patent.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,994,829	02/07/06	Pacific Northwest National Laboratory	Fluid processing device and method	A fluid processing unit having first and second interleaved flow paths in a cross flow configuration. The device can be used for vaporization of water, gasoline, and other fluids, and is useful for automotive fuel cell applications requiring rapid startup.	Research complete; seeking to license.
6,986,963	01/17/06	Oak Ridge National Laboratory	Metallization of bacterial cellulose for electrical and electronic device manufacture	Metallized bacterial cellulose used in constructing fuel cells and other electronic devices.	No commercialization. No longer being pursued.
6,986,961	01/17/06	Los Alamos National Laboratory	Fuel cell stack with passive air supply	A fuel cell stack comprised of a plurality of polymer electrolyte fuel cells.	Not licensed and not being used at LANL for research.
6,977,122	12/20/05	Argonne National Laboratory	Proton conducting membrane for fuel cells	An ion conducting membrane comprising dendrimeric polymers covalently linked into a network structure.	No licensee and no further development of this technology at ANL.
6,962,760	11/08/05	Los Alamos National Laboratory	Methods of conditioning direct methanol fuel cells	Methods for conditioning the membrane electrode assembly of a direct methanol fuel cell.	Not licensed and not being used at LANL for research.
6,960,235	11/01/05	Lawrence Livermore National Laboratory	Chemical microreactor and method thereof	A chemical microreactor for generation of hydrogen fuel from liquid sources such as ammonia, methanol, and butane by steam reforming. The microreactor contains capillary microchannels with integrated resistive heaters to facilitate the occurrence of catalytic steam reforming reactions.	Licensed to Bren-Tronics, Inc.; part of a commercial fuel cell technology project.
6,956,083	10/18/05	Lawrence Berkeley National Laboratory	Single ion conductor cross-linked polymeric networks	The invention relates to the synthesis, characterization, and electrochemical response of a new type of single-ion comb-branch polymer electrolyte that can be used as a proton exchange membrane in fuel cells.	Being used in research at LBNL and seeking to license.
6,926,986	08/09/05	Energy Conversion Devices, Inc.	Fuel cell with encapsulated electrodes	A fuel cell utilizing parallel flow of a hydrogen stream, an oxygen stream, and an electrolyte solution with respect to the electrodes, while maintaining mechanical support within the fuel cell. The fuel cell utilizes encapsulated electrodes to maintain a high airflow rate and low pressure throughout the fuel cell.	No longer being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,921,605	07/26/05	Symyx Technologies, Inc.	Platinum-ruthenium-nickel fuel cell electrocatalyst	A catalyst suitable for use in a fuel cell, especially as an anode catalyst, that contains platinum, ruthenium, and nickel.	Not licensed and no research being done with this patent.
6,921,595	07/26/05	Nuvera Fuel Cells, Inc.	Joint-cycle high-efficiency fuel cell system with power generating turbine	Process for increasing the efficiency of a system comprising a fuel reformer coupled to a fuel cell. Pressurized air and heat generated by the fuel cell are used to make a pressurized air and steam mixture. The air and steam mixture is then fed as an oxidant into a fuel burner; producing a steam-containing exhaust having an expansion potential from the fuel burner; driving an expander using the expansion potential of the steam-containing exhaust; and recovering mechanical energy from the expander in excess of the energy used in compressing the pressurized air.	No longer being pursued.
6,916,564	07/12/05	Nuvera Fuel Cells, Inc.	High-efficiency fuel cell power system with power generating expander	A hydrogen fuel cell power system with improved efficiency comprising of a fuel cell, hydrogen gas source, compressor for creating a pressurized air stream, and a liquid supply which is heated by waste heat form the power system to produce a pressurized air and steam mixture.	No longer being pursued.
6,884,290	04/26/05	Michigan State	Electrically conductive polycrystalline diamond and particulate metal based electrodes	An electrically conducting and dimensionally stable diamond and metal particle electrode produced by electrodepositing the metal on the diamond is described. The electrode is useful in harsh chemical environments and at high current densities and potentials. The electrode is useful for generating hydrogen, and for reducing oxygen and oxidizing methanol in reactions which are of importance in fuel cells.	Still being used in ongoing research.
6,864,007	03/08/05	Hybrid Power Generation Systems, LLC	Corrosion resistant coated fuel cell plate with graphite protective barrier and method of making the same	A corrosion resistant coated fuel cell plate and method of construction using a metal plate with a graphite emulsion coating and a layer of graphite foil pressed over the coating. The graphite emulsion bonds the graphite foil to the metal plate and seals fine scale porosities in the graphite foil. Flow fields are formed by stamping the coated fuel cell plate.	No longer being pursued.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,864,004	03/08/05	Los Alamos National Laboratory	Direct methanol fuel cell stack	A stack of direct methanol fuel cells exhibiting a circular footprint.	Not licensed and not being used at LANL for research.
6,861,169	03/01/05	Nuvera Fuel Cells, Inc.	Cogeneration of power and heat by an integrated fuel cell power system	Methods and apparatus for the cogeneration of power and heat from a fuel cell stack and an associated fuel processor assembly (i.e., a fuel reforming system) to provide both electricity and heating for a particular site, such as a building or a group of buildings.	No longer being pursued.
6,847,188	01/25/05	General Motors Corporation	Fuel cell stack monitoring and system control	A control method for monitoring a fuel cell stack in a fuel cell system in which the actual voltage and actual current from the fuel cell stack are monitored.	Being used in continuing research at the company.
6,828,057	12/07/04	Energy Conversion Devices, Inc.	Fuel cell with framed electrodes	A fuel cell utilizing parallel flow of a hydrogen stream, an oxygen stream, and an electrolyte solution with respect to the electrodes, while maintaining mechanical support within the fuel cell. The fuel cell utilizes framed electrodes to maintain a high air flow rate and low pressure throughout the fuel cell.	Being used in ongoing research as part of Tactical Fuel Cells at Energy Technologies, Inc.
6,818,341	11/16/04	Los Alamos National Laboratory	Fuel cell anode configuration for CO tolerance	A polymer electrolyte fuel cell (PEFC) is designed to operate on a reformate fuel stream containing oxygen and diluted hydrogen fuel with CO impurities.	Still being used in ongoing research; seeking to license.
6,808,838	10/26/04	Los Alamos National Laboratory	Direct methanol fuel cell and system	A fuel cell having an anode and a cathode and a polymer electrolyte membrane located between anode and cathode gas diffusion backings that uses a methanol vapor fuel supply.	Not licensed and not being used at LANL for research.
6,790,548	09/14/04	General Motors Corporation	Staged venting of fuel cell system during rapid shutdown	A venting methodology and system for rapid shutdown of a fuel cell apparatus used in a vehicle propulsion system.	Being used in continuing research at the company.
6,723,678	04/20/04	Symyx Technologies, Inc.	Platinum-ruthenium-nickel alloy for use as a fuel cell catalyst	An improved noble metal alloy composition for a fuel cell catalyst, the alloy containing platinum, ruthenium, and nickel. The alloy shows methanol oxidation activity.	Not licensed and no research being done with this patent.
6,696,382	02/24/04	Los Alamos National Laboratory	Catalyst inks and method of application for direct methanol fuel cells	Inks are formulated for forming anode and cathode catalyst layers and applied to anode and cathode sides of a membrane for a direct methanol fuel cell.	Not licensed and not being used at LANL for research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,692,851	02/17/04	General Motors Corporation	Fuel cell stack monitoring and system control	A control method for monitoring the voltage and current from a fuel cell stack.	Being used in continuing research at the company.
6,686,084	02/03/04	Hybrid Power Generation Systems, LLC	Gas block mechanism for water removal in fuel cells	An apparatus and method for removing water from the cathode side of a fuel cell.	No longer being used.
6,682,837	01/27/04	Symyx Technologies, Inc.	Method for producing electricity using a platinum-ruthenium-palladium catalyst in a fuel cell	A method for producing electricity using a fuel cell that utilizes a ternary alloy composition as a fuel cell catalyst, the ternary alloy composition containing platinum, ruthenium, and palladium.	Not licensed and no research being done with this patent.
6,670,305	12/30/03	Argonne National Laboratory	Free-standing monolithic catalyst with micro-scale channel dimensions	A monolithic catalyst with micro-scale flow channels and methods of making such a monolithic catalyst.	No longer being pursued.
6,670,301	12/30/03	Brookhaven National Laboratory	Carbon monoxide tolerant electrocatalyst with low platinum loading and a process for its preparation	An electrocatalyst is provided for use in a fuel cell that has low platinum loading and a high tolerance to carbon monoxide poisoning.	Still being used in research and seeking to license. Part of an emerging fuel cell technology.
6,653,005	11/25/03	University of Central Florida	Portable hydrogen generator-fuel cell apparatus	A compact hydrogen generator is coupled to or integrated with a fuel cell for portable power applications.	Being used in research at University of Central Florida but no licensees.
6,649,031	11/18/03	Hybrid Power Generation Systems, LLC	Corrosion resistant coated fuel cell bipolar plate with filled-in fine scale porosities and method of making the same	A corrosion resistant coated fuel cell plate and method of construction using a metal plate with a multilayered conductive coating and an overcoating which fills in fine scale porosities. The overcoating can be amorphous graphite or a thin layer of oxide created by a chemical anodization.	No longer being pursued.
6,635,378	10/21/03	Hybrid Power Generation Systems, LLC	Fuel cell having improved condensation and reaction product management capabilities	A fuel cell bipolar plate including a plurality of reactant channels defining respective inlets and outlets and at least two flow restrictors respectively associated with at least two adjacent reactant channels.	No longer being pursued.
6,635,369	10/21/03	Los Alamos National Laboratory	Method for improving fuel cell performance	A method is provided for operating a fuel cell at high voltage for sustained periods of time.	Still being used in ongoing research; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,617,065	09/09/03	Teledyne Energy Systems, Inc.	Method and apparatus for maintaining neutral water balance in a fuel cell system	A method for maintaining a neutral water balance in a fuel cell system, wherein water from the exhaust of a fuel cell stack is recycled for use in the system's humidifiers and other components. The water balance is maintained by adjusting the fuel cell stack operating temperature based on the water level in the system's water reservoir.	No longer being used.
6,607,854	08/19/03	Honeywell International, Inc.	Three-wheel air turbocompressor for PEM fuel cell systems	A fuel cell system that utilizes a pair of parallel turbines engaged to a compressor for increased system efficiency.	No longer being used.
6,602,624	08/05/03	General Motors Corporation	Control apparatus and method for efficiently heating a fuel processor in a fuel cell system	An apparatus and method for efficiently controlling the amount of heat generated by a fuel processor in a fuel cell system. A temperature error between actual and desired fuel processor temperature is determined; this error is converted to a combustor fuel injector command signal or a heat dump valve position command signal depending upon the type of error.	Being used in continuing research at the company.
6,596,422	07/22/03	Los Alamos National Laboratory	Air breathing direct methanol fuel cell	A method for activating a membrane electrode assembly for a direct methanol fuel cell is disclosed. The method comprises operating the fuel cell with humidified hydrogen as the fuel followed by running the fuel cell with methanol as the fuel.	Not licensed and not being used at LANL for research.
6,586,561	07/01/03	Case Western Reserve University	Rigid rod ion conducting copolymers	Sulfonated polyimide polymers incorporating bulky monomers are disclosed. The polymers have a liquid crystalline structure and exhibit high conductivity, high water uptake and water stability over a range of relative humidities and temperatures. The polymers are adapted for use as a polymer electrolyte membrane in fuel cells.	Research complete; seeking to license.
6,576,359	06/10/03	General Motors Corporation	Controlled air injection for a fuel cell system	A method and apparatus for injecting oxygen into a fuel cell reformate stream to reduce the level of carbon monoxide while preserving the level of hydrogen in a fuel cell system.	Being used in continuing research at the company.
6,551,736	04/22/03	Teledyne Energy Systems, Inc.	Fuel cell collector plates with improved mass transfer channels	Fuel cell collector plates with new channel constructions for improving the transportation of gases to the cell's gas diffusion layers.	Research complete; seeking to license.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,528,198	03/04/03	Plug Power, LLC	Fuel cell membrane hydration and fluid metering	A hydration system includes fuel cell fluid flow plates and injection ports.	No longer being used.
6,517,965	02/11/03	Symyx Technologies, Inc.	Platinum-ruthenium-nickel alloy for use as a fuel cell catalyst	An improved noble metal alloy composition for a fuel cell catalyst, the alloy containing platinum, ruthenium, and nickel. The alloy shows methanol oxidation activity.	Not licensed and no research being done with this patent.
6,498,121	12/24/02	Symyx Technologies, Inc.	Platinum-ruthenium-palladium alloys for use as a fuel cell catalyst	A noble metal alloy composition for a fuel cell catalyst, a ternary alloy composition containing platinum, ruthenium and palladium. The alloy shows increased activity compared with well-known catalysts.	Not licensed and no research being done with this patent.
6,497,970	12/24/02	General Motors Corporation	Controlled air injection for a fuel cell system	A method and apparatus for injecting oxygen into a fuel cell reformate stream to reduce the level of carbon monoxide while preserving the level of hydrogen in a fuel cell system.	Being used in continuing research at the company.
6,492,052	12/10/02	Los Alamos National Laboratory	Air breathing direct methanol fuel cell	An air breathing direct methanol fuel cell is provided with a membrane electrode assembly, a conductive anode assembly that is permeable to air and directly open to atmospheric air, and a conductive cathode assembly that is permeable to methanol and directly contacting a liquid methanol source.	Not licensed and not being used at LANL for research.
6,490,812	12/10/02	Pacific Northwest National Laboratory	Active microchannel fluid processing unit and method of making	An active microchannel fluid processing unit.	Exclusive license to Velocys, Inc.
6,458,479	10/01/02	Los Alamos National Laboratory	Air breathing direct methanol fuel cell	An air breathing direct methanol fuel cell is provided with a membrane electrode assembly, a conductive anode assembly that is permeable to air and directly open to atmospheric air, and a conductive cathode assembly that is permeable to methanol and directly contacting a liquid methanol source.	Not licensed and not being used at LANL for research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,455,180	09/24/02	General Motors Corporation	Flexible method for monitoring fuel cell voltage	A method for monitoring the voltage of different groups of cells (a.k.a., "clusters") within a fuel cell stack, wherein the number of cells in a cluster can be varied. The method improves fuel cell stack diagnostic monitoring by enabling identification of individual cells within the stack that are contributing to a voltage drop across the entire stack.	Being used in continuing research at the company.
6,454,922	09/24/02	Los Alamos National Laboratory	Corrosion test cell for bipolar plates	A corrosion test cell for evaluating corrosion resistance in fuel cell bipolar plates.	Exclusive license to Fuel Cell Technologies, Inc. Part of a fuel cell commercial technology.
6,451,471	09/17/02	Teledyne Energy Systems, Inc.	Conductivity fuel cell collector plate and method of fabrication	An improved method of manufacturing PEM fuel cell collector plates that increases the electrical conductivity and mechanical strength of the plates.	Research complete; seeking to license.
6,451,465	09/17/02	General Motors Corporation	Method for operating a combustor in a fuel cell system	A method of operating a combustor to heat a fuel processor in a fuel cell system, in which the fuel processor includes a reactor which generates a hydrogen containing stream.	No longer being pursued.
6,436,561	08/20/02	General Motors Corporation	Methanol tailgas combustor control method	A method for controlling the power, temperature, and fuel source of a combustor used to supply heat to a fuel reformer used for generating hydrogen from liquid fuels (e.g., methanol) in on-board automotive applications.	Being used in continuing research at the company.
6,416,893	07/09/02	General Motors Corporation	Method and apparatus for controlling combustor temperature during transient load changes	A method and apparatus for controlling the temperature of a combustor in an automotive fuel cell system. The method includes a fast acting air bypass valve connected in parallel with an air inlet to the combustor.	Being used in continuing research at the company.
6,413,662	07/02/02	General Motors Corporation	Fuel cell system shutdown with anode pressure control	A venting methodology and pressure sensing and vent valving arrangement for monitoring anode bypass valve operating during the normal shutdown of a fuel cell apparatus of the type used in vehicle propulsion systems.	Being used in continuing research at the company.
6,413,661	07/02/02	General Motors Corporation	Method for operating a combustor in a fuel cell system	A method of operating a combustor to heat a fuel processor to a desired temperature in a fuel cell system, wherein the fuel processor generates hydrogen from a hydrocarbon for reaction within a fuel cell to generate electricity.	No longer being pursued, abandoned.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,395,414	05/28/02	General Motors Corporation	Staged venting of fuel cell system during rapid shutdown	A venting methodology and system for rapid shutdown of a fuel cell apparatus of the type used in a vehicle propulsion system.	Being used in continuing research at the company.
6,376,112	04/23/02	General Motors Corporation	Controlled shutdown of a fuel cell	A method is provided for the shutdown of a fuel cell system to relieve system overpressure while maintaining air compressor operation, and corresponding vent valving and control arrangement. The method and venting arrangement can be employed in a fuel cell system used for vehicle propulsion.	Being used in continuing research at the company.
6,372,376	04/16/02	General Motors Corporation	Corrosion resistant PEM fuel cell	A PEM fuel cell having electrical contact elements comprising a corrosion-susceptible substrate metal coated with an electrically conductive, corrosion-resistant polymer.	Being used in continuing research at the company.
6,322,919	11/27/01	Allied Signal, Inc.	Fuel cell and bipolar plate for use with same	A fuel cell bipolar plate including a fuel side having a series of fuel channels defining respective fuel paths and an oxidant side having a series of oxidant channels defining respective oxidant paths. Some fuel channels are offset from adjacent oxidant channels in a direction transverse to the fuel and oxidant paths. Manifolds are connected to the fuel and oxidant channels. One of the two manifolds is located between the biplate and the other manifold, where a connector extends from whichever manifold is outermost to the associated fuel or oxidant channels.	No longer being pursued.
6,306,531	10/23/01	General Motors Corporation	Combustor air flow control method for fuel cell apparatus	A method for controlling the heat output of a combustor used to provide heat to a fuel reformer in a fuel cell apparatus.	Being used in continuing research at the company.
6,296,964	10/02/01	Los Alamos National Laboratory	Enhanced methanol utilization in direct methanol fuel cell	The fuel utilization of a direct methanol fuel cell is enhanced for improved cell efficiency.	Not licensed and not being used at LANL for research.
6,277,513	08/21/01	General Motors Corporation	Layered electrode for electrochemical cells	A fuel cell electrode structure consisting of a current collector sheet and first and second layers of electrode material. The electrode design improves catalyst utilization and water management.	Being used in continuing research at the company.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,268,074	07/31/01	General Motors Corporation	Water injected fuel cell system compressor	A fuel cell system that uses a dry compressor for pressurizing air supplied to the cathode side of the fuel cell. An injector sprays a controlled amount of water onto the compressor's rotors to improve the energy efficiency of the compressor.	Being used in continuing research at the company.
6,265,222	07/24/01	Advanced Technology Materials, Inc.	Micro-machined thin film hydrogen gas sensor and method of making and using the sensor	A hydrogen sensor including a thin film sensor element formed, e.g., by metal organic chemical vapor deposition or physical vapor deposition, on a micro hotplate structure.	Patent sold to Honeywell but no further R&D being done with the patent at this time.
6,265,092	07/24/01	General Motors Corporation	Method of controlling injection of oxygen into hydrogen-rich fuel cell feed stream	A method of operating a H_2-O_2 fuel cell fueled by hydrogen-rich fuel stream containing CO. The CO content is reduced to acceptable levels by injecting oxygen into the fuel gas stream.	Being used in continuing research at the company.
6,255,012	07/03/01	Los Alamos National Laboratory	Pleated metal bipolar assembly	Bipolar plates for electrochemical cells are formed from conductive foils supported by a polymer support plate. The polymer support plate can be readily configured with flow fields during a manufacturing process, such as injection molding, without the need for machining. Likewise, the conductive foils can be stamped or corrugated to matching configurations without any need for machining. The resulting structure is inexpensive to form and is compact and lightweight.	Being used in continuing research at LANL.
6,248,469	06/19/01	Foster-Miller, Inc.	Composite solid polymer electrolyte membranes	Composite solid polymer electrolyte membranes which include a porous polymer substrate interpenetrated with an ion-conducting material. These membranes can be used in fuel cells and electrodialysis.	Being used in continuing research at the company.
6,248,467	06/19/01	Los Alamos National Laboratory	Composite bipolar plate for electrochemical cells	A bipolar separator plate for fuel cells consists of a molded mixture of a vinyl ester resin and graphite powder.	Exclusive license to Bulk Molding Compounds, Inc. Part of a commercial fuel cell technology.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,245,214	06/12/01	Allied Signal, Inc.	Electro-catalytic oxidation (ECO) device to remove CO from reformate for fuel cell application	A method and apparatus that removes carbon monoxide from hydrogen rich fuel with a catalytic material that preferentially adsorbs carbon monoxide. The catalytic material is regenerated by an oxidizing agent that reacts with the absorbed carbon monoxide. The reaction is initiated by an electrical current generated either galvanically or electrolytically.	No longer being pursued.
6,232,005	05/15/01	General Motors Corporation	Fuel cell system combustor	A fuel cell system including a fuel reformer heated by a catalytic combustor fired by anode and cathode effluents.	No longer being pursued, abandoned.
6,207,312	03/27/01	Energy Partners, L.C.	Self-humidifying fuel cell	A self-humidifying polymer electrolyte membrane (PEM) fuel cell assembly that has an ion-exchange membrane interposed between hydrogen and oxygen diffusion layers to form a membrane electrode assembly (MEA).	No longer being used.
6,207,310	03/27/01	Los Alamos National Laboratory	Fuel cell with metal screen flow-field	A polymer electrolyte membrane fuel cell is provided with electrodes supplied with a reactant on each side of a catalyzed membrane assembly.	Not licensed and not being used at LANL for research.
6,200,536	03/13/01	Pacific Northwest National Laboratory	Active microchannel heat exchanger	An active microchannel heat exchanger with an active heat source and with microchannel architecture. The invention is useful as a liquid fuel vaporizer or a steam generator for fuel cell power systems.	Exclusive license to Velocys, Inc.
6,192,596	02/27/01	Pacific Northwest National Laboratory	Active microchannel fluid processing unit and method of making	An active microchannel fluid processing unit.	Exclusive license to Velocys, Inc.
6,183,894	02/06/01	Brookhaven National Laboratory	Electrocatalyst for alcohol oxidation in fuel cells	Binary and ternary electrocatalysts are provided for oxidizing alcohol in a fuel cell.	Not licensed or commercialized. Research is on-going.
6,180,275	01/30/01	Energy Partners, L.C.	Fuel cell collector plate and method of fabrication	An improved molding composition is provided for compression molding or injection molding a current collector plate for a polymer electrolyte membrane fuel cell.	No longer being used in research.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,171,720	01/09/01	Oak Ridge National Laboratory	Bipolar plate/diffuser for a proton exchange membrane fuel cell	A combination bipolar plate and diffuser fuel cell component that includes an electrically conducting solid material having a porous region and a hermetic region.	No longer being used.
6,159,626	12/12/00	General Motors Corporation	Fuel cell system logic for differentiating between rapid and normal shutdown commands	A method of controlling the operation of a fuel cell system wherein each shutdown command for the system is subjected to decision logic which determines whether the command should be a normal shutdown command or rapid shutdown command.	Being used in continuing research at the company.
6,159,533	12/12/00	Southwest Research Institute	Method of depositing a catalyst on a fuel cell electrode	Fuel cell electrodes comprising a minimal load of catalyst having maximum catalytic activity and a method of forming such fuel cell electrodes.	No licensee and no research being done with this technology.
6,129,973	10/10/00	Pacific Northwest National Laboratory	Microchannel laminated mass exchanger and method of making	A microchannel mass exchanger having a first plurality of inner thin sheets and a second plurality of outer thin sheets is described. The device enables solute molecules in a solvent to pass from the solvent to a mass transfer medium efficiently.	Exclusive license to Velocys, Inc.
6,126,723	10/03/00	Pacific Northwest National Laboratory	Microcomponent assembly for efficient contacting of fluid	Method and apparatus for a microcomponent assembly that achieves state-of-the-art chemical separation via absorption or adsorption mechanisms. The device can be utilized as a fuel processing system in fuel-cell-powered automobiles for removal of catalyst poisons (e.g., H_2S and CO) from the fuel stream.	Exclusive license to Velocys, Inc.
6,117,577	09/12/00	Los Alamos National Laboratory	Ambient pressure fuel cell system	An ambient pressure fuel cell system is provided with a fuel cell stack formed from a plurality of fuel cells having membrane and electrode assemblies.	Non-exclusive license to IdaTech - Not being used.
6,103,409	08/15/00	General Motors Corporation	Fuel cell flooding detection and correction	A method and apparatus for monitoring PEM fuel cells to detect and correct flooding.	Being used in continuing research at the company.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,099,988	08/08/00	Case Western Reserve University	Proton conducting polymer electrolyte prepared by direct acid casting	An acid solution for casting solid polymer electrolyte membranes comprising proton conducting polymers stable at temperatures more than 100°C directly from acid solution. The invention further relates to the enhanced performance of the membrane conductivity. Particularly, the invention relates to the use of trifluoroacetic acid (TFA) as an acid solvent doped with H_3PO_4 from which polybenzimiadazole (PBI) solid polymer electrolyte membranes may be cast.	Research complete; seeking to license.
6,099,984	08/08/00	General Motors Corporation	Mirrored serpentine flow channels for fuel cell	A PEM fuel cell having serpentine flow field channels, wherein the input/inlet legs of each channel border the input/inlet legs of the adjacent channels in the same flow field.	Being used in continuing research at the company.
6,077,620	06/20/00	General Motors Corporation	Fuel cell system with combustor-heated reformer	A fuel cell system including a fuel reformer heated by a catalytic combustor fired by anode effluent or fuel from a liquid fuel supply providing fuel for the fuel cell.	No longer being pursued, abandoned.
6,074,692	06/13/00	General Motors Corporation	Method of making MEA for PEM/SPE fuel cell	A method of making a membrane-electrode-assembly (MEA) for a PEM/SPE fuel cell by applying a slurry of electrode-forming material directly onto a membrane-electrolyte film.	Being used in continuing research at the company.
6,066,408	05/23/00	Plug Power, LLC	Fuel cell cooler-humidifier plate	A cooler-humidifier plate for use in a proton exchange membrane fuel cell stack assembly. The cooler-humidifier plate combines functions of cooling and humidification within the fuel cell stack assembly, providing a more compact structure, simpler manifolding, and reduced reject heat from the fuel cell.	No longer being used.
6,063,516	05/16/00	General Motors Corporation	Method of monitoring CO concentrations in hydrogen feed to a PEM fuel cell	The CO concentration in the H_2 feed stream to a PEM fuel cell stack is monitored by measuring current or voltage behavior patterns from a PEM-probe communicating with the reformate feed stream.	Being used in continuing research at the company.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,037,072	03/14/00	Los Alamos National Laboratory	Fuel cell with metal screen flow field	A polymer electrolyte membrane (PEM) fuel cell is provided with electrodes supplied with a reactant on each side of a catalyzed membrane assembly (CMA). The fuel cell includes a metal mesh defining a rectangular flow-field pattern having an inlet at a first corner and an outlet at a diagonally opposed second corner. All the flow paths from the inlet to the outlet through the square flow field pattern uniformly distribute the reactant over the CMA. The bipolar plates can be electrically connected to adjacent fuel cells, cooling plates can be incorporated for distributing cooling water flow over the electrodes to remove heat generated by the fuel cells.	No longer being pursued.
6,017,648	01/25/00	Plug Power, LLC	Insertable fluid flow passage bridgepiece and method	A fluid flow passage bridgepiece for insertion into an open-face fluid flow channel of a fluid flow plate.	No longer being used.
6,007,933	12/28/99	Plug Power, LLC	Fuel cell assembly unit for promoting fluid service and electrical conductivity	Fluid service or electrical conductivity for a fuel cell assembly.	Still being used in research.
6,001,499	12/14/99	General Motors Corporation	Fuel cell CO sensor	The CO concentration in the H_2 feed stream to a PEM fuel cell stack is monitored by measuring current or voltage behavior patterns from a PEM-probe communicating with the reformate feed stream.	Being used in continuing research at the company.
5,998,054	12/07/99	Plug Power, LLC	Fuel cell membrane hydration and fluid metering	A hydration system including fuel cell fluid flow plates and injection ports. Each plate has flow channels with respective inlets for receiving portions of a reactant fluid for a fuel cell.	No longer being used.
5,952,119	09/14/99	Los Alamos National Laboratory	Fuel cell membrane humidification	A method for supplying liquid water to the polymer electrolyte membrane of a fuel cell using distribution channels over the gas diffusion backing. This simple membrane humidification system uniformly distributes water to the membrane surface thus improving the performance of the fuel cell.	Non-exclusive license to IdaTech - not being used.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
5,945,229	08/31/99	General Motors Corporation	Pattern recognition monitoring of PEM fuel cell	The CO-concentration in the H_2 feed stream to a PEM fuel cell stack is monitored by measuring current and voltage behavior patterns from an auxiliary cell attached to the end of the stack.	Being used in continuing research at the company.
5,932,185	08/03/99	Lawrence Livermore National Laboratory	Method for making thin carbon foam electrodes	A method for fabricating thin, flat carbon electrodes by infiltrating highly porous carbon papers, membranes, felts, metal fibers and powders, or fabrics with an appropriate carbon foam precursor material.	No licenses and no research being done with this patent.
5,916,710	06/29/99	Lawrence Berkeley National Laboratory	Sodium cobalt bronze batteries and a method for making same	A solid-state secondary battery utilizing a low-cost, environmentally sound, sodium cobalt bronze electrode.	No longer being used.
5,798,187	08/25/98	Los Alamos National Laboratory	Fuel cell with metal screen flow-field	A polymer electrolyte membrane fuel cell is provided with electrodes supplied with a reactant on each side of a catalyzed membrane assembly.	Not licensed and not being used at LANL for research.
5,783,152	07/21/98	Savannah River National Laboratory	Thin-film fiber optic hydrogen and temperature sensor system	A sensor probe device for monitoring of hydrogen gas concentrations and temperatures.	No longer being used in research; returned to DOE.
5,776,624	07/07/98	General Motors Corporation	Brazed bipolar plates for PEM fuel cells	A liquid-cooled, bipolar plate separating adjacent cells of a PEM fuel cell comprising corrosion-resistant metal sheets brazed together to provide a passage between the sheets through which a dielectric coolant flows.	Being used in continuing research at the company.
5,763,113	06/09/98	General Motors Corporation	PEM fuel cell monitoring system	A method and apparatus for monitoring the performance of PEM fuel cells. Outputs from a cell or stack voltage monitor and a cathode exhaust gas hydrogen sensor are corrected for stack operating conditions, and then compared to predetermined levels of acceptability.	Being used in continuing research at the company.
5,743,646	04/28/98	General Motors Corporation	Temperature sensor with improved thermal barrier and gas seal between the probe and housing	An improved temperature sensor that can be used to measure gas temperature in automotive exhaust systems or in fuel cell subsystems for generating electric power.	Being used in continuing research at the company.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
5,707,755	01/13/98	General Motors Corporation	PEM/SPE fuel cell	A PEM/SPE fuel cell including a membrane-electrode assembly (MEA) having a plurality of oriented filaments embedded in the face thereof supporting the MEA and conducting current therefrom contiguous electrode plates.	Being used in continuing research at the company.
5,654,109	08/05/97	Dow Chemical Company	Composite fuel cell membranes	A bilayer or trilayer composite ion exchange membrane suitable for use in a fuel cell. The composite membrane has a high equivalent weight thick layer in order to provide sufficient strength and low equivalent weight surface layers for improved electrical performance in a fuel cell.	No longer being pursued.
5,641,586	06/24/97	Los Alamos National Laboratory	Fuel cell with interdigitated porous flow-field	A polymer electrolyte membrane fuel cell is formed with an improved system for distributing gaseous reactants to the membrane surface.	Not licensed and not being used at LANL for research.
5,636,437	06/10/97	Lawrence Livermore National Laboratory	Fabricating solid carbon porous electrodes from powders	Fabrication of conductive solid porous carbon electrodes for use in batteries, double layer capacitors, fuel cells, capacitive deionization, and waste treatment.	No licenses and no research being done with this patent.
5,624,769	04/29/97	General Motors Corporation	Corrosion resistant PEM fuel cell	A PEM fuel cell having electrical contact elements (e.g., bipolar plates) that consist of a titanium-nitride-coated, lightweight metal core, with a passivating, protective metal layer between the core and the titanium nitride.	Being used in continuing research at the company.
5,601,938	02/11/97	Lawrence Livermore National Laboratory	Carbon aerogel electrodes for direct energy conversion	A direct energy conversion device, such as a fuel cell, using carbon aerogel electrodes, wherein the carbon aerogel is loaded with a noble catalyst, such as platinum or rhodium and soaked with phosphoric acid.	No licenses and no research being done with this patent.
5,595,834	01/21/97	Los Alamos National Laboratory	Annular feed air breathing fuel cell stack	A stack of polymer electrolyte fuel cells is formed from a plurality of unit cells where each unit cell includes fuel cell components stacked along a common axis. Each fuel cell component has a polymer electrolyte membrane, anode, cathode and provision for fuel and oxygen flow fields. A fuel distribution manifold is connected to deliver fuel to the fuel flow field in each of the unit cells.	Not licensed and not being used for research at LANL.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
5,558,961	09/24/96	Lawrence Berkeley National Laboratory	Secondary cell with orthorhombic alkali metal/ manganese oxide phase active cathode material	An alkali metal manganese oxide secondary cell that can provide a high rate of discharge, cycling capabilities, stability of the cathode material, high specific energy (energy per unit of weight) and high energy density (energy per unit volume).	No longer being used.
5,443,601	08/22/95	Lawrence Berkeley National Laboratory	Method for intercalating alkali metal ions into carbon electrodes	A low-cost, relatively flexible, carbon electrode for use in a secondary battery. Methods for producing the electrode are also provided, including intercalating alkali metal salts such as sodium and lithium into carbon.	No longer being used.
5,316,871	05/31/94	General Motors Corporation	Method of making membrane-electrode assemblies for electrochemical cells and assemblies made thereby	A method of making a combination, unitary, membrane and electrode assembly having a solid polymer electrolyte membrane, and first and second electrodes at least partially embedded in opposed surfaces of the membrane.	Being used in continuing research at the company.
5,248,566	09/28/93	Argonne National Laboratory	Fuel cell system for transportation applications	A propulsion system for a vehicle having pairs of front and rear wheels and a fuel tank.	Not licensed but being used in research at ANL.
5,234,777	08/10/93	Los Alamos National Laboratory	Membrane catalyst layer for fuel cells	A gas reaction fuel cell incorporates a thin catalyst layer between a solid polymer electrolyte (SPE) membrane and a porous electrode backing. The film is formed as an ink that is spread and cured on a film release blank. The cured film is then transferred to the SPE membrane and hot pressed into the surface to form a catalyst layer having a controlled thickness and catalyst distribution. The catalyst layer is formed by direct application of a perfluorosulfonate ionomer directly to the membrane, drying the film at a high temperature, and then converting the film back to the protonated form of the ionomer. The layer has adequate gas permeability so that cell performance is not affected.	Not licensed and not being used for research at LANL.

Fuel Cell Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
5,211,984	05/18/93	Los Alamos National Laboratory	Membrane catalyst layer for fuel cells	A gas reaction fuel cell incorporates a thin catalyst layer between a solid polymer electrolyte (SPE) membrane and a porous electrode backing. The film is formed as an ink that is spread and cured on a film release blank. The cured film is then transferred to the SPE membrane and hot pressed into the surface to form a catalyst layer having a controlled thickness and catalyst distribution.	Not licensed and not being used for research at LANL.
4,657,829	04/14/87	United Technologies Corporation	Fuel cell power supply with oxidant and fuel gas switching	Relating to a fuel cell vehicular power plant, fuel for the fuel stack is supplied by a hydrocarbon (methanol) catalytic cracking reactor and CO shift reactor.	Patent has expired and not used by UTC in commercial products.
4,650,727	03/17/87	Los Alamos National Laboratory	Fuel processor for fuel cell power system	A catalytic organic fuel processing apparatus, which can be used in a fuel cell power system, contains within a housing a catalyst chamber, a variable speed fan, and a combustion chamber.	Not licensed and not being used for research at LANL.

A.2 Production/Delivery Patents Status

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,845,239	12/19/17	Intelligent Energy, Inc.	Hydrogen generation systems and methods utilizing sodium silicide and sodium silica gel materials	Systems, devices, and methods combine thermally stable reactant materials and aqueous solutions to generate hydrogen and a non-toxic liquid by-product. The hydrogen generation devices are used in fuels cells and other industrial applications. One system combines cooling, pumping, water storage, and other devices to sense and control reactions between reactant materials and aqueous solutions to generate hydrogen.	Still being used in ongoing research.
9,739,418	08/22/17	Argonne National Laboratory	Enhanced methods for operating refueling station tube-trailers to reduce refueling cost	A method and apparatus for operating a refueling station including source tube-trailers and at least one compressor to reduce refueling cost. The station includes a gaseous fuel supply source including tanks on a tube trailer coupled to a control unit, and high-pressure buffer storage capacity. The refueling station is operated at different modes depending on the state of the refueling station at the beginning of each operational mode. The operational modes include consolidating hydrogen, or any gaseous fuel, within the tubes mounted on the trailer.	Research complete; seeking to license.
9,669,371	06/06/17	Intelligent Energy, Inc.	Hydrogen generation systems utilizing sodium silicide and sodium silica gel materials	Systems, devices, and methods combine reactant materials and aqueous solutions to generate hydrogen. The reactant materials can be sodium silicide or sodium silica gel. The hydrogen generation devices are used in fuels cells and other industrial applications. One system combines cooling, pumping, water storage, and other devices to sense and control reactions between reactant materials and aqueous solutions to generate hydrogen. Another system operates over a range of temperatures and pressures and includes a hydrogen separator, a heat removal mechanism, and state of reaction control devices. The systems, devices, and methods of generating hydrogen provide thermally stable solids, near-instant reaction with the aqueous solutions, and a non-toxic liquid by-product.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,657,400	05/23/17	General Electric Company	Electrolyzer assembly method and system	The techniques provide a novel electrolyzer and methods for welding components of such electrolyzers. The techniques may use conductors, such as resistance wires, placed in paths around the internal structural features and edges of the components. The conductors may be incorporated into the components during manufacture by injection molding, or other molding techniques, or may be tacked or otherwise applied to the surface of the components after manufacture. When current, a field or other excitation is applied to the conductors, the plastic surrounding the wire is melted. If this plastic is in direct contact with an adjoining component, a strong, hermetic seal may be formed between the two components, including the internal structural features.	Still being used in ongoing research.
9,517,445	12/13/16	University of Missouri	High surface area carbon and process for its production	Activated carbon materials and methods of producing and using activated carbon materials are provided. In particular, biomass-derived activated carbon materials and processes of producing the activated carbon materials with prespecified surface areas and pore size distributions are provided. Activated carbon materials with preselected high specific surface areas, porosities, sub-nm (<1 nm) pore volumes, and supra-nm (1–5 nm) pore volumes may be achieved by controlling the degree of carbon consumption and metallic potassium intercalation into the carbon lattice during the activation process.	Still being used in ongoing research.
9,399,575	07/26/16	University of Colorado	Methods and apparatus for gas-phase reduction/oxidation processes	A method and apparatus for gas-phase reduction and oxidation is disclosed. The apparatus includes a reactor including at least one reactor tube or containment vessel with active redox material within the reactor tube or containment vessel, a first reactant gas or vacuum for reducing the active redox material, and a second reactant gas for oxidizing the active redox material. The method may be run under substantially isothermal conditions or energy supplied to the apparatus may include solar energy, which may be concentrated.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,391,334	07/12/16	Intelligent Energy, Inc.	Hydrogen gas generator	Hydrogen generator includes a removable cartridge of multiple thermal conductors with surface deposited fuel pellets which carry a hydrogen-containing reactant that will react to release hydrogen gas when heated. The hydrogen generator also includes heating elements that heat one or more fuel pellets to initiate a reaction to produce hydrogen gas.	Still being used in ongoing research.
9,316,228	04/19/16	Concepts NREC, LLC	High-flow-capacity centrifugal hydrogen gas compression systems, methods and components therefor	Hydrogen gas compression systems that each include a multistage centrifugal compressor in which each stage has an inlet-to-outlet pressure rise ratio of about 1.20 or greater. In one embodiment, the multistage compressor includes six high-speed centrifugal compressors driven at a speed of about 60,000 RPM. The compressor has an output of more than 200,000 kg/day at a pressure of more than 1,000 psig. The compressors for the compression stages are distributed on both sides of a common gearbox, which has gearing that allows axial thrusts from the compressors to be handled effectively. Each stage's compressor has a unique impeller, which is secured to a support shaft using a tension-rod-based attachment system. In another embodiment, the multistage compressor is driven by a combustion turbine and one or more intercoolers are provided between compression stages. Each intercooler is cooled by coolant from an absorption chiller utilizing exhaust gas from the combustion turbine.	Still being used in ongoing research.
9,295,958	03/29/16	Intelligent Energy, Inc.	Fuel unit, refillable hydrogen generator and fuel cell system	A packaged fuel unit and a refillable hydrogen generator that uses the fuel unit to produce hydrogen gas. The fuel unit includes a reactant that can undergo a thermal decomposition reaction to produce hydrogen gas when heated to at least a minimum initiation temperature. The fuel unit is removable and contains a heating system for heating the fuel unit. The hydrogen generator can be part of a fuel cell system including a fuel cell battery that is provided with hydrogen gas from the hydrogen generator.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,255,646	02/09/16	Air Products & Chemicals, Inc.	Excess flow shutoff valve	Excess flow shutoff valve comprising a valve body, a valve plug, a partition, and an activation component where the valve plug, the partition, and activation component are disposed within the valve body. A suitable flow restriction is provided to create a pressure difference between the upstream end of the valve plug and the downstream end of the valve plug when fluid flows through the valve body. The pressure difference exceeds a target pressure difference needed to activate the activation component when fluid flow through the valve body is higher than a desired rate, and closes the valve.	Still being used in ongoing research.
9,243,560	01/26/16	Intelligent Energy, Inc.	Hydrogen generator having a thermal actuator	A hydrogen generator having one or more actuators coupled to one or more heating elements in which the actuators are used to improve the transfer of thermal energy from heating elements to one or more fuel units contained within the generator. The actuators containing the fuel units can be inserted or removed without removing the heating elements.	Still being used in ongoing research.
9,199,844	12/01/15	Savannah River National Laboratory	Two step novel hydrogen system using additives to enhance hydrogen release from the hydrolysis of alane and activated aluminum	A system for the generation of hydrogen for use in portable power systems using a two-step process that involves the thermal decomposition of AlH_3 (10 wt.% H_2) followed by the hydrolysis of the activated aluminum (Al*) byproduct to release more H_2. Additionally, a process in which water is added directly without prior history to the AlH_3:PA composite is also disclosed.	Still being used in ongoing research.
9,162,201	10/20/15	Intelligent Energy, Inc.	Hydrogen generator having liquid delivery member	A hydrogen generator is provided for generating hydrogen gas for a fuel cell stack. The hydrogen generator includes container, and a first reactant storage area. The hydrogen generator also includes a reaction area and a solid second reactant within the reaction area, and a hydrogen outlet. The hydrogen generator also includes a flexible liquid delivery member extending into the reaction area and configured to deliver either liquid reactant or solid reactant.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,150,968	10/06/15	Brookhaven National Laboratory	Platinum-based electrocatalysts synthesized by depositing contiguous adlayers on carbon nanostructures	A manufacturing process involving initial oxidation of the carbon nanostructures followed by immersion in an alkaline solution containing one or more noble metals. The process can be used for high-performance electrodes in supercapacitors, batteries, or other electric storage devices.	Still being used in ongoing research.
9,139,432	09/22/15	University of Central Florida	Apparatus for decomposing water and releasing hydrogen	A methods and apparatus for producing high purity hydrogen from water. Metals or alloys capable of reacting with water to produce hydrogen in aqueous solutions at ambient conditions are reacted with one or more inorganic hydrides to release hydrogen and transition metal compounds or alkali metal-based compounds are used to catalyze the reaction.	Research complete; seeking to license.
9,102,528	08/11/15	Intelligent Energy, Inc.	Hydrogen generation systems and methods utilizing sodium silicide and sodium silica gel materials	Systems, devices, and methods combine thermally stable reactant materials and aqueous solutions to generate hydrogen and a non-toxic liquid by-product. The reactant materials can be either sodium silicide or sodium silica gel. The hydrogen generation devices are used in fuels cells and other industrial applications.	Still being used in ongoing research.
9,093,681	07/28/15	Intelligent Energy, Inc.	Hydrogen generation having CO_2 removal with steam reforming	A method for producing hydrogen using fuel cell off gases by feeding hydrocarbon fuel to a sulfur adsorbent to produce a desulfurized fuel and a spent sulfur adsorbent. Desulfurized fuel and water are then fed to an adsorption enhanced reformer to produce hydrogen.	Still being used in ongoing research.
9,079,146	07/14/15	Intelligent Energy, Inc.	Hydrogen generation systems utilizing sodium silicide and sodium silica gel materials	Systems, devices, and methods combine thermally stable reactant materials and aqueous solutions to generate hydrogen and a non-toxic liquid by-product. The reactant materials can be either sodium silicide or sodium silica gel. The hydrogen generation devices are used in fuels cells and other industrial applications.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,067,172	06/30/15	Air Products & Chemicals, Inc.	Solid-state membrane module	A module for separating oxygen from an oxygen-containing gaseous mixture comprising planar solid-state membrane units, each membrane unit comprising planar dense mixed conducting oxide layers, planar channel-free porous support layers, and one or more planar intermediate support layers comprising at least one channeled porous support layer. The porosity of the planar channeled porous support layers is less than the porosity of the planar channel-free porous support layers.	Still being used in ongoing research.
9,057,136	06/16/15	University of South Carolina	Production of low temperature electrolytic hydrogen	A process for electrochemical hydrogen production using an electrochemical cell consisting of an anode, cathode and a membrane separator. The process feeds gaseous reactant at the anode, oxidizing one or more molecules of the gaseous reactant to produce gas product and protons. The protons pass through the membrane to the cathode and hydrogen gas is formed by reduction.	Research complete; seeking to license.
9,028,720	05/12/15	Air Products & Chemicals, Inc.	Ion transport membrane reactor systems and methods for producing synthesis gas	Cost-effective systems and methods for producing a synthesis gas product using a steam reformer system and an ion transport membrane (ITM) reactor having multiple stages, without requiring inter-stage reactant injections. The system compensates for changes in membrane performance degradation and system operating conditions.	Still being used in ongoing research.
9,005,486	04/14/15	Savannah River National Laboratory	Proton conducting ceramics in membrane separations	Perovskite materials of the general formula $SrCeO_3$ and $BaCeO_3$ with improved conductivity and an original ratio of chemical constituents. The process alters the microstructure of the material using wet chemical techniques.	Still being used in ongoing research; seeking to license.
8,835,153	09/16/14	National Renewable Energy Laboratory	Process and genes for expression and over expression of active [FeFe] hydrogenases	The invention relates to the use of genes to provide expression and over-expression of any active [FeFe]-hydrogenases, expressed in any suitable host, using an [FeFe]-hydrogenase assembly of genes from a suitable organism.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,834,587	09/16/14	Virent Energy Systems, Inc.	Method of producing gaseous products using a downflow reactor	Reactor systems and methods are provided for the catalytic conversion of liquid feedstocks to synthesis gases and other non-condensable gaseous products. The reactor systems include a heat exchange reactor configured to allow the liquid feedstock and gas product to flow concurrently. The reactor systems and methods can be used for producing hydrogen and light hydrocarbons from biomass-derived oxygenated hydrocarbons using aqueous phase reforming.	Still being used in ongoing research. Non-exclusive license to Equilon Enterprises LLC DBA as Shell Oil Products U.S. (a subsidiary of Royal Dutch Shell)
8,754,263	07/17/14	Virent Energy Systems, Inc.	Methods and systems for generating polyols	Methods for generating propylene glycol, ethylene glycol and other polyols, diols, ketones, aldehydes, carboxylic acids and alcohols from biomass using hydrogen produced from the biomass.	Still being used in ongoing research. Non-exclusive license to Equilon Enterprises LLC DBA as Shell Oil Products U.S. (a subsidiary of Royal Dutch Shell)
8,728,202	05/20/14	Air Products & Chemicals, Inc.	Staged membrane oxidation reactor system	An ion transport membrane system for converting methane to synthesis gas (hydrogen and carbon monoxide).	No longer being pursued.
8,721,973	05/13/14	Catacel Corporation	Stackable structural reactors	A reactor for carrying out catalytic reactions. The reactor includes a reactor component optionally arranged on a central rod in a reactor tube. The reactor component can have fluid ducts for directing fluid flow through the reactor. The fluid ducts are effective for increasing heat transfer in the reactor. The reactor component can further have a washer attached to a top or bottom surface for directing fluid flow.	Part of a commercial hydrogen production technology.
8,715,868	05/06/14	University of South Carolina	Electrochemical removal of contaminants from hydrogen	A proton exchange membrane fuel cell including a twin-cell electrochemical filter. A flow of reformate H_2 and pulse potential is switched between each respective filter cell such that CO-contaminated H_2 is fed to one filter cell, a pulse potential is simultaneously applied to the other.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,703,642	04/22/14	University of Central Florida	Method of forming supported doped palladium containing oxidation catalysts	A method of forming palladium-containing, supported oxidation catalysts that can be used as a chemochromic (color-changing) pigment for detecting hydrogen leaks.	Licensed to HySense Technology LLC. Part of a commercial production technology.
8,691,068	04/08/14	University of Central Florida	Solar metal sulfate-ammonia based thermochemical water splitting cycle for hydrogen production	Describes two classes of hybrid/thermochemical water splitting processes for the production of hydrogen and oxygen based on (1) metal sulfate-ammonia cycles (2) metal pyrosulfate-ammonia cycles.	Research complete; seeking to license.
8,685,878	04/01/14	Argonne National Laboratory	Highly durable nanoscale electrocatalyst based on core shell particles	A nanoscale catalyst having a core enveloped by a shell with high catalytic activity and improved durability. The core and shell nanoparticles comprise a gold particle coated with a catalytically active platinum bimetallic material. The nanoparticles may be dispersed on a high surface area substrate for use as a catalyst.	Still being used in ongoing research.
8,685,364	04/01/13	Los Alamos National Laboratory	Liquid composition having ammonia borane and decomposing to form hydrogen and liquid reaction product	Liquid compositions of ammonia borane and a suitably chosen amine borane material were prepared and subjected to conditions suitable for their thermal decomposition in a closed system that resulted in hydrogen and a liquid reaction product.	Still being used in ongoing research.
8,663,958	03/04/14	National Renewable Energy Laboratory	Oxygen-resistant hydrogenases and methods for designing and making same	An oxygen-resistant iron-hydrogenases ([Fe]-hydrogenases) for use in the production of H_2. The methods used to design and engineer these oxygen-resistant [Fe]-hydrogenases are provided. A process that utilizes the transformed, oxygen insensitive, host cells in the bulk production of H_2 in a light catalyzed reaction with water as the reactant is also described.	Research complete; seeking to license.
8,652,993	02/18/14	University of Central Florida	Doped palladium containing oxidation catalysts	A palladium-containing oxidation catalyst that can be used as a chemochromic (color-changing) pigment for detecting hydrogen leaks.	Licensed to HySense Technology LLC. Part of a commercial production technology.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,623,662	01/07/14	University of Central Florida	Methods of forming visual hydrogen detector with variable reversibility	Methods of forming a chemochromic hydrogen detector with variable, reversible color change. In the presence of hydrogen, a hydrogen-sensitive pigment changes color from white or light-gray or light-tan to dark gray, navy-blue or black depending on the exposure time and hydrogen concentration. After hydrogen exposure ceases, the original color of the pigment is restored, allowing the visual hydrogen detector to be used repeatedly.	Licensed to HySense Technology LLC. Part of a commercial production technology.
8,609,054	12/17/13	Bing Energy International	Hydrogen production from borohydrides and glycerol	A method of forming hydrogen gas utilizing an alcoholysis reaction of a borohydride component and a glycerol component.	No longer being pursued.
8,591,818	11/26/13	University of Central Florida	Gas permeable chemochromic compositions for hydrogen sensing	A hydrogen sensor composition that includes a gas-permeable matrix material intermixed and encapsulating at least one chemochromic pigment. The chemochromic pigment produces a detectable change in color of the overall sensor composition in the presence of hydrogen.	Licensed to HySense Technology LLC. Part of a commercial production technology.
8,568,582	10/29/13	National Renewable Energy Laboratory	Systems and methods for selective hydrogen transport and measurement	Systems and methods for selectively removing hydrogen gas from a hydrogen-containing fluid. The system contains a proton exchange membrane (PEM) selectively permeable to hydrogen with metal deposited as layers onto opposite sides or faces of the PEM to form a membrane-electrode assembly (MEA) that functions as a hydrogen selective membrane (HSM).	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,501,105	08/06/13	Ohio State University	Separation of carbon dioxide (CO_2) from gas mixtures by calcium based reaction separation (CaRS-CO_2) process	A reaction-based process developed for the selective removal of CO_2 from a multicomponent gas mixture to provide a gaseous stream depleted in CO_2 compared to the inlet CO_2 concentration. The proposed process affects the separation of CO_2 from a mixture of gases by its reaction with metal oxides. The calcium-based reaction separation for CO_2 (CaRS-CO_2) process consists of contacting CO_2 laden gas with CaO in a reactor such that CaO captures CO_2 by the formation of $CaCO_3$. $CaCO_3$ regenerated by calcination forms of fresh CaO sorbent and a concentrated stream of CO_2. The regenerated CaO is then recycled for the further capture of CO_2. This carbonation-calcination cycle forms the basis of the CaRS-CO_2 process. This process also may use a mesoporous $CaCO_3$ structure that attains > 90% conversion over multiple carbonation and calcination cycles.	Research complete; seeking to license.
8,499,612	08/06/13	University of California - Irvine	Hydrogen gas detection using single palladium nanowires	Devices and methods for fast, sensitive hydrogen gas detection using a single palladium nanowire. The nanowire can rapidly detect hydrogen down to 2 ppm with excellent reproducibility and baseline stability at room temperature.	Research complete; seeking to license.
8,496,909	07/30/13	Ohio State University	Calcium looping process for high purity hydrogen production integrated with capture of carbon dioxide, sulfur and halides	A process for producing hydrogen comprising of several steps, fuel gasifying into raw synthesis gas comprising CO, hydrogen, steam, sulfur and halide contaminants and passing the raw synthesis gas through a water gas shift reactor (WGSR) into which CaO and steam are injected. The CaO reacting with the shifted gas to remove CO_2, sulfur and halides in a solid-phase calcium-containing product. Then separation of the solid-phase calcium-containing product from an enriched gaseous hydrogen product occurs followed by regenerating the CaO by calcining the solid-phase calcium-containing product.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,492,595	07/23/13	Virent Energy Systems, Inc.	Methods and systems for generating polyols	Methods for generating propylene glycol, ethylene glycol and other polyols, diols, ketones, aldehydes, carboxylic acids and alcohols using hydrogen produced from biomass.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).
8,491,679	07/23/13	Intelligent Energy, Inc.	Hydrogen generation utilizing integrated CO_2 removal with steam reforming	A steam reformer for hydrogen production that removes carbon dioxide from the product gas stream using pressure swing adsorption.	Still being used in ongoing research.
8,460,409	06/11/13	Ceramatec, Inc.	Plasma-catalyzed fuel reformer	Fuel reformer that uses a plasma zone to receive a pre-heated mixture of reactants and ionize the reactants by applying an electrical potential. The reformer includes a reaction zone to transform the ionized reactants into synthesis gas.	Research complete.
8,455,382	06/04/13	Air Products & Chemicals, Inc.	Fabrication of catalyzed ion transport membrane systems	A process for fabricating a catalyzed ion transport membrane having constant oxygen stoichiometry and no anion mobility.	No longer being pursued.
8,453,515	06/04/13	Oak Ridge National Laboratory	Apparatus and method for fatigue testing of a material specimen in a high-pressure fluid environment	Fatigue testing of a material specimen in a high-pressure fluid environment. Pressurized fluid is provided in compression and tension chambers between a piston and a vessel allowing the specimen to be subjected to either compression or tension forces. The specimen when subjected to either force is surrounded by the pressurized fluid which in some examples can be hydrogen.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,419,827	04/16/13	Air Products & Chemicals, Inc.	Staged membrane oxidation reactor system	Ion transport membrane oxidation system comprising (a) two or more membrane oxidation stages, each stage comprising a reactant zone, an oxidant zone, one or more ion transport membranes separating the reactant zone from the oxidant zone, a reactant gas inlet region, a reactant gas outlet region, an oxidant gas inlet region, and an oxidant gas outlet region; (b) an interstage reactant gas flow path disposed between each pair of membrane oxidation stages and adapted to place the reactant gas outlet region of a first stage of the pair in flow communication with the reactant gas inlet region of a second stage of the pair; and (c) one or more reactant interstage feed gas lines, each line being in flow communication with any interstage reactant gas flow path or with the reactant zone of any membrane oxidation stage receiving interstage reactant gas.	Still being used in ongoing research.
8,410,183	04/02/13	Virent Energy Systems, Inc.	Method for producing bio-fuel that integrates heat from carbon-carbon bond-forming reactions to drive biomass gasification reactions	A low-temperature catalytic process for converting biomass (preferably glycerol recovered from the fabrication of bio-diesel) to synthesis gas (i.e., H_2/CO gas mixture) in an endothermic gasification reaction.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).
8,397,508	03/19/13	University of Colorado	Metal ferrite spinel energy storage device and methods for making and using same	Metal ferrite spinel coatings on substrates using an atomic layer deposition. The coatings are able to store energy such as solar energy, and to release that stored energy, via a redox reaction.	Licensed to ALD NanoSolutions, Inc.
8,372,170	02/12/13	Intelligent Energy, Inc.	Fuel steam reformer system and reformer startup process	A hydrogen generation system is disclosed that has a fuel vaporization section receiving fuel along with water. To generate reformate gas, fuel and water are passed to a reformer catalyst section heated by a combustor section, fueled by off-gas from an H_2 purification unit and a combustion air source. An H_2 storage unit connected to the purification unit has an outlet selectively connectable to the reformer assembly process inlet during startup without the need for a spark igniter.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,349,151	1/8/13	Giner Electrochemical Systems, LLC	Universal cell frame for high-pressure water electrolyzer and electrolyzer including the same	A universal cell frame generic for use as an anode frame and as a cathode frame in a water electrolyzer.	Being used in ongoing research. Part of a commercial hydrogen production technology.
8,349,035	01/08/13	Argonne National Laboratory	Autothermal and partial oxidation reformer-based fuel processor, method for improving catalyst function in autothermal and partial oxidation reformer-based processors	Segmented catalyst systems for reforming fuels for use in fuel cells.	Still being used in ongoing research.
8,323,614	12/04/12	University of South Carolina	Hydrolysis reactor for hydrogen production	A novel reactor configuration and method for delivering a hydride to a reaction zone in a manner that enables rapid reaction with water to produce hydrogen.	Research complete; seeking to license.
8,309,616	11/13/12	University of Kentucky	Incorporation of catalytic dehydrogenation into Fischer-Tropsch synthesis to significantly reduce carbon dioxide emissions	A new method of producing liquid transportation fuels from coal and other hydrocarbons that significantly reduces carbon dioxide emissions by combining Fischer-Tropsch synthesis with catalytic dehydrogenation is claimed. Catalytic dehydrogenation (CDH) of the gaseous products (C1-C4) of Fischer-Tropsch synthesis (FTS) can produce large quantities of hydrogen while converting the carbon to multi-walled carbon nanotubes (MWCNT). Incorporation of CDH into an FTS-CDH plant converting coal to liquid fuels can eliminate all or most of the CO_2 emissions from the water-gas shift (WGS) reaction that is currently used to elevate the H_2 level of coal-derived syngas for FTS. Additionally, the FTS-CDH process saves large amounts of water used by the WGS reaction and produces a valuable by-product, MWCNT.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,287,762	10/16/12	Air Products & Chemicals, Inc.	Operation of staged membrane oxidation reactor systems	A method of operating a multi-stage ion transport membrane oxidation system. The method comprises providing a multi-stage ion transport membrane oxidation system with at least a first membrane oxidation stage and a second membrane oxidation stage, operating the ion transport membrane oxidation system at operating conditions including a characteristic temperature of the first membrane oxidation stage and a characteristic temperature of the second membrane oxidation stage; and controlling the production capacity or the product quality by changing the characteristic temperature of the first membrane oxidation stage or changing the characteristic temperature of the second membrane oxidation stage.	Still being used in ongoing research.
8,273,140	09/25/12	University of Central Florida	Method and apparatus for hydrogen production from water	A method, apparatuses and chemical compositions are provided for producing high purity hydrogen from water. Metals or alloys capable of reacting with water and producing hydrogen in aqueous solutions at ambient conditions are reacted with one or more inorganic hydrides capable of releasing hydrogen in aqueous solutions at ambient conditions.	Research complete; seeking to license.
8,268,897	09/18/12	University of Kentucky	Incorporation of catalytic dehydrogenation into Fischer-Tropsch synthesis to lower carbon dioxide emissions	A method for producing liquid fuels by gasifying a starting material selected from a group consisting of coal, biomass, carbon nanotubes and mixtures thereof to produce a syngas, subjecting that syngas to Fischer-Tropsch synthesis (FTS) to produce a hydrocarbon product stream. The hydrocarbon product stream is separated for used as liquid fuels and subjected to catalytic dehydrogenation (CDH) to produce hydrogen and carbon nanotubes.	Research complete; seeking to license.
8,268,392	09/18/12	University of Central Florida	Visual hydrogen detector with variable reversibility	Methods, processes and compositions are provided for a visual or chemochromic hydrogen-detector with variable or tunable reversible color change.	Licensed to HySense Technology LLC. Part of a commercial production technology.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,262,755	09/11/12	Air Products & Chemicals, Inc.	Staged membrane oxidation reactor system	An ion transport membrane oxidation system comprising two or more membrane oxidation stages, each stage comprising a reactant zone, an oxidant zone, one or more ion transport membranes separating the reactant zone from the oxidant zone, a reactant gas inlet region, a reactant gas outlet region, an oxidant gas inlet region, and an oxidant gas outlet region.	No longer being pursued.
8,246,719	08/21/12	Air Products & Chemicals, Inc.	Use of impure inert gases in the controlled heating and cooling of mixed conducting metal oxide materials	Method for processing an article comprising mixed conducting metal oxide material. The article is exposed to an oxygen-containing gas and either reducing the temperature of the oxygen-containing gas during a cooling period or increasing the temperature of the oxygen-containing gas during a heating period.	Still being used in ongoing research.
8,231,857	07/31/12	Virent Energy Systems, Inc.	Catalysts and methods for reforming oxygenated compounds	Catalysts and methods that can reform aqueous solutions of oxygenated compounds such as ethylene glycol, glycerol, sugar alcohols, and sugars to generate products such as hydrogen and alkanes.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).
8,231,697	07/31/12	Pacific Northwest National Laboratory	Rapid start fuel reforming systems and techniques	An on-board fuel processor includes a microchannel steam reforming reactor and a water vaporizer heated in series with a combustion gas.	Research complete; seeking to license.
8,226,750	07/24/12	Genesis Fueltech, Inc.	Hydrogen purifier module with membrane support	Hydrogen purifier utilizing a hydrogen-permeable membrane to purify hydrogen from mixed gases containing hydrogen. A purifier module with improved mechanical support for the permeable membrane is described, enabling forward or reverse differential pressurization of the membrane.	Research complete; seeking to license.
8,210,360	07/03/12	Synkera Technologies, Inc.	Composite membranes and methods for making same	Composite membranes that are adapted for separation, purification, filtration, analysis, reaction and sensing. The composite membranes can include a porous support structure having elongate pore channels extending through the support structure.	Being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,207,081	06/26/12	University of Central Florida	Nanocomposite for photocatalytic Hydrogen production and method for its preparation	Nanocomposite cocatalysts and their preparation method. The cocatalysts loaded on CdS photocatalyst enhance the photocatalytic activity.	Research complete; seeking to license.
8,198,486	06/12/12	Virent Energy Systems, Inc.	Methods and systems for generating polyols	Methods for generating propylene glycol, ethylene glycol and other polyols, diols, ketones, aldehydes, carboxylic acids and alcohols using hydrogen produced from biomass.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).
8,187,731	05/29/12	University of Colorado	Metal ferrite spinel energy storage devices and methods for making and using same	Metal ferrite spinel coatings are provided on substrates, preferably by using an atomic layer deposition process. The coatings are able to store energy such as solar energy, and to release that stored energy, via a redox reaction. The coating is first thermally or chemically reduced. The reduced coating is then oxidized in a second step to release energy or hydrogen, carbon monoxide or other reduced species.	Licensed to ALD NanoSolutions, Inc.
8,172,913	05/08/12	Intelligent Energy, Inc.	Array of planar membrane modules for producing hydrogen	Membrane reactor containing planar membrane modules with top and bottom thin foil membranes supported by both an intermediary porous support plate and a central base which has both solid extended members and hollow regions or a hollow region whereby the two sides of the base are in fluid communication. The membrane reactor operates at elevated temperatures for generating hydrogen from hydrogen rich feed fuels.	Still being used in ongoing research.
8,153,698	04/10/12	Virent Energy Systems, Inc.	Method for producing bio-fuel that integrates heat from carbon-carbon bond-forming reactions to drive biomass gasification reactions	A low-temperature catalytic process for converting biomass (preferably glycerol recovered from the fabrication of bio-diesel) to synthesis gas (i.e., H_2/CO gas mixture) in an endothermic gasification reaction.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,148,583	04/03/12	Air Products & Chemicals, Inc.	Feed gas contaminant removal in ion transport membrane systems	An oxygen ion transport membrane process wherein a heated oxygen-containing gas having one or more contaminants is contacted with a reactive solid material to remove one or more contaminants.	No longer being pursued.
8,147,765	04/03/12	University of Central Florida	Apparatus for hydrogen and carbon production via carbon aerosol-catalyzed dissociation of hydrocarbons	A novel process and apparatus is disclosed for sustainable, continuous production of hydrogen and carbon by catalytic dissociation or decomposition of hydrocarbons at elevated temperatures using in situ generated carbon particles. Carbon particles are produced by decomposition of carbonaceous materials in response to an energy input.	Research complete; seeking to license.
8,114,193	02/14/12	Air Products & Chemicals, Inc.	Ion transport membrane module and vessel system	An ion transport membrane system comprising (a) a pressure vessel having an interior, an exterior, an inlet, and an outlet; (b) a plurality of planar ion transport membrane modules disposed in the interior of the pressure vessel and arranged in series, each membrane module comprising mixed metal oxide ceramic material and having an interior region and an exterior region, wherein any inlet and any outlet of the pressure vessel are in flow communication with exterior regions of the membrane modules; and (c) one or more gas manifolds in flow communication with interior regions of the membrane modules and with the exterior of the pressure vessel. The ion transport membrane system may be utilized in a gas separation device to recover oxygen from an oxygen-containing gas or as an oxidation reactor to oxidize compounds in a feed gas stream by oxygen permeated through the mixed metal oxide ceramic material of the membrane modules.	Still being used in ongoing research.
8,110,022	02/07/12	Genesis Fueltech, Inc.	Hydrogen purifier module and method for forming the same	A hydrogen purifier utilizing a hydrogen permeable membrane, and a gas-tight seal. The seal uses a low temperature melting point metal, which forms when heated above the melting point which is greater than the purifier operating temperature.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,088,261	01/03/12	Gas Technology Institute	CuCl thermochemical cycle for hydrogen production	A method and apparatus for electrochemically producing high porosity, high activity copper powders for high-temperature thermochemical water splitting.	Still being used in ongoing research.
8,084,265	12/27/11	National Renewable Energy Laboratory	Method and Pd/V_2O_5 device for H_2 detection	Pd/V_2O_5 devices for hydrogen detection are described. The devices are chemochromic sensors and can detect hydrogen gas over a wide response range with stability during repeated exposure and removal of hydrogen gas.	Research complete; seeking to license.
8,070,860	12/06/11	United Technologies Corporation	Pd membrane having improved H_2-permeance, and method of making	Improved palladium membranes for the separation of hydrogen from a gas stream.	Being used in ongoing research.
8,048,384	11/01/11	University of Central Florida	Chemochromic hydrogen sensors	A chemochromic hydrogen sensor includes supports, a plurality of metal oxide particles exclusive of titania, and a platinum group metal (PGM) compound.	Licensed to HySense Technology LLC. Part of a commercial production technology.
8,003,055	08/23/11	University of Central Florida	Visual hydrogen detector with variable reversibility	Methods, processes and compositions are provided for a visual or chemochromic hydrogen-detector with variable or tunable reversible color change.	Licensed to HySense Technology LLC. Part of a commercial production technology.
8,002,854	08/23/11	University of Central Florida	Thermocatalytic process for CO_2-free production of hydrogen and carbon from hydrocarbons	Process and apparatus for sustainable CO_2-free production of hydrogen and carbon by thermocatalytic decomposition (dissociation, pyrolysis, cracking) of hydrocarbon fuels over carbon-based catalysts in the absence of air or water. The apparatus and thermocatalytic process improve the activity and stability of carbon catalysts during the thermocatalytic process and produce both high purity hydrogen ($\geq$ 99%) and carbon, from any hydrocarbon fuel, including sulfurous fuels.	Research complete; seeking to license.
7,989,664	08/02/11	Virent Energy Systems, Inc.	Methods and systems for generating polyols	Methods for generating propylene glycol, ethylene glycol and other polyols, diols, ketones, aldehydes, carboxylic acids and alcohols using hydrogen produced from biomass.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,988,925	08/02/11	Argonne National Laboratory	Fuel processing device	An improved fuel processor for fuel cells is provided whereby the startup time of the processor is less than sixty seconds and can be as low as 30 seconds, if not less. A rapid startup time is achieved by either igniting or allowing a small mixture of air and fuel to react over and warm up the catalyst of an autothermal reformer (ATR).	Still being used in ongoing research.
7,981,261	07/19/11	Argonne National Laboratory	Integrated device and substrate for separating charged carriers and reducing photocorrosion and method for the photoelectrochemical production of electricity and photocatalytic production of hydrogen	A system for separating oppositely charged charge carriers that can be used for producing electricity or hydrogen gas.	Still being used in ongoing research.
7,955,423	06/07/11	Air Products & Chemicals, Inc.	Solid-state membrane module	Solid-state membrane modules comprising at least one membrane unit, where the membrane unit has a dense mixed conducting oxide layer, and at least one conduit or manifold wherein the conduit or manifold comprises a dense layer and at least one of a porous layer and a slotted layer contiguous with the dense layer. The solid-state membrane modules may be used to carry out various processes including the separating of any ionizable component from a feedstream and transported through the dense mixed conducting oxide layer of the membrane units that make up the membrane modules. For ease of construction, the membrane units may be planar.	Still being used in ongoing research.
7,951,283	05/31/11	Idaho National Laboratory	High temperature electrolysis for syngas production	A method for producing at least one syngas component that involves directly exposing water and carbon dioxide to heat generated by a nuclear power source.	No longer being pursued.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,947,116	05/24/11	Eltron Research & Development, Inc.	Hydrogen separation process	Method for separating a hydrogen-rich product stream from a feed stream comprised of hydrogen and at least one carbon-containing gas. The hydrogen separation membrane system is selectively permeable to hydrogen, and producing a hydrogen-rich permeate product stream on the permeate side of the membrane and a carbon dioxide-rich product raffinate stream on the raffinate side of the membrane.	Still being used in ongoing research.
7,939,026	05/10/11	Idaho National Laboratory	Apparatus for chemical synthesis	A method and apparatus for forming a chemical hydride using a pseudo-plasma-electrolysis reactor. The reactor has a cathode and a movable anode. The anode is moved into and out of fluidic, ohmic electrical contact with the chemical hydride forming solution.	No longer being pursued.
7,932,437	04/26/11	Oak Ridge National Laboratory	Designer proton-channel transgenic algae for photobiological hydrogen production	A designer proton-channel transgenic alga for photobiological hydrogen production that is specifically designed for production of molecular hydrogen through photosynthetic water splitting.	Assigned to inventor - no longer being pursued.
7,926,793	04/19/11	Pacific Northwest National Laboratory	Mixing in wicking structures and the use of enhanced mixing within wicks in microchannel devices	Wicking structures and methods utilizing these structures are described. Improved results in fluid contacting processes can be achieved by enhanced mixing within a wicking layer within a microchannel.	Being used in continuing research at PNNL and seeking to license.
7,914,683	03/29/11	University of Central Florida	Particles of spilled oil-absorbing carbon in contact with water	Hydrogen generator coupled to or integrated with a fuel cell for portable power applications. Hydrogen is produced via thermocatalytic decomposition (cracking, pyrolysis) of hydrocarbon fuels in oxidant-free environment. The apparatus can utilize various hydrocarbon fuels, including natural gas, propane, gasoline, kerosene, diesel fuel, crude oil (including sulfurous fuels). The hydrogen-rich gas produced is free of carbon oxides or other reactive impurities, so it could be directly fed to any type of a fuel cell.	Research complete; seeking to license.
7,910,373	03/22/11	National Renewable Energy Laboratory	H_2O doped WO_3, ultra-fast, high-sensitivity hydrogen sensors	An improved sensor for optically detecting hydrogen gas at low concentrations. The sensor consists of a substrate, a water-doped WO_3 layer coated on the substrate, and a palladium layer coated on the water-doped WO_3 layer.	Licensed to Element One, Inc. Part of commercial production/ delivery technology.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,906,079	03/15/11	Catacel Corporation	Stackable structural reactor	A reactor including a monolith having a plurality of fins in an annular arrangement for receiving fluid flow through the reactor. The monolith is disposed within a cylindrical outer tube, and around a corrugated inner tube. The reactor includes a device for urging the monolith radially outward to maintain contact between the monolith and the outer tube.	Part of a commercial hydrogen production technology.
7,897,122	03/01/11	Media and Process Technology, Inc.	Hybrid adsorptive membrane reactor	A hybrid adsorbent-membrane reactor in which the chemical reaction, membrane separation, and product adsorption are coupled. In the reaction chamber, one or more reactants and a catalyst react in a water-gas-shift (WGS) reaction producing at least one desired product and at least one by-product. A membrane selectively permits the desired product and the by-product to pass from the chamber to an adsorbent for the by-product; and an outlet for the desired product.	Still being used in ongoing research. Part of an emerging hydrogen production technology.
7,896,953	3/1/11	University of South Florida	Practical method of CO_2 sequestration	A process and device to capture of CO_2 at its originating source, such as a power plant, is disclosed. The absorbent material recharges by desorbing CO_2, so that it may be sequestered or used in another application.	Research complete; seeking to license.
7,879,750	02/01/11	General Electric Company	Anodes for alkaline electrolysis	A method of making an anode for alkaline electrolysis cells used for the production of hydrogen.	Research complete; seeking to license.
7,872,054	01/18/11	Virent Energy Systems, Inc.	Method for producing bio-fuel that integrates heat from carbon-carbon bond-forming reactions to drive biomass gasification reactions	A low-temperature catalytic process for converting biomass (preferably glycerol recovered from the fabrication of bio-diesel) to synthesis gas (i.e., H_2/CO gas mixture) in an endothermic gasification reaction.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).
7,850,838	12/14/10	Proton Energy Systems, Inc.	Cold weather hydrogen generation system and method of operation	An enclosed system that produces hydrogen gas from the electrolysis of water. Operation in cold climates is enabled by one or more heat generation devices that prevent the system's components from freezing.	Being used by Proton OnSite in a commercial product.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,842,276	11/30/10	University of Central Florida	Catalysts for the evolution of hydrogen from borohydride solution	Organic pigments which can catalyze the decomposition reaction of hydrogen-rich, stabilized, borohydride solutions to generate hydrogen gas. The pigments are useful for on-board hydrogen-consuming devices such as motor vehicles or other combustion engines. The organic pigments can be used in hydrogen generating systems and for controlling the generation of hydrogen gas from metal hydride solutions.	Research complete; seeking to license.
7,820,022	10/26/10	General Electric Company	Photoelectrochemical cell and method of manufacture	An apparatus that generates hydrogen by using solar energy to electrolyze water. The photoelectrochemical cell has a particulate-loaded thermoplastic film membrane within an interior cavity of the cell.	No longer being pursued.
7,818,993	10/26/10	Argonne National Laboratory	High-performance flexible hydrogen sensors	Single-walled carbon nanotubes (SWNTs) are decorated with metal nanoparticles to form high-performance flexible hydrogen sensors.	Still being used in ongoing research.
7,771,519	08/10/10	Air Products & Chemicals, Inc.	Liners for ion transport membrane systems	An ion transport membrane system consisting of a pressure vessel and a series of planar ion transport membrane modules. A gas manifold is connected to each membrane module.	No longer being pursued.
7,767,867	08/03/10	Virent Energy Systems, Inc.	Methods and systems for generating polyols	Methods for generating propylene glycol, ethylene glycol and other polyols, diols, ketones, aldehydes, carboxylic acids and alcohols using hydrogen produced from biomass.	Being used in continuing research at the company; non-exclusive license to Equilon Enterprises, LLC (DBA Shell Oil Products U.S.).
7,766,986	08/03/10	Air Products & Chemicals, Inc.	Dehydrogenation of liquid fuel in microchannel catalytic reactor	Process for the storage and delivery of hydrogen by the reversible hydrogenation and dehydrogenation of an organic compound wherein the organic compound is initially in its hydrogenated state.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,763,217	07/27/10	Pacific Northwest National Laboratory	Rapid start fuel reforming systems and techniques	An on-board fuel processor includes a microchannel steam reforming reactor and a water vaporizer heated in series with a combustion gas. A rapid cold start can be achieved in under 30 seconds with some electric power consumption, making the device advantageous for use in automotive fuel cell applications.	Research complete; seeking to license.
7,763,086	07/27/10	Intelligent Energy, Inc.	Hydrogen purification process and system	A hydrogen generation system including a fuel reforming reactor generating a hydrogen-rich reformate gas, a pressure swing adsorption (PSA) hydrogen purification unit that separates hydrogen from the reformate gas, and a catalytic reactor downstream of the PSA to convert carbon monoxide and hydrogen into methane.	Still being used in ongoing research.
7,745,696	06/29/10	University of California - Berkeley	Suppression of TLA1 gene expression for improved solar conversion efficiency and photosynthetic productivity in plants and algae	Methods and compositions to minimize the chlorophyll antenna size of photosynthesis by decreasing TLA1 gene expression, improving solar conversion efficiencies and photosynthetic productivity in plants, e.g., green microalgae, under bright sunlight conditions.	Non-exclusive license to Benson Hill Biosystems. Part of an emerging production technology project.
7,744,733	06/29/10	Proton Energy Systems, Inc.	Gas venting system	A system for venting a moist gas stream resulting from operation of electrochemical cells within an enclosure, and for preventing the water vapor in the moist gas stream from freezing within the enclosure.	Being used by Proton OnSite in a commercial product.
7,736,609	06/15/10	Ergenics Corporation	Hydrogen purification system	The invention provides a system to purify hydrogen involving the use of a hydride compressor and catalytic converters combined with a process controller.	Research complete; seeking to license.
7,732,174	06/08/10	National Renewable Energy Laboratory	Multi-stage microbial system for continuous hydrogen production	The invention relates to a continuous H_2 production system in which photosynthetic O_2 evolution and H_2 photo-production are separated physically in two separate bioreactors.	Being used in continuing research efforts at NREL and seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,722,853	05/25/10	University of Central Florida	Catalysts for the evolution of hydrogen from borohydride solution	Organic pigments which can catalyze the decomposition reaction of hydrogen-rich, stabilized, borohydride solutions to generate hydrogen gas. The pigments are useful for on-board hydrogen-consuming devices such as motor vehicles or other combustion engines. The organic pigments can be used in hydrogen generating systems and for controlling the generation of hydrogen gas from metal hydride solutions.	Research complete; seeking to license.
7,722,757	05/25/10	Argonne National Laboratory	Process for the production of hydrogen from water	A method and device for the production of hydrogen from water and electricity using an active metal alloy. The active metal alloy reacts with water producing hydrogen and a metal hydroxide.	No longer being pursued. DOE now owns patent.
7,703,472	04/27/10	Air Products & Chemicals, Inc.	Module isolation devices	Gas flow isolation devices for Ion Transport Membrane (ITM) modules designed for producing purified oxygen from an oxygen-containing gas (e.g., air) or for producing synthesis gas. The devices isolate the flow of gas from one module into one or more other modules that are joined together through one or more common headers.	No longer being pursued.
7,695,580	04/13/10	Air Products & Chemicals, Inc.	Method of forming a ceramic to ceramic joint	A method of forming a joint at an interface between two sintered bodies comprising metallic oxides of specific crystal structure. The method can be used to form gas-tight joints between ceramic components in an oxygen separation device.	No longer being pursued.
7,695,545	04/13/10	Air Products & Chemicals, Inc.	Adsorption process to recover hydrogen from feed gas mixtures having low hydrogen concentration	A process for selectively separating hydrogen from at least one more strongly adsorbable component in a plurality of adsorption beds to produce a hydrogen-rich product gas from a low hydrogen concentration feed with a high recovery rate.	Still being used in ongoing research.
7,691,775	04/06/10	University of Michigan	Reducible oxide based catalysts	The invention relates to an improved catalyst for the water gas shift reaction, which is used in the production of hydrogen. The catalyst includes a reducible oxide support and at least one noble metal fixed on the reducible oxide support.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,687,051	03/30/10	Symyx Technologies, Inc.	Platinum and rhodium and/ or iron containing catalyst formulations for hydrogen generation	A method and catalysts for producing a hydrogen-rich syngas using CO-containing gas which contacts a water gas shift (WGS) catalyst. The water gas shift catalyst is formulated from Pt, its oxides or mixtures thereof, at least one of Fe and Rh, their oxides and mixtures thereof, and at least one member selected from the group consisting of Sc, Y, Ti, Zr, V, Nb, Ta, Mo, Re, Co, Ni, Pd, Ge, Sn, Sb, La, Ce, Pr, Nd, Sm, and Eu, their oxides and mixtures thereof. The WGS catalyst may be supported on a carrier, such as any one member or a combination of alumina, zirconia, titania, ceria, magnesia, lanthania, niobia, yttria and iron oxide. Fuel processors containing such water gas shift catalysts are also disclosed.	Still being used in ongoing research.
7,682,580	03/23/10	Catacel Corporation	Catalytic reactor having radial leaves	All-metal structure, cylindrical reactor for surface catalytic reactions or heat exchange and avoids the low conductivity problems associated with the use of packed bed ceramic materials in the manufacture and operation of catalytic reactors. Also, the thermal mismatch between the metal and ceramic portions of prior art reactors eventually lead to pulverization of the ceramic material, thus limiting the useful life of the reactor. This design has leaves that are not spiral, but radially extend outward from the interior of the reactor to its exterior to provide improved heat transfer between the exterior and the interior of the reactor.	No licenses issued & no internal research being done with this patent
7,678,251	03/16/10	Proton Energy Systems, Inc.	System and method for detecting gas	A method for detecting the presence of a specific gas in a mixture of gases resulting from operation of an electrochemical cell.	Being used by Proton OnSite in a commercial product.
7,666,534	02/23/10	Argonne National Laboratory	Electro-catalytic oxidation device for removing carbon from a fuel reformate	An electrocatalytic oxidation device (ECOD) for the removal of contaminates, preferably carbonaceous materials, from an influent comprising an ECOD anode, an ECOD cathode, and an ECOD electrolyte.	Being used in continuing research efforts at ANL.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,658,788	02/09/10	Air Products & Chemicals, Inc.	Ion transport membrane module and vessel system with directed internal gas flow	An ion transport membrane reactor system which can be used to oxidize a reactant gas feed stream containing hydrocarbons, such as methane, and produce a product gas stream containing hydrogen and carbon oxides.	No longer being pursued.
7,651,669	01/26/10	Pacific Northwest National Laboratory	Microsystem process networks	Applications of microsystem process networks improved by employing ortho-cascading mass, heat, or other unit process operations. One application is the production of hydrogen via steam reformation of hydrocarbons.	No longer being pursued at PNNL; owned by the U.S. Department of Energy.
7,648,566	01/19/10	General Electric Company	Methods and apparatus for carbon dioxide removal from a fluid stream	An apparatus for purifying synthesis gas streams by performing the water-gas shift reaction and selectively removing the resulting carbon dioxide so that the product stream has a higher hydrogen purity.	No longer being pursued.
7,642,405	01/05/10	Oak Ridge National Laboratory	Switchable photosystem-II designer algae for photobiological hydrogen production	A switchable photosystem-II designer algae for photobiological hydrogen production. The transgenic algae include at least two transgenes for enhanced photobiological H_2 production.	No longer being used.
7,604,771	10/20/09	Argonne National Laboratory	Thermal method for fabricating a hydrogen separation membrane on a porous substrate	A thermal method of making a hydrogen permeable composition for use in hydrogen separation membranes.	Being used in continuing research efforts at ANL.
7,591,864	09/22/09	University of Central Florida	Catalysts for the evolution of hydrogen from borohydride solution	Organic pigments which can catalyze the decomposition reaction of hydrogen-rich, stabilized, borohydride solutions to generate hydrogen gas. The pigments are useful for on-board hydrogen-consuming devices such as motor vehicles or other combustion engines. The organic pigments can be used in hydrogen generating systems and for controlling the generation of hydrogen gas from metal hydride solutions.	Research complete; seeking to license.
7,588,626	09/15/09	Boston University	Composite mixed oxide ionic and electronic conductors for hydrogen separation	A mixed ionic and electrically conducting membrane that includes a two-phase solid-state ceramic composite, wherein the first phase is an oxygen ion conductor and the second phase is an n-type electrically conductive oxide. The membrane can be used to separate hydrogen from a mixture of gases and purify it for use in fuel cells.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,581,765	09/01/09	Air Products & Chemicals, Inc.	Seal assembly for materials with different coefficients of thermal expansion	An improved seal assembly for couplings and joints between materials with different coefficients of thermal expansion (e.g., metals and ceramics) used in high-temperature gas processing devices.	No longer being pursued.
7,575,614	08/18/09	Nuvera Fuel Cells, Inc.	Startup burner	Startup burner design to make fuel reformers with sufficient energy density suitable for automotive use. The burner produces a hot gas emission suitable for heating a catalyst (e.g., a catalyst used in an autothermal reforming (ATR)) to a desired temperature (e.g., the light-off temperature of the catalyst).	No longer being pursued.
7,569,293	08/04/09	Nuvera Fuel Cells, Inc.	Methods and systems for efficient operation of integrated fuel cell-fuel reformer systems	Methods and related systems for determining an efficient operating state for an integrated fuel cell or fuel reformer power system. The method optimizes the efficiency of operation of a power system comprising a fuel processor and a fuel cell operating in an integrated way. The operating properties of the system components are used for controlling and optimizing system efficiency at any desired power output level.	No longer being pursued.
7,565,743	07/28/09	Catacel Corporation	Method for insertion and removal of a catalytic reactor cartridge	Cartridge that can be used for catalytic or non-catalytic combustion or as a heat exchanger which can be stacked with similar cartridges in a long tube or pipe. The cartridge also requires a method of moving a cartridge into or out of a pipe, and a tool for accomplishing such a transfer.	No licenses issued & no internal research being done with this patent.
7,563,292	07/21/09	Argonne National Laboratory	Fuel processor and method for generating hydrogen for fuel cells	A method of producing a H_2 rich gas stream includes supplying an O_2 rich gas, steam, and fuel to an inner reforming zone of a fuel processor that includes a partial oxidation catalyst and a steam reforming catalyst or a combined partial oxidation and stream reforming catalyst.	Being used in continuing research efforts at ANL.
7,559,978	07/14/09	General Electric Company	Gas-liquid separator and method of operation	A system for gas-liquid separation in electrolysis equipment used for hydrogen production.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,556,675	07/07/09	Air Products & Chemicals, Inc.	Feed gas contaminant control in ion transport membrane systems	Methods for constructing ion transport membrane (ITM) reactor systems so that the system's metal components do not react with high-temperature mixtures of steam, methane, or synthesis gas, preventing the production of ITM-poisoning contaminant vapors.	No longer being pursued.
7,540,892	06/02/09	Millenium Cell, Inc.	Hydrogen gas generation system	A system for generating hydrogen gas utilizes a volume exchange housing for the storage of a fuel material that reacts to generate hydrogen gas and a hydrogen separation chamber. The system includes a gas permeable membrane or membranes that allow hydrogen gas to pass through the membrane while preventing aqueous solutions from passing therethrough. The system is orientation independent. A throttle valve is also used to self-regulate the reaction generating the hydrogen gas.	No longer being pursued.
7,540,475	06/02/09	Pacific Northwest National Laboratory	Mixing in wicking structures and the use of enhanced mixing within wicks in microchannel devices	Wicking structures and methods utilizing these structures are described. Improved results in fluid contacting processes can be achieved by enhanced mixing within a wicking layer within a microchannel.	Being used in continuing research at PNNL and seeking to license.
7,530,931	05/12/09	Millenium Cell, Inc.	Hydrogen generator	A hydrogen generation system includes a fuel container, a spent fuel container, a catalyst system and a control system for generating hydrogen in a manner which provides for a compact and efficient construction while producing hydrogen from a reaction involving a hydride solution such as sodium borohydride.	No longer being pursued.
7,520,917	04/21/09	Pacific Northwest National Laboratory	Devices with extended area structures for mass transfer processing of fluids	The invention relates to microchannel devices used for performing fluid processing and heat exchange.	Being used in continuing research at PNNL.
7,519,462	04/14/09	Caterpillar, Inc.	Crowd force control in electrically propelled machine	A method of operating an electrically propelled machine including the power source, and limiting output torque of the electrical propulsion motor system based on the occurrence of a crowd force condition of the machine.	Research complete.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,513,978	04/07/09	Millenium Cell, Inc.	Method and apparatus for generating hydrogen	An electro-galvanic hydrogen generator system that has two or more anode materials; a cathode material; and an electrolyte. The electrolyte comprises a metal hydride, at least one stabilizing agent, and a solvent. Hydrogen gas is generated whenever an anode material and the cathode material are electrically connected, and the different anode materials can be used separately or in combination to control the quantity and rate of hydrogen generation.	No longer being pursued.
7,513,932	04/07/09	Air Products & Chemicals, Inc.	Planar ceramic membrane assembly and oxidation reactor system	A planar ceramic membrane assembly comprising a dense layer of mixed-conducting multicomponent metal oxide material.	No longer being pursued.
7,507,690	03/24/09	Argonne National Laboratory	Autothermal reforming catalyst having perovskite structure	A novel fuel reforming catalyst with a perovskite structure that can be used to produce hydrogen for use in fuel cells.	Being used in continuing research efforts at ANL.
7,507,384	03/24/09	Nuvera Fuel Cells, Inc.	Preferential oxidation reactor temperature regulation	Hydrocarbon fuel reforming system for reforming a gaseous or liquid hydrocarbon fuel to produce a hydrogen-rich product stream for use in, among other things, fuel cells.	No longer being pursued.
7,501,270	03/10/09	National Renewable Energy Laboratory	Oxygen-resistant hydrogenases and methods for designing and making same	Oxygen-resistant iron-hydrogenases ([Fe]-hydrogenases) for use in the production of H_2 and methods for the design and engineering of the oxygen-resistant [Fe]-hydrogenases. Also provided are methods for utilizing the transformed, oxygen insensitive, host cells in the bulk production of H_2 in a light catalyzed reaction having water as the reactant.	Being used in continuing research efforts at NREL and seeking to license.
7,501,102	03/10/09	Catacel Corporation	Reactor having improved heat transfer	A reactor or heat exchanger with an annular monolith with multiple leaves inside a cylindrical outer tube, and around a corrugated inner tube. The reactor includes a device for urging the monolith radially outward, to maintain contact between the monolith and the outer tube. The reactor compensates for metal creep, and virtually insures continued contact between the monolith and the outer tube for heat transfer.	No licenses issued & no internal research being done with this patent.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,501,101	03/10/09	Pacific Northwest National Laboratory	Microchannel apparatus comprising plural microchannels and methods of conducting unit operations	A microchannel apparatus comprising a header and plural flow microchannels in which orifices connect the header and the flow microchannels. Methods of conducting unit operations in the apparatus are also described.	Exclusive license to Velocys, Inc.
7,485,161	02/03/09	Air Products & Chemicals, Inc.	Dehydrogenation of liquid fuel in microchannel catalytic reactor	An improved process for the storage and delivery of hydrogen by the reversible hydrogenation and dehydrogenation of an organic compound in a microchannel reactor.	No longer being pursued.
7,472,936	01/06/09	Catacel Corporation	Tool for insertion and removal of a catalytic reactor cartridge	A reactor cartridge includes a plurality of monoliths, formed along a tube or other mandrel. Each monolith is formed of a pair of flat and corrugated metal strips, spirally wound around the tube. The corrugations are skewed, such that the monolith imparts a swirl to gases flowing through it to promote mixing of gases and better heat transfer from the exterior to the interior of the cartridge. An insertion and removal tool simplifies the procedure for stacking such cartridges in a long pipe, or for removing cartridges from the pipe. The all-metal construction facilitates heat transfer through the entire reactor, and avoids the problems associated with packed ceramic beds.	No licenses Issued & no internal research being done with this patent
7,468,092	12/23/08	Air Products & Chemicals, Inc.	Operation of mixed conducting metal oxide membrane systems under transient conditions	A method of operating an oxygen-permeable mixed conducting membrane having an oxidant feed side, an oxidant feed surface, a permeate side, and a permeate surface. The method consists of controlling the differential strain between the permeate surface and the oxidant feed surface by varying the oxygen partial pressure on either or both sides of the membrane.	No longer being pursued.
7,452,407	11/18/08	Air Products & Chemicals, Inc.	Production of carbon monoxide-free hydrogen and helium from a high-purity source	Vacuum swing adsorption processes that produce carbon monoxide-free hydrogen or helium gas stream from, respectively, a high-purity (e.g., pipeline grade) hydrogen or helium gas stream using one or two adsorber beds.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,434,547	10/14/08	Nuvera Fuel Cells, Inc.	Fuel fired hydrogen generator	A system that combines an IC engine with a fuel processor for hydrocarbon fuels and generates and stores hydrogen with high efficiency and low operation cost.	Still being used in ongoing research.
7,429,372	09/30/08	Air Products & Chemicals, Inc.	Hydrogen storage by reversible hydrogenation of pi-conjugated substrates	A novel process for the storage and release of hydrogen by reversible catalytic hydrogenation of extended pi-conjugated substrates.	Part of an emerging hydrogen production technology.
7,425,231	09/16/08	Air Products & Chemicals, Inc.	Feed gas contaminant removal in ion transport membrane systems	A method for purification of a gas stream containing contaminants such as volatile metal oxy-hydroxides, volatile metal oxides, and volatile silicon hydroxide. The method consists of contacting the feed gas stream with a reactive solid material in a guard bed to form a solid reaction product, after which the purified gas stream is withdrawn from the guard bed.	No longer being pursued.
7,419,635	09/02/08	National Renewable Energy Laboratory	Pd/V_2O_5 device for colorimetric H_2 detection	A sensor structure for chemochromic optical detection of hydrogen gas over a wide response range.	Research complete; seeking to license.
7,407,458	08/05/08	Caterpillar, Inc.	In-line drivetrain and four wheel drive work machine using same	A four-wheel drive articulated mine loader powered by a fuel cell and propelled by an in-line, single electric motor using a single reduction gear to power the four-wheel drive mine loader.	Research complete.
7,396,382	07/08/08	General Electric Company	Functionalized inorganic membranes for gas separation	A porous membrane for separation of carbon dioxide from a fluid stream at a temperature higher than about 200 ºC with selectivity higher than Knudsen diffusion selectivity. The porous membrane comprises of porous support and separation layers comprising alumina, silica, zirconia or stabilized zirconia; and a functional layer comprising a ceramic oxide contactable with the fluid stream to preferentially transport carbon dioxide.	No longer being pursued.
7,367,996	05/06/08	Nuvera Fuel Cells, Inc.	Heat transfer optimization in multi shelled reformers	Hydrocarbon fuel reformers for reforming a gaseous or liquid hydrocarbon fuel into a hydrogen-enriched product stream or reformate for use in hydrogen fuel cells. The reformer consists of coaxially arranged zones, through which reactants and processed streams are cooperatively flowed to accomplish necessary reactions, preheating and thermal efficiency.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,354,465	04/08/08	Nuvera Fuel Cells, Inc.	Device for cooling and humidifying reformate	A device for cooling and humidifying a reformate stream from a reforming reactor and related methods, modules and systems including a heat exchanger and a sprayer.	No longer being pursued.
7,351,395	04/01/08	Air Products & Chemicals, Inc.	Hydrogen storage by reversible hydrogenation of pi-conjugated substrates	A novel process for the storage and release of hydrogen by reversible catalytic hydrogenation of extended pi-conjugated substrates.	Part of an emerging hydrogen production technology.
7,344,576	03/18/08	Pacific Northwest National Laboratory	Conditions for fluid separations in microchannels, capillary-driven fluid separations, and laminated devices capable of separating fluids	Methods of separating fluids using capillary forces or improved conditions. The improved methods may include control of the ratio of gas and liquid Reynolds numbers relative to the Suratman number. Also disclosed are wick-containing, laminated devices capable of separating fluids.	Exclusive license to Velocys, Inc.
7,340,938	03/11/08	University of Colorado	MIS-based sensors with hydrogen selectivity	Hydrogen-selective metal-insulator-semiconductor sensors which include a layer of hydrogen-selective material.	Licensed to the Electric Power Research Institute.
7,335,247	02/26/08	Air Products & Chemicals, Inc.	Ion transport membrane module and vessel system	An ion transport membrane reactor system which can be used to oxidize a reactant gas feed stream containing hydrocarbons, such as methane, and produce a product gas stream containing hydrogen and carbon oxides.	No longer being pursued.
7,311,755	12/25/07	Air Products & Chemicals, Inc.	Control of differential strain during heating and cooling of mixed conducting metal oxide membranes	A method of operating an oxygen-permeable mixed conducting membrane having an oxidant feed side and a permeate side. The method consists of controlling the differential strain between the oxidant feed side and the permeate side by varying the oxygen partial pressure on either or both sides of the membrane.	No longer being pursued.
7,297,324	11/20/07	Pacific Northwest National Laboratory	Microchannel reactors with temperature control	Microchannel devices and methods of use are disclosed wherein a reaction microchamber is in thermal contact with a heat exchange channel. A catalyst can be provided in the microchamber in sheet form such that reactants flow by the catalyst sheet.	Exclusive license to Velocys, Inc.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,279,027	10/09/07	Air Products & Chemicals, Inc.	Planar ceramic membrane assembly and oxidation reactor system	Planar ceramic membrane assembly comprising a dense layer of mixed-conducting multicomponent metal oxide material, wherein the dense layer has a first side and a second side, a porous layer of mixed-conducting multicomponent metal oxide material in contact with the first side of the dense layer, and a ceramic channeled support layer in contact with the second side of the dense layer.	No longer being pursued.
7,276,306	10/02/07	Lawrence Livermore National Laboratory	System for the co-production of electricity and hydrogen	System for the co-generation of hydrogen gas and electricity, wherein the proportion of hydrogen to electricity can be adjusted from 0–100%.	No license issued and no research being done with this patent.
7,272,941	09/25/07	Pacific Northwest National Laboratory	Methods for fluid separations, and devices capable of separating fluids	A wick-containing apparatus and methods of separating fluids using wicks.	Being used in continuing research at PNNL.
7,270,905	09/18/07	Pacific Northwest National Laboratory	Microsystem process networks	Various aspects and applications of microsystem process networks which can be improved by employing ortho-cascading mass, heat, or other unit process operations are described. One such application is the production of hydrogen via steam reformation of hydrocarbons.	Research complete; seeking to license.
7,242,311	07/10/07	Caterpillar, Inc.	Method and system for providing work machine multi-functional user interface	A multi-functional user interface on a work machine for displaying suggested corrective action. Status information associated with the work machine is analyzed to determine an abnormal condition and then a display warning message indicating the abnormal condition and one or more corrective actions.	Research complete.
7,233,034	06/19/07	National Renewable Energy Laboratory	Hydrogen permeable protective coating for a catalytic surface	A protective coating for a surface comprising a layer permeable to hydrogen, said coating being deposited on a catalyst layer wherein the catalytic activity of the catalyst layer is preserved.	Exclusive license to Nuclear Filter Technology. Still working with NREL via CRADA on further development.
7,229,785	06/12/07	National Renewable Energy Laboratory	Fluorescence technique for on-line monitoring of state of hydrogen-producing microorganisms	An in situ method for external on-line monitoring of the physiological state of an algal culture inside a closed photobioreactor system to ascertain the culture's production of hydrogen.	Not licensed but still being used in research at NREL.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,179,323	02/20/07	Air Products & Chemicals, Inc.	Ion transport membrane module and vessel system	An ion transport membrane reactor system which can be used to oxidize a reactant gas feed stream containing hydrocarbons, such as methane, and produce a product gas stream containing hydrogen and carbon oxides.	No longer being pursued.
7,176,005	02/13/07	University of California - Berkeley	Modulation of sulfate permease for photosynthetic hydrogen production	Sustained hydrogen production by culturing genetically modified algae, where the ability of the chloroplasts to intake sulfate is reduced or eliminated compared with wild-type algae.	Part of an emerging hydrogen production technology.
7,157,167	01/02/07	University of Central Florida	Thermocatalytic process for CO_2-free production of hydrogen and carbon from hydrocarbons	A novel process and apparatus for sustainable CO_2-free production of hydrogen and carbon by thermocatalytic decomposition (dissociation, pyrolysis, cracking) of hydrocarbon fuels over carbon-based catalysts in the absence of air or water.	Exclusive license to Contained Energy, Inc. Continued development with the goal of a commercial product in 3-5 years.
7,148,389	12/12/06	University of Michigan	Selective sorbents for purification of hydrocarbons	A method for removing thiophene and thiophene compounds from liquid fuel using an adsorbent. The adsorption takes place at a selected temperature and pressure, producing a non-adsorbed component and a thiophene/thiophene compound-rich adsorbed component. A further method includes selective removal of aromatic compounds from a mixture of aromatic and aliphatic compounds.	Research complete; seeking to license.
7,125,540	10/24/06	Pacific Northwest National Laboratory	Microsystem process networks	Applications of microsystem process networks which can be improved by employing ortho-cascading mass, heat, or other unit process operations.	Exclusive license to Velocys, Inc.
7,122,873	10/17/06	University of Hawaii	Hybrid solid state/ electrochemical photoelectrode for hydrogen production	A semiconductor device for producing a gas from a material comprising the gas using light as the sole power source.	No longer being used.
7,101,530	09/05/06	Air Products & Chemicals, Inc.	Hydrogen storage by reversible hydrogenation of pi-conjugated substrates	A novel process for the storage and release of hydrogen by reversible catalytic hydrogenation of extended pi-conjugated substrates.	Part of an emerging hydrogen production technology.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,094,333	08/22/06	University of Michigan	Selective sorbents for purification of hydrocarbons	A method for removing thiophene and thiophene compounds from liquid fuel using an adsorbent. The adsorption takes place at a selected temperature and pressure, producing a non-adsorbed component and a thiophene/thiophene compound-rich adsorbed component. A further method includes selective removal of aromatic compounds from a mixture of aromatic and aliphatic compounds.	Research complete; seeking to license.
7,094,301	08/22/06	Air Products & Chemicals, Inc.	Method of forming a joint	Method of forming a joint at an interface between two sintered bodies comprising multicomponent metallic oxides of specific crystal structure. Typical sintered bodies are an ion transport membrane, ceramic tubes, and equipment such as seals and conduits.	No longer being pursued.
7,087,211	08/08/06	Argonne National Laboratory	Hydrogen production by high temperature water splitting using electron conducting membranes	A device and method for separating water into hydrogen and oxygen.	No longer being pursued.
7,074,369	07/11/06	University of Central Florida	Method and apparatus for decoupled thermo-catalytic pollution control	Method for design and scale-up of thermo-catalytic processes based on optimizing process energetics by decoupling of the process energetics from the destruction and removal efficiency (DRE) for target contaminants. The method is based on the implementation of polymeric and other low-pressure drop support for thermo-catalytic media and multifunctional catalytic media with a novel rotating fluidized particle bed reactor.	Research complete; seeking to license.
7,067,453	06/27/06	InnovaTek, Inc.	Hydrocarbon fuel reforming catalyst and use thereof	The subject invention is a catalyst consisting of an oxide or mixed oxide support and bimetallic catalytically active compounds.	Part of a commercial hydrogen production/ delivery technology.
7,066,973	06/27/06	Nuvera Fuel Cells, Inc.	Integrated reformer and shift reactor	A hydrocarbon fuel reformer for producing diatomic hydrogen gas.	No longer being pursued.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,063,131	06/20/06	Nuvera Fuel Cells, Inc.	Perforated fin heat exchangers and catalytic support	Perforated fins are provided to improve the capabilities of fin and tube type heat exchangers, and to adapt them for flow outside of the tube that is parallel to the axis of the tube. The perforations allow heat exchange with the contents of a tube of a fluid flowing parallel to the axis of the tube, in contrast to conventional fin-tube heat exchangers. In addition, the fins may carry a catalyst, optionally carried on a washcoat or similar treatment to increase surface area.	No longer being pursued.
7,059,364	06/13/06	Gas Technology Institute	Control method for high-pressure hydrogen vehicle fueling station dispensers	A method for quick filling a vehicle hydrogen storage vessel with hydrogen, the key component of which is an algorithm used to control the fill process, which interacts with the hydrogen dispensing apparatus to determine the vehicle hydrogen storage vessel capacity.	Being used in a commercial product, H2 ProGen, by GreenField Compression.
7,053,256	05/30/06	University of Michigan	Selective sorbents for purification of hydrocarbons	A method for removing thiophene and thiophene compounds from liquid fuel using an adsorbent. The adsorption takes place at a selected temperature and pressure, producing a non-adsorbed component and a thiophene/thiophene compound-rich adsorbed component. A further method includes selective removal of aromatic compounds from a mixture of aromatic and aliphatic compounds.	Research complete; seeking to license.
7,051,540	05/30/06	Pacific Northwest National Laboratory	Methods for fluid separations, and devices capable of separating fluids	A wick-containing apparatus and methods of separating fluids using wicks.	Being used in continuing research at PNNL and seeking to license.
7,033,570	04/25/06	University of Colorado	Solar-thermal fluid-wall reaction processing	A method for carrying out high temperature thermal dissociation reactions requiring rapid-heating and short residence times using solar energy.	Licensed to Sundrop Fuels, Inc. and still being used in research at the company.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,029,574	04/18/06	University of Michigan	Selective sorbents for purification of hydrocarbons	A method for removing thiophene and thiophene compounds from liquid fuel using an adsorbent. The adsorption takes place at a selected temperature and pressure, producing a non-adsorbed component and a thiophene/thiophene compound-rich adsorbed component. A further method includes selective removal of aromatic compounds from a mixture of aromatic and aliphatic compounds.	Research complete; seeking to license.
7,011,898	03/14/06	Air Products & Chemicals, Inc.	Method of joining ITM materials using a partially or fully-transient liquid phase	A method of forming a joint at an interface between two sintered bodies comprising multicomponent metallic oxides of specific crystal structure. Typical sintered bodies are an ion transport membrane (an electrolyte), ceramic tubes, and additional supporting equipment such as seals and conduits.	No longer being pursued.
7,011,694	03/14/06	University of Kentucky	CO_2-selective membranes containing amino groups	A CO_2-selective membrane constructed in the hollow-fiber configuration using air as the sweep gas for use in water gas shift reactors to aid in the production of high-purity H_2.	Still being used in ongoing research.
7,001,446	02/21/06	Eltron Research & Development, Inc.	Dense, layered membranes for hydrogen separation	Hydrogen-permeable membranes for separation of hydrogen from hydrogen-containing gases. The membranes are multi-layer having a central hydrogen-permeable layer with one or more catalyst layers, barrier layers, or protective layers. These reactors could be combined with additional reactor systems for direct use of the separated hydrogen.	Still being used in ongoing research.
6,989,252	01/24/06	National Renewable Energy Laboratory	Hydrogen production using hydrogenase-containing oxygenic photosynthetic organisms	A reversible physiological process provides for the temporal separation of oxygen evolution and hydrogen production in a microorganism.	Research complete; seeking to license.
6,986,797	01/17/06	Nuvera Fuel Cells, Inc.	Auxiliary reactor for a hydrocarbon reforming system	An integrated hydrocarbon fuel reforming system for reforming a gaseous or liquid hydrocarbon fuel to produce a hydrogen-rich product stream used in among other things, hydrogen fuel cells.	No longer being pursued.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,985,082	01/10/06	NexTech Materials, Ltd.	Carbon monoxide sensor and method of use	A sensor and method of use for detection of low levels of carbon monoxide in gas mixtures.	No longer being pursued.
6,967,063	11/22/05	Argonne National Laboratory	Autothermal hydrodesulfurizing reforming method and catalyst	A method for reforming a sulfur-containing carbonaceous fuel in which the sulfur-containing carbonaceous fuel is mixed with H_2O and an oxidant, forming a fuel/H_2O/ oxidant mixture.	Licensed to a small company that wishes to remain anonymous and being used in research.
6,899,744	05/31/05	Eltron Research & Development, Inc.	Hydrogen transport membranes	Composite hydrogen transport membranes used for extraction of hydrogen from gas mixtures. Support materials are chosen to be lattice matched to the metals and metal alloys with high permeability for hydrogen such as vanadium, niobium, tantalum, zirconium, palladium, and alloys thereof.	Still being used in ongoing research.
6,889,710	05/10/05	Air Products & Chemicals, Inc.	Rotary sequencing valve with flexible port plate	Rotary sequencing valve comprising a rotor having multiple openings, at select radial distances from the rotation axis. The rotor includes at least one passage connecting at least one pair of openings. The valve includes a flexible port plate attached to the rotor such that the flexible port plate can rotate coaxially by the rotor and can move axially with respect to the rotor. The valve also includes a stator that is coaxial with the rotor and the flexible port plate, wherein the opposite side of the flexible port plate is in sealable, slidable rotary contact with the stator face. The stator face also has a plurality of openings, at select radial distances from the axis which can extend the passages through the stator. The valve may be used in pressure or temperature swing adsorption systems.	Still being used in ongoing research.
6,887,728	05/03/05	University of Hawaii	Hybrid solid state/ electrochemical photoelectrode for hydrogen production	A semiconductor device for production of a gas from a material comprising the gas using light as the sole power source.	No longer being used.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,878,362	04/12/05	General Electric Company	Fuel processor apparatus and method based on autothermal cyclic reforming	A fuel processor based on autothermal cyclic reforming process and a method of generating hydrogen gas includes receiving a mixture of fuel and steam in the reformer reactor operating in a reforming step to produce hydrogen-rich reformate gas.	Research not continuing in this area and nothing being done with patent.
6,875,247	04/05/05	Pacific Northwest National Laboratory	Conditions for fluid separations in microchannels, capillary-driven fluid separations, and laminated devices capable of separating fluids	Methods of separating fluids using capillary forces or improved conditions. The improved methods may include control of the ratio of gas and liquid Reynolds numbers relative to the Suratman number. Also disclosed are wick-containing, laminated devices capable of separating fluids.	Exclusive license to Velocys, Inc. Being developed for distillation uses.
6,872,378	03/29/05	National Renewable Energy Laboratory	Solar thermal aerosol flow reaction process	An environmentally beneficial process using concentrated sunlight to heat radiation absorbing particles to carry out highly endothermic gas phase chemical reactions ultimately resulting in the production of hydrogen or hydrogen synthesis gases.	Licensed to Sundrop Fuels, Inc. and still being used in research at the company.
6,869,462	03/22/05	Pacific Northwest National Laboratory	Methods of contacting substances and microsystem contactors	The invention provides an apparatus and methods for efficiently capturing and separating fluids from gas or liquid streams. One possible application of the invention is for recycling water used in fuel cells.	Being used in continuing research at PNNL and seeking to license.
6,783,742	08/31/04	Nuvera Fuel Cells, Inc.	Reactor for producing hydrogen from hydrocarbon fuels	A reformer for producing a hydrogen-rich gas with multiple reaction zones and a product gas collection space. This technique can be used at lower pressure for flowing the reaction stream to reduce the parasitic requirements of the reactor, and increase throughput of the reactor.	Still being used in ongoing research.
6,726,893	04/27/04	Argonne National Laboratory	Hydrogen production by high-temperature water splitting using electron-conducting membranes	A device and method for separating water into hydrogen and oxygen.	No longer being pursued.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,723,566	04/20/04	National Renewable Energy Laboratory	Pd/Ni-WO_3 anodic double layer gasochromic device	An anodic double layer gasochromic sensor structure for optical detection of hydrogen in improved response time and with improved optical absorption real time constants.	Exclusive license to Nuclear Filter Technology. Still working with NREL via CRADA on further development.
6,716,275	04/06/04	Sandia National Laboratory	Gas impermeable glaze for sealing a porous ceramic surface	A process for fabricating a gas impermeable seal on a porous ceramic surface using a thin, glass-based, pinhole free glaze.	Not licensed and no research being done at SNL.
6,713,040	03/30/04	Argonne National Laboratory	Method for generating hydrogen for fuel cells	A method of producing a H_2 rich gas stream includes supplying an O_2 rich gas, steam, and fuel to an inner reforming zone of a fuel processor that includes a partial oxidation catalyst and a steam reforming catalyst or a combined partial oxidation and stream reforming catalyst.	Being used in continuing research efforts at ANL.
6,670,058	12/20/03	University Central Florida	Thermocatalytic process for CO_2-free production of hydrogen and carbon from hydrocarbons	A novel process for sustainable CO_2-free production of hydrogen and carbon by thermocatalytic decomposition (or dissociation, pyrolysis, cracking) of hydrocarbon fuels over carbon-based catalysts in the absence of air or water.	Exclusive license to Contained Energy, Inc. Continued development with the goal of a commercial product in 3-5 years.
6,666,909	12/23/03	Pacific Northwest National Laboratory	Microsystem capillary separations	Laminated, multiphase separators and contactors having wicking structures and gas flow channels. Some preferred embodiments are combined with microchannel heat exchange.	Exclusive license to Velocys, Inc. Being developed for distillation uses.
6,641,625	11/04/03	Nuvera Fuel Cells, Inc.	Integrated hydrocarbon reforming system and controls	A hydrocarbon reformer system including a first reactor configured to generate hydrogen-rich reformate.	No longer being pursued.
6,623,720	09/23/03	University of Michigan	Transition metal carbides, nitrides and borides, and their oxygen containing analogs useful as water gas shift catalysts	Mono- and bimetallic transition metal carbides, nitrides and borides, and their oxygen containing analogs (e.g., oxycarbides) for use as water gas shift catalysts.	No license, but looking for a commercial partner for future research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,602,324	08/05/03	Air Products & Chemicals, Inc.	Sulfur control in ion-conducting membrane systems	A method for controlling the sulfur dioxide partial pressure in a pressurized, heated, oxygen-containing gas mixture which is contacted with an ion-conducting metallic oxide membrane which permeates oxygen ions. The sulfur dioxide partial pressure in the oxygen-depleted non-permeate gas from the membrane module is maintained below a critical sulfur dioxide partial pressure, P_{SO2*}, to protect the membrane material from reacting with sulfur dioxide and reducing the oxygen flux of the membrane. Each ion-conducting metallic oxide material has a characteristic critical sulfur dioxide partial pressure which is useful in determining the required level of sulfur removal from the feed gas or from the fuel gas used in a direct-fired feed gas heater.	Still being used in ongoing research.
6,582,666	06/24/03	University of Central Florida	Apparatus for high flux photocatalytic pollution control using a rotating fluidized bed reactor	An apparatus based on optimizing photoprocess energetics by decoupling of the process energy efficiency from the destruction and removal efficiency (DRE) for target contaminants. The technique is applicable to both low- and high-flux photoreactor design and scale-up. An apparatus for high-flux photocatalytic pollution control is based on the implementation of multifunctional metal oxide aerogels and other media with a novel rotating fluidized particle bed reactor.	Research complete; seeking to license.
6,572,829	06/03/03	University Central Florida	Closed cycle photocatalytic process for decomposition of hydrogen sulfide to its constituent elements	System for separating hydrogen and sulfur from hydrogen sulfide (H_2S) gas produced from oil and gas waste streams.	Not licensed and no research being done at University of Central Florida.
6,551,561	04/22/03	University Central Florida	Apparatus for decoupled thermo-photocatalytic pollution control	A new method for design and scale-up of photo-catalytic and thermocatalytic processes.	Not licensed and no research being done at University of Central Florida.
6,531,035	03/11/03	University Central Florida	Apparatus and method for low flux photocatalytic pollution control	A new method for design and scale-up of photocatalytic and thermocatalytic processes.	Not licensed and no research being done at University of Central Florida.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,524,550	02/25/03	Nuvera Fuel Cells, Inc.	Process for converting carbon monoxide and water in a reformate stream	A process for converting carbon monoxide and water in a reformate stream into carbon dioxide and hydrogen.	No longer being pursued.
6,492,290	12/10/02	Air Products & Chemicals, Inc.	Mixed conducting membranes for syngas production	A new class of multicomponent metallic oxides that are suited in fabricating components used in processes for producing syngas.	No longer being pursued.
6,478,077	11/12/02	Sandia National Laboratory	Self-supporting heat transfer element	An improved internal heat exchange element arranged to traverse the inside diameter of a container vessel to make good mechanical contact with the interior wall of the vessel.	Not licensed and no research being done at SNL.
6,468,499	10/22/02	Argonne National Laboratory	Method of generating hydrogen by catalytic decomposition of water	A method for producing hydrogen includes providing a feed stream comprising water; contacting at least one proton conducting membrane adapted to interact with the feed stream; splitting the water into hydrogen and oxygen at a predetermined temperature; and separating the hydrogen from the oxygen.	No longer being pursued.
6,468,480	10/22/02	Nuvera Fuel Cells, Inc.	Apparatus for converting hydrocarbon fuel into hydrogen gas and carbon dioxide	Hydrocarbon fuel reformer suitable for producing synthesis hydrogen gas from reactions with hydrocarbon fuels, oxygen, and steam.	No longer being pursued.
6,448,068	09/10/02	National Renewable Energy Laboratory	System for rapid biohydrogen phenotypic screening of microorganisms using a chemochromic sensor	A system for identifying a hydrogen gas producing organism.	Research complete; seeking to license.
6,401,767	06/11/02	Air Products & Chemicals, Inc.	Apparatus and method for grounding compressed fuel fueling operator	A safety system for grounding an operator at a fueling station before removing a fuel fill nozzle from a fuel tank upon completion of a fuel filling operation. The system includes a fuel tank port in communication with the fuel tank for receiving and retaining the nozzle during the fuel filling operation and a grounding device with a switch next to the fuel tank port. A contact member receives physical contact by the operator to activate the grounding switch.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,395,252	05/28/02	Oak Ridge National Laboratory	Method for the continuous production of hydrogen	A method for the continuous production of hydrogen.	Not licensed and no research being done at ORNL.
6,391,484	05/21/02	General Motors Corporation	Fuel processor temperature monitoring and control	A method and system for maintaining temperature control in a fuel processor (reformer) used to produce hydrogen for a fuel cell.	Being used in continuing research at the company.
6,342,128	01/29/02	University of Central Florida	Apparatus and Method for Decoupled Thermo-Photocatalytic Pollution Control	Method for design and scale-up of photocatalytic and thermocatalytic processes based on optimizing photoprocess energetics by decoupling of the process energy efficiency from the destruction and removal efficiency (DRE) for target contaminants.	Not licensed and no research being done at University of Central Florida.
6,334,936	01/01/02	University of Central Florida	Apparatus for decoupled thermo-photocatalytic pollution control	Method for design and scale-up of thermocatalytic processes based on optimizing process energetics by decoupling of the process energetics from the destruction and removal efficiency (DRE) for target contaminants.	Not licensed and no research being done at University of Central Florida.
6,328,945	12/11/01	Air Products & Chemicals, Inc.	Integrated steam methane reforming process for producing carbon monoxide	A process for producing carbon monoxide (CO) by reforming methane and steam in the presence of a reforming catalyst to produce a reformate product enriched in CO, carbon dioxide (CO_2) and hydrogen. CO_2 in the enriched reformate is shifted to CO in an integrated sorption enhanced reaction (SER) cycle which employs a series of cyclic steps to facilitate reaction of CO_2 and hydrogen at high conversion and to produce a CO-enriched product obtained at reactor feed pressure and at constant flow rate. A series of adsorbent regeneration steps including depressurization, purging and product pressurization are used to desorb water which is selectively adsorbed by the adsorbent during the shift reaction and to prepare the reactor for a subsequent process cycle.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,315,973	11/13/01	Air Products & Chemicals, Inc.	Process for operating equilibrium controlled reactions	A cyclic process for operating an equilibrium-controlled reaction in a plurality of reactors containing an admixture of an adsorbent and a reaction catalyst suitable for performing the desired reaction. The process is operated in a predetermined timed sequence wherein the heating and cooling requirements in a moving reaction mass transfer zone within each reactor are provided by indirect heat exchange with a fluid capable of phase change at temperatures maintained in each reactor during sorpreaction, depressurization, purging and pressurization steps during each process cycle.	Still being used in ongoing research.
6,315,870	11/13/01	University of Central Florida	Method for High Flux Photocatalytic Pollution Control	A new method for design and scale-up of photocatalytic and thermocatalytic processes is disclosed. The method is based on optimizing photoprocess energetics by decoupling of the process energy efficiency from the destruction and removal efficiency (DRE) for target contaminants.	Not licensed and no research being done at University of Central Florida.
6,312,658	11/06/01	Air Products & Chemicals, Inc.	Integrated steam methane reforming process for producing carbon monoxide and hydrogen	The present invention is a process for producing a pure carbon monoxide (CO) product and a pure hydrogen product by reforming a hydrocarbon such as methane and steam in the presence of a reforming catalyst to produce a reformate product enriched in CO, carbon dioxide and hydrogen. The reformate is subjected to an integrated series of separation steps and carbon dioxide present in a portion of the waste effluent recovered from such series of separation steps is shifted to CO in an integrated sorption enhanced reaction (SER) process.	Still being used in ongoing research.
6,309,611	10/30/01	University of Central Florida	Apparatus for Low Flux Photocatalytic Pollution Control	A new apparatus for design and scale-up of photocatalytic and thermocatalytic processes is disclosed. The apparatus is based on optimizing photoprocess energetics by decoupling of the process energy efficiency from the destruction and removal efficiency (DRE) for target contaminants and is applicable to both low- and high-flux photoreactor design and scale-up.	Not licensed and no research being done at University of Central Florida.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,303,098	10/16/01	Argonne National Laboratory	Steam reforming catalyst	A method of forming a hydrogen rich gas from a source of hydrocarbon fuel.	No longer being used in research.
6,303,092	10/16/01	Air Products & Chemicals, Inc.	Process for operating equilibrium controlled reactions	The present invention is a process for operating equilibrium-controlled reactions in continuous mode wherein a feedstock is reacted in a plurality of reactors containing an admixture of a desired process catalyst and an adsorbent to form a product which is selectively adsorbed by the adsorbent and an admixture containing a product which is withdrawn from the reactor. A series of separation steps is used to desorb the product which is selectively adsorbed by the adsorbent and to prepare the reactor for a subsequent process cycle. The process utilizes a novel series of adsorption and desorption steps to collect the less selectively adsorbed product in substantially pure form under relatively constant flow rate at feedstock pressure.	Still being used in ongoing research.
6,302,402	10/16/01	Air Products & Chemicals, Inc.	Compliant high temperature seals for dissimilar materials	A high temperature, gas-tight seal is formed by utilizing one or more compliant metallic toroidal ring sealing elements, where the applied pressure serves to activate the seal, thus improving the quality of the seal. The compliant nature of the sealing element compensates for differences in thermal expansion between the materials to be sealed, and is useful in sealing a metallic member and a ceramic tube at elevated temperatures.	No longer being pursued.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,280,503	08/28/01	Air Products & Chemicals, Inc.	Carbon dioxide adsorbents containing magnesium oxide suitable for use at high temperatures	Adsorption of carbon dioxide from gas streams at temperatures in the range 300–500 ºC is carried out with a solid adsorbent containing magnesium oxide, preferably promoted with an alkali metal carbonate or bicarbonate so that the atomic ratio of alkali metal to magnesium is in the range of 0.006 – 2.60. Preferred adsorbents are made from the precipitate formed on addition of alkali metal and carbonate ions to an aqueous solution of a magnesium salt. Atomic ratios of alkali metal to magnesium can be adjusted by washing the precipitate with water. Low surface area adsorbents are made by dehydration and CO_2 removal of magnesium hydroxycarbonate, with or without alkali metal promotion. The process is especially valuable in pressure swing adsorption operations.	Still being used in ongoing research.
6,277,589	08/21/01	National Renewable Energy Laboratory	Method and apparatus for rapid biohydrogen phenotypic screening of microorganisms using a chemochromic sensor	An assay system for identifying a hydrogen-gas-producing organism, including a sensor film having a first layer comprising a transition metal oxide or oxysalt and a second layer comprising hydrogen-dissociative catalyst metal.	Research complete; seeking to license.
6,254,839	07/03/01	Arthur D. Little, Inc.	Apparatus for converting hydrocarbon fuel into hydrogen gas and carbon dioxide	A hydrocarbon fuel reformer suitable for producing synthesis hydrogen gas from reactions with hydrocarbons fuels, oxygen, and steam.	No longer being used by Nuvera in research.
6,248,218	06/19/01	University of Central Florida	Closed cycle photocatalytic process for decomposition of hydrogen sulfide to its constituent elements	A method and system for separating hydrogen and sulfur from hydrogen sulfide gas being produced from oil and gas waste streams. The hydrogen sulfide gas is first scrubbed and filtered into a polysulfide solution. Elemental sulfur is freed when the hydrogen sulfide interacts with the solution, the sulfur is filtered through a porous media such as a ceramic frit, and continues to a stripper unit where the excess H_2S is removed from the sulfide solution. The excess H_2S returns to the scrubber and filtration unit, while the sulfide solution passes into a photoreactor containing a semiconductor photocatalyst.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,244,367	06/12/01	Argonne National Laboratory	Methanol partial oxidation reformer	A partial oxidation reformer comprising a longitudinally extending chamber having methanol, water, and an air inlet and outlet.	No longer being used in research.
6,238,815	05/29/01	General Motors Corporation	Thermally integrated staged methanol reformer and method	A thermally integrated two-stage methanol reformer including a heat exchanger and first and second reactors colocated in a common housing in which a gaseous heat transfer medium circulates to carry heat from the heat exchanger into the reactors.	No longer being pursued, abandoned.
6,214,066	04/10/01	Air Products & Chemicals, Inc.	Synthesis gas production by ion transport membranes	Synthesis gas is produced from a methane-containing reactant gas in a mixed conducting membrane reactor in which the reactor is operated to maintain the product gas outlet temperature above the reactant gas feed temperature wherein the total gas pressure on the oxidant side of the membrane is less than the total gas pressure on the reactant side of the membrane. Preferably, the reactant gas feed temperature is below a maximum threshold temperature of about 1400 ºF (760 ºC), and typically is between about 950 ºF (510 ºC) and about 1400 ºF (760 ºC). The maximum temperature on the reactant side of the membrane reactor is greater than about 1500 ºF (815 ºC).	Still being used in ongoing research.
6,207,122	03/27/01	Arthur D. Little, Inc.	Method for converting hydrocarbon fuel into hydrogen gas and carbon dioxide	A hydrocarbon fuel reforming method suitable for producing synthesis hydrogen gas from reactions with hydrocarbons fuels, oxygen, and steam.	No longer being used by Nuvera in research.
6,162,558	12/19/00	General Motors Corporation	Method and apparatus for selective removal of carbon monoxide	A method and apparatus for reducing the carbon monoxide content of a hydrogen-rich gas.	Being used in continuing research at the company.
6,132,689	10/17/00	General Motors Corporation	Multi-stage, isothermal CO preferential oxidation reactor	A multi-stage, isothermal, carbon monoxide preferential oxidation (PrO_x) reactor comprising a plurality of serially arranged, catalyzed heat exchangers, each separated from the next by a mixing chamber for homogenizing the gases exiting one heat exchanger and entering the next.	Being used in continuing research at the company.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,126,908	10/03/00	Arthur D. Little, Inc.	Method and apparatus for converting hydrocarbon fuel into hydrogen gas and carbon dioxide	An apparatus and a method for converting hydrocarbon fuel or an alcohol into hydrogen gas and carbon dioxide.	No longer being used by Nuvera in research.
6,123,913	09/26/00	Arthur D. Little, Inc.	Method for converting hydrocarbon fuel into hydrogen gas and carbon dioxide	A method for synthesizing hydrogen gas from hydrocarbon fuel. A first mixture of steam and a first fuel is directed into a first tube to subject the first mixture to a first steam reforming reaction in the presence of a first catalyst.	No longer being used by Nuvera in research.
6,114,400	09/05/00	Air Products & Chemicals, Inc.	Synthesis gas production by mixed conducting membranes with integrated conversion into liquid products	Natural gas or other methane-containing feed gas is converted to a C5-C19 hydrocarbon liquid in an integrated system comprising an oxygenative synthesis gas generator, a non-oxygenative synthesis gas generator, and a hydrocarbon synthesis process such as the Fischer-Tropsch process. The oxygenative synthesis gas generator is a mixed conducting membrane reactor system.	No longer being pursued.
6,110,979	08/29/00	Air Products & Chemicals, Inc.	Utilization of synthesis gas produced by mixed conducting membranes	Hydrocarbon feedstocks are converted into synthesis gas in a two-stage process comprising an initial steam reforming step followed by final conversion to synthesis gas in a mixed conducting membrane reactor.	Still being used in ongoing research.
6,110,861	08/29/00	Argonne National Laboratory	Partial oxidation catalyst	A two-part catalyst comprising a dehydrogenation portion and an oxide-ion conducting portion.	Research complete; seeking to license.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,103,143	08/15/00	Air Products & Chemicals, Inc.	Process and apparatus for the production of hydrogen by steam reforming of hydrocarbon	In the steam reforming of hydrocarbon into methane under elevated temperature and pressure to produce hydrogen, a feed of steam and hydrocarbon is fed into a first reaction volume containing only reforming catalyst to partially reform the feed. The balance of the feed and the reaction products of carbon dioxide and hydrogen are then fed into a second reaction volume containing a mixture of catalyst and adsorbent which removes the carbon dioxide from the reaction zone as it is formed. The process is conducted in a cycle which includes these reactions followed by countercurrent depressurization and purge of the adsorbent to regenerate it and repressurization of the reaction volumes preparatory to repeating the reaction-sorption phase of the cycle.	Still being used in ongoing research.
6,083,425	07/04/00	Arthur D. Little, Inc.	Method for converting hydrocarbon fuel into hydrogen gas and carbon dioxide	A method for converting hydrocarbon fuel into hydrogen gas and carbon dioxide within a reformer.	No longer being used by Nuvera in research.
6,077,323	06/20/00	Air Products & Chemicals, Inc.	Synthesis gas production by ion transport membranes	Synthesis gas is produced from a methane-containing reactant gas in a mixed conducting membrane reactor in which the reactor is operated to maintain the product gas outlet temperature above the reactant gas feed temperature wherein the total gas pressure on the oxidant side of the membrane is less than the total gas pressure on the reactant side of the membrane.	Still being used in ongoing research.
6,056,807	05/02/00	Air Products & Chemicals, Inc.	Fluid separation devices capable of operating under high carbon dioxide partial pressures which utilize creep-resistant solid-state membranes formed from a mixed conducting multicomponent metallic oxide	The present invention presents a fluid separation device capable of separating oxygen from an oxygen-containing gaseous mixture which utilizes at least one solid-state membrane comprising a dense mixed conducting multicomponent metallic oxide layer formed from a mixed conducting multicomponent metallic oxide represented by the formula wherein Ln is an element selected from the f block lanthanides. The subject mixed conducting multicomponent metallic oxides demonstrate improved resistance to degradation by carbon dioxide and sulfur dioxide and improved oxygen flux and reduced creep rates at operating temperature.	Still being used in ongoing research.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,051,125	04/18/00	Lawrence Livermore National Laboratory	Natural gas-assisted steam electrolyzer	A method of producing hydrogen by high temperature steam electrolysis that will lower the electricity consumption to an estimated 65 percent lower than has been achievable with previous steam electrolyzer systems.	One commercial license was issued but is terminated.
6,048,472	04/11/00	Air Products & Chemicals, Inc.	Production of synthesis gas by mixed conducting membranes	Hydrocarbon feedstocks are converted into synthesis gas in a two-stage process comprising an initial steam reforming step followed by final conversion to synthesis gas in a mixed conducting membrane reactor. The steam reforming step converts a portion of the methane into synthesis gas and converts all of the hydrocarbons heavier than methane into methane, hydrogen, and carbon oxides. The steam reforming and mixed conducting membrane reactors can be heat-integrated for maximum operating efficiency and produce synthesis gas with compositions suitable for a variety of final products.	Still being used in ongoing research.
5,942,346	08/24/99	Argonne National Laboratory	Methanol partial oxidation reformer	A partial oxidation reformer comprising a longitudinally extending chamber having a methanol, water, and an air inlet and an outlet.	No longer being used in research.
5,939,025	08/17/99	Argonne National Laboratory	Methanol partial oxidation reformer	A partial oxidation reformer comprising a longitudinally extending chamber having a methanol, water and an air inlet and an outlet.	No longer being used in research.
5,929,286	07/27/99	Argonne National Laboratory	Method for making hydrogen rich gas from hydrocarbon fuel	A method of forming a hydrogen rich gas from a source of hydrocarbon fuel in which the hydrocarbon fuel contacts a two-part catalyst comprising a dehydrogenation portion and an oxide-ion conducting portion.	Research complete; seeking to license.
5,917,136	06/29/99	Air Products & Chemicals, Inc.	Carbon dioxide pressure swing adsorption process using modified alumina adsorbents	A pressure swing adsorption process for absorbing CO_2 from a gaseous mixture containing CO_2 comprising introducing the gaseous mixture at a first pressure into a reactor containing a modified alumina adsorbent.	Still being used in ongoing research.
5,895,518	04/20/99	Sandia National Laboratory	Synthesis of alloys with controlled phase structure	A method for preparing controlled phase alloys useful for engineering and hydrogen storage applications.	Not licensed and no research being done at SNL.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
5,886,614	03/23/99	General Motors Corporation	Thin film hydrogen sensor	A thin film hydrogen sensor consisting of a flat ceramic substrate, a thin film temperature-responsive resistor, and a thin film hydrogen-responsive metal resistor.	Being used in continuing research at the company.
5,871,952	02/16/99	National Renewable Energy Laboratory	Process for selection of oxygen-tolerant algal mutants that produce H_2 under aerobic conditions	A process for selecting oxygen-tolerant algal mutants that produce hydrogen under aerobic conditions, based on the toxic effect of metronidazole on photosynthetic organisms.	Being used in continuing research and seeking to license.
5,821,111	10/13/98	Bioengineering Resources, Inc.	Bioconversion of waste biomass to useful products	A process for converting waste biomass to useful products by gasifying the biomass to produce synthesis gas and converting the synthesis gas substrate to one or more useful products.	No longer being pursued for hydrogen production.
5,681,373	10/28/97	Air Products & Chemicals, Inc.	Planar solid-state membrane module	Planar solid-state membrane modules for separating oxygen from an oxygen-containing gaseous mixture which provide improved pneumatic and structural integrity and ease of manifolding.	Still being used in ongoing research.
5,637,415	06/10/97	General Motors Corporation	Controlled CO preferential oxidation	A method for controlling the supply of air to a preferential oxidation reactor in which the CO content of a hydrogen-rich gas stream is reduced.	Being used in continuing research at the company.
5,541,486	05/07/96	Los Alamos National Laboratory	Annular feed air breathing fuel cell stack	A stack of polymer electrolyte fuel cells is formed from a plurality of unit cells where each unit cell includes fuel cell components stacked along a common axis. Each fuel cell component has a polymer electrolyte membrane, anode, cathode and provision for fuel and oxygen flow fields. A fuel distribution manifold is connected to deliver fuel to the fuel flow field in each of the unit cells.	Not licensed and not being used for research at LANL.
5,451,920	09/19/95	Oak Ridge National Laboratory	Thick film hydrogen sensor	A thick film hydrogen sensor element includes an inert, electrically insulating substrate having deposited thereon a thick film metallization forming at least two resistors. The metallization is a sintered composition of Pd and a sinterable binder such as glass frit. An inert, electrically insulating, hydrogen impermeable passivation layer covers at least one of the resistors.	Licensed to DCH Technology, Inc.

Production/Delivery Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
5,367,283	11/22/94	Oak Ridge National Laboratory	Thin film hydrogen sensor	A hydrogen sensor comprised of an inert, electrically insulating substrate having a thin-film metallization layer deposited to form at least two resistors on the substrate. The metallization comprises a layer of Pd or a Pd alloy for sensing hydrogen and an underlying intermediate metal layer for providing enhanced adhesion of the metallization to the substrate. An inert, electrically insulating, hydrogen impermeable passivation layer covers at least one of the resistors, and at least one of the resistors is left uncovered. The difference in electrical resistances between the covered and uncovered resistors determines the hydrogen concentration in the gas the sensor is exposed to.	No longer being used.
5,271,916	12/21/93	General Motors Corporation	Device for staged carbon monoxide oxidation	A method and apparatus for selectively oxidizing carbon monoxide in a hydrogen-rich feed stream.	Being used in continuing research at the company.
4,473,622	09/25/84	United Technologies Corporation	Rapid starting methanol reactor system	A methanol-to-hydrogen cracking reactor for use with a fuel cell vehicular power plant.	Patent has expired and is not being used at UTC.
4,358,429	11/09/82	Argonne National Laboratory	Oxygen stabilized zirconium vanadium intermetallic compound	A new oxygen stabilized intermetallic compound that can repeatedly sorb hydrogen from a mixture of gases.	No licensee and no further development of this technology at ANL.
4,142,300	03/06/79	Argonne National Laboratory	Lanthanum nickel aluminum alloy	A ternary intermetallic compound capable of reversible sorption of hydrogen having the chemical formula $LaNi_5$-xAl_x, where x is in the range 0.01–1.5 and the method of storing hydrogen using the intermetallic compound.	No licensee and no further development of this technology at ANL.

A.3 Storage Patents Status

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,840,412	12/12/17	Savannah River National Laboratory	High capacity hydrogen storage nanocomposite materials	A novel hydrogen absorption material is provided comprising a mixture of a lithium hydride with a fullerene. The subsequent reaction product provides for a hydrogen storage material which reversibly stores and releases hydrogen at temperatures of about 270°C.	Still being used in ongoing research.
9,683,704	06/20/17	Savannah River National Laboratory	Heating and cooling system for an on-board gas adsorbent storage vessel	A system for controlling the temperature within a gas adsorbent storage vessel including an air conditioning system which forms a continuous flow loop of heat exchange fluid cycled between a heated flow and a cooled flow. The system may also include at least one fluid by-pass line extending at least partially within the gas adsorbent storage vessel.	Still being used in ongoing research.
9,677,713	06/13/17	Lawrence Livermore National Laboratory	Compact insert design for cryogenic pressure vessels	A pressure vessel apparatus for cryogenic capable storage of hydrogen or other cryogenic gases at high pressure which includes an insert with a parallel inlet duct and a perpendicular inlet duct connected to the parallel inlet. The perpendicular inlet duct and the parallel inlet duct connect the interior cavity with the external components. The insert also includes a parallel outlet duct and a perpendicular outlet duct connected to the parallel outlet duct. The perpendicular outlet duct and the parallel outlet duct connect the interior cavity with the external components.	Still being used in ongoing research.
9,604,847	03/28/17	Delaware State University	Rubidium hydride catalyzed alloys	A catalyzed metal hydride alloy is disclosed, which includes lithium amide and magnesium hydride and rubidium hydride as the catalyst. A method of making the metal hydride alloy includes combining rubidium hydride with lithium amide and magnesium hydride in a vessel to form a mixture and mechanically milling the mixture. A method of manufacturing rubidium hydride is also disclosed which includes milling rubidium metal in a vessel pressurized with hydrogen gas at an initial minimum rotation rate and increasing the rotation rate to a maximum rotation rate, alternating between periods of milling and rest, re-pressurizing the vessel with hydrogen during the rest periods, and incubating the contents of the vessel.	Still being used in ongoing research.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,562,646	02/07/17	Oak Ridge National Laboratory	Hydrogen storage container	An apparatus and system is described for storing high-pressure fluids such as hydrogen. An inner tank and pre-stressed concrete pressure vessel share the structural or pressure load on the inner tank. The system and apparatus provide a high-performance and low-cost container while mitigating hydrogen embrittlement of the metal tank. System is useful for distributing hydrogen to a power grid or to a vehicle refueling station.	Research complete; seeking to license.
9,440,850	09/13/16	Southwest Research Institute	Carbon material for hydrogen storage	The present invention relates to carbon-based materials that are employed for hydrogen storage applications. The material may be described as the pyrolysis product of a molecular precursor such as a cyclic quinone compound. The pyrolysis product may then be combined with selected transition metal atoms which may be in nanoparticulate form, where the metals may be dispersed on the material surface. Such product may then provide for the reversible storage of hydrogen. The metallic nanoparticles may also be combined with a second metal as an alloy to improve hydrogen storage performance.	Research complete; seeking to license.
9,365,685	06/14/16	Oak Ridge National Laboratory	Method of improving adhesion of carbon fibers with a polymeric matrix	A functionalized carbon fiber having covalently bound on its surface a partially cured epoxy or amine-containing sizing agent. Composites comprised of these functionalized carbon fibers embedded in a polymeric matrix are also described and used for producing the functionalized carbon fibers and composites.	Still being used in ongoing research.
9,340,677	05/17/16	Oak Ridge National Laboratory	Apparatus and process for the surface treatment of carbon fibers	A method for surface treating a carbon-containing material in which carbon-containing material is reacted with decomposing ozone in a reactor (e.g., a hollow tube reactor), wherein a concentration of ozone is maintained throughout the reactor by appropriate selection of processing temperature, gas stream flow rate, reactor dimensions, ozone concentration entering the reactor to produce a surface-oxidized carbon or carbon-containing material. The resulting surface-oxidized carbon material and solid composites made therefrom are also described.	Still being used in ongoing research.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,321,638	04/26/16	Savannah River National Laboratory	Use of triphenyl phosphate as risk mitigant for metal amide hydrogen storage materials	A process in which a hydrogen storage metal amide modified by ball milling and adding triphenyl phosphate (TPP). The resulting product provides for a hydrogen storage metal amide having a coating that renders the hydrogen storage metal amide resistant to air, ambient moisture, and liquid water while improving useful hydrogen storage and release kinetics.	Still being used in ongoing research; seeking to license.
9,266,642	02/23/16	Wiretough Cylinders, LLC	Steel wrapped pressure vessel	A lightweight pressure vessel has been proposed. The vessel is made of a steel, aluminum or non-metal liner which is reinforced with high strength steel wires of 2000–7000 MPa strength. The matrix is filled with a polymer epoxy resin. A top layer of fabric tape soaked in resin has been used to embed the finish end of the wire and to provide a protective layer over the wire reinforced area. The mesh or net fabric wrap tape has periodic openings to allow penetration of polymer epoxy resin. A top coat of a UV resistant polyurethane paint is applied.	Still being used in ongoing research.
9,234,626	01/12/16	Pacific Northwest National Laboratory	Conformable pressure vessel for high pressure gas storage	A non-cylindrical pressure vessel storage tank and internal structure are described. The internal structure is coupled to at least one wall of the storage tank which internally supports the storage tank. The pressure vessel storage tank has a conformability of about 0.8 to about 1.0. The internal structure can be, but is not limited to, a Schwarz-P structure, an egg-crate shaped structure, or carbon fiber ligament structure.	Still being used in ongoing research.
9,057,483	06/16/15	Lawrence Livermore National Laboratory	Threaded insert for compact cryogenic-capable pressure vessels	An insert for a cryogenic capable pressure vessel for storage of hydrogen or other cryogenic gases at high pressure. The insert provides the interface between a tank and internal and external components of the tank system. The insert can be used with tanks with any or all combinations of cryogenic, high pressure, and highly diffusive fluids. The insert can be threaded into the neck of a tank with an inner liner. The threads withstand the stress when the fluid inside the tank is under pressure.	Still being used in ongoing research.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
9,006,137	04/14/15	Ford Motor Company	Adsorbent material with anisotropic layering	A compressed gaseous fuel storage pellet is provided comprising a gas adsorbent material and a thermally conductive material extending substantially an entire dimension of the pellet and having a thermal conductivity of at least 75 W/mK. The pellet may include at least two layers of gas adsorbent material spaced apart along a compression direction of the pellet and a continuous layer of the thermally conductive material disposed between at least two layers of gas adsorbent material. The pellet may further include thermally conductive projections which intersect the layers of thermally conductive material.	Being used in ongoing research.
8,945,500	02/03/15	Savannah River National Laboratory	High capacity hydrogen storage nanocomposite materials	A novel hydrogen absorption material is provided comprising a mixture of a lithium hydride with a fullerene. The subsequent reaction product provides for a hydrogen storage material which reversibly stores and releases hydrogen at temperatures of about 270 °C.	Still being used in ongoing research.
8,921,554	12/30/14	University of Oregon	Substituted 1,2-azaborine heterocycles	Aromatic heterocycles incorporating boron and nitrogen atoms, in particular, 1,2-azaborine compounds and their use as synthetic intermediates.	Still being used in ongoing research.
8,889,097	11/18/14	Pacific Northwest National Laboratory	Combined on-board hydride slurry storage and reactor system and process for hydrogen-powered vehicles and devices	An integrated storage and reactor system and process for storing and reacting variable concentration slurries containing hydride storage materials that release hydrogen on-board vehicles and devices.	Being used in continuing research at PNNL and seeking to license.
8,883,109	11/11/14	Savannah River National Laboratory	High capacity stabilized complex hydrides for hydrogen storage	Complex hydrides based on $Al(BH_4)_3$ are stabilized by the presence of one or more additional metal elements or organic adducts to provide high-capacity hydrogen storage material.	Still being used in ongoing research.
8,758,715	06/24/14	Savannah River National Laboratory	Porous wall hollow glass microspheres as a medium or substrate for storage and formation of novel materials	A porous wall hollow glass microsphere in which the pore walls and interior walls of the microsphere provide at least one of a patterned surface, an improved substrate, or a nucleating site for the formation of a nanomaterial which may include a hydrogen storage material.	Research complete; seeking to license.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,517,206	08/27/13	Quantum Fuel Systems Technologies Worldwide, Inc.	High pressure storage vessel	Composite pressure vessel with a liner, polar boss and a blind boss. A shell is formed around the liner via one or more filament wrappings continuously disposed around the liner assembly.	Still being used in ongoing research. Part of commercial storage technology.
8,470,156	08/07/12	Savannah River National Laboratory	Electrochemical process and production of novel complex hydrides	A process for producing aluminum hydride, which can be used as a source of hydrogen for vehicles or fuel cell devices.	Still being used in ongoing research.
8,440,100	05/14/13	University of South Florida	Method of generating hydrogen-storing hydride complexes	A method for preparing complex hydride materials composed of lightweight elements or compounds for hydrogen storage applications.	Research complete; seeking to license.
8,426,337	12/11/12	University of Michigan	Metal salt catalysts for enhancing hydrogen spillover	A composition for hydrogen storage including receptor with hydrogen dissociating metal and metal salt doping configured to spill over hydrogen to the receptor, and the metal salt is configured to increase the rate of the spillover of the hydrogen to the receptor.	Research complete; seeking to license.
8,410,185	04/02/13	Argonne National Laboratory	Porous polymeric materials for hydrogen storage	A hydrogen storage medium that consists of a porous polymer tribeenzohexazatriphenylene (TBHTP) and its derivatives as created through the polymer synthesis method. These polymers have a high specific area, narrow micropore distribution, and are thermally stable up to 250 °C.	Still being used in ongoing research.
8,377,555	02/19/13	Savannah River National Laboratory	Gas storage materials, including hydrogen storage materials	A material for the storage and release of gases that comprises a plurality of hollow elements, each hollow element comprising a porous wall enclosing an interior cavity, the interior cavity including structures of a solid-state storage material.	Research complete; seeking to license.
8,377,416	02/19/13	Purdue University	Method for releasing hydrogen from ammonia borane.	A method of releasing hydrogen from ammonia borane that consists of heating a pressurized aqueous ammonia borane solution to release hydrogen by hydrothermolysis.	Research complete; seeking to license.
8,377,415	02/19/13	Savannah River National Laboratory	Methods for synthesizing alane without the formation of adducts and free of halides	Processes and methods for synthesizing aluminum hydride and other hydrogen storage materials to be used in the development of on-board hydrogen-fueled vehicles.	Still being used in ongoing research.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,372,369	02/12/13	University of Michigan	Enhancing hydrogen spillover and storage	Methods for enhancing hydrogen spillover and storage are disclosed. One embodiment of the method includes doping a hydrogen receptor with metal particles, and exposing the hydrogen receptor to ultrasonication during doping. Another embodiment includes doping a hydrogen receptor with metal particles, and exposing the doped hydrogen receptor to a plasma treatment.	Research complete; seeking to license.
8,338,330	12/25/12	University of Michigan	Chemical bridges for enhancing hydrogen storage by spillover and methods for forming the same	A composition for hydrogen storage includes a source of hydrogen atoms, a receptor, and a chemical bridge formed between the source and the receptor. The chemical bridge is formed from a precursor material. The receptor is adapted to receive hydrogen spillover from the source.	Research complete; seeking to license.
8,329,140	12/11/12	Los Alamos National Laboratory	Method and system for hydrogen evolution and storage	A method and system for storing and evolving hydrogen that uses chemical compounds that can be hydrogenated to store hydrogen and dehydrogenated to evolve hydrogen. A catalyst lowers the energy required for storing and evolving hydrogen.	Still being used in ongoing research.
8,268,288	09/18/12	Brookhaven National Laboratory	Regeneration of aluminum hydride	Methods and materials for the formation of hydrogen storage alanes, AlH_x, where $0< x \leq 6$ at reduced H_2 pressures and temperatures.	No longer being pursued.
8,236,196	08/07/12	Savannah River National Laboratory	Systems and methods for facilitating hydrogen storage using naturally occurring nanostructure assemblies	Recyclable canisters containing microorganisms called diatoms, which contain naturally occurring nanostructure assemblies. These nanostructure assemblies can be used to store hydrogen until it is ultimately used as a fuel for vehicles or other applications.	Exclusive License to Microbes Unlimited LLC
8,193,113	06/05/12	General Electric Company	Hydrogen storage material and related processes	A metal hydride comprising of a complex hydride and a borohydride catalyst that can be used for hydrogen storage. The borohydride catalyst comprises a BH_4 group, and a group IV metal, a group V metal, or a combination of a group IV and a group V metal.	Research complete; seeking to license.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,153,554	04/10/12	University of South Carolina	Reversible hydrogen storage materials	Process for synthesis of a complex hydride material for hydrogen storage and includes mixing a borohydride with at least one additive agent and at least one catalyst and heating the mixture at a temperature <600ºC. The hydride material comprises of an alkali metal or group IIA metal, aluminum and boron. The material can undergo cyclic dehydrogenation and rehydrogenation and has a hydrogen capacity of at least 4 weight percent.	Research complete; seeking to license.
8,153,020	04/10/12	University of South Florida	Hydrogen-storing hydride complexes	Hydrogen storage material comprising of a complex hydride using light-weight elements or compounds.	Research complete; seeking to license.
8,147,796	04/03/12	University of Utah	Hydrogen storage in a combined $M_xAlH_6/M'_y(NH_2)_z$ system and methods of making and using the same	Reversible hydrogen storage compositions, methods for reversibly storing hydrogen, and methods of making reversible hydrogen storage compositions.	Research complete; seeking to license.
8,147,788	04/03/12	Sandia National Laboratory	Direct synthesis of magnesium borohydride	Method of directly synthesizing an alkaline earth metal borohydride compound and a method to produce magnesium borohydride.	Still being used in ongoing research.
8,124,559	02/28/12	Savannah River National Laboratory	Destabilized and catalyzed borohydride for reversible hydrogen storage	A process for forming a hydrogen storage material from a first material (a metal containing borohydride) and a second material (a metal alanate). The resulting material has a lower hydrogen release temperature than the first material and a higher hydrogen gravimetric density than the second material.	Research complete; seeking to license.
8,119,198	02/21/12	University of Central Florida	Three-dimensional carbon fibers and method and apparatus for their production	This invention relates to three-dimensional (3D) carbon fibers which are original (or primary) carbon fibers (OCF) with secondary carbon filaments (SCF) grown thereon, and, if desired, tertiary carbon filaments (TCF) are grown from the surface of SCF forming a filamentous carbon network with high surface area. The methods and apparatus are provided.	Research complete; seeking to license.
8,105,974	01/31/12	Savannah River National Laboratory	Destabilized and catalyzed borohydride for reversible hydrogen storage	Hydrogen storage materials with improved thermodynamic properties.	No longer being pursued.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
8,101,786	01/24/12	Los Alamos National Laboratory	Energy efficient synthesis of boranes	Borane material for hydrogen storage, and an energy efficient synthesis of boranes (boron compounds having at least one B-H bond).	Still being used in ongoing research.
8,083,907	12/27/11	University of South Florida	Hydrogen storage nano-foil and method of manufacture	A hydrogen storage system using a coiled nano-foil hydride and methods for forming the hydrogen absorbing nano-foil coil without backing materials.	Research complete; seeking to license.
8,076,382	12/13/11	Argonne National Laboratory	Porous polymeric materials for hydrogen storage	Porous polymers that have a higher hydrogen storage capacity at ambient temperatures than benchmark materials.	Still being used in ongoing research.
8,003,073	08/23/11	Air Products & Chemicals, Inc.	Autothermal hydrogen storage and delivery systems	Process of releasing the stored hydrogen from hydrogen carrier compositions ("carrier") for use in a fuel cell or internal combustion engine. The methods and apparatus provide a thermally self-sustaining or autothermal catalytic dehydrogenation of a carrier to supply hydrogen wherein the necessary heat for this reaction is derived, at least in part, from an accompanying exothermic dehydrogenation of the carrier.	Research complete; seeking to license.
7,963,116	06/21/11	Pacific Northwest National Laboratory	Bulk-scaffolded hydrogen storage and releasing materials and methods for preparing and using same	Materials and processes for storing hydrogen using bulk-scaffolded materials, compounds, materials, and combinations that provide storage and release of bulk quantities of hydrogen at lower release temperatures and faster release rates for operation of hydrogen-fueled on-board and off-board devices and applications.	Still being used in ongoing research.
7,951,749	05/31/11	University of Michigan	Enhancing hydrogen spillover and storage	Methods for enhancing hydrogen spillover and storage. One method includes doping a hydrogen receptor with metal particles, and exposing the hydrogen receptor to ultrasonification as doping occurs while another method dopes a hydrogen receptor with metal particles, and exposes the doped hydrogen receptor to a plasma treatment.	Research complete; seeking to license.
7,927,507	04/19/11	HRL Laboratories, LLC	Hydrogen storage compositions	Materials for reversible hydrogen storage that employ an alloy exhibiting reversible formation and deformation of BH_4^- anions. The materials are prepared by combining a metal hydride with a ternary alloy consisting of magnesium, boron and another metal.	Being used in continuing research at the company.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,897,129	03/01/11	Pacific Northwest National Laboratory	Process for synthesis of ammonia borane for bulk hydrogen storage	The invention describes new methods for synthesizing ammonia borane, which shows promise as a chemical hydrogen storage material for fuel-cell-powered applications.	Being used in continuing research at PNNL and seeking to license.
7,846,410	12/07/10	Los Alamos National Laboratory	Regeneration of polyborazylene	The invention provides methods for regenerating ammonia borane, a hydrogen storage material, from polyborazylene.	Being used in continuing research at LANL.
7,837,852	11/23/10	Los Alamos National Laboratory	Energy efficient synthesis of boranes	An energy-efficient method for synthesizing boranes that are used for storing hydrogen. The boranes are prepared at close to ambient temperature without the need for thermal quenching and rapid separation, and without the energy cost of generating active metal hydrides.	Being used in continuing research at LANL.
7,816,004	10/19/10	University of Central Florida	Three-dimensional carbon fibers and method and apparatus for their production	A novel three-dimensional (3D) carbon fiber which is original (or primary) carbon fibers (OCF) with secondary carbon filaments (SCF) grown thereon, and, if desired, tertiary carbon filaments (TCF) are grown from the surface of SCF forming a filamentous carbon network with high surface area. The methods and apparatus are provided for growing SCF on the OCF by thermal decomposition of carbonaceous gases (CG) over the hot surface of the OCF without use of metal-based catalysts. The thickness and length of SCF can be controlled by varying operational conditions of the process. An optional activation step enables one to produce 3D activated carbon fibers with high surface area. The TCF growth on SCF is by thermal decomposition of carbonaceous gases over the hot surface of the SCF using metal catalyst particles.	Research complete; seeking to license.
7,790,133	09/07/10	Universal Oil Products, LLC (UOP, LLC)	Multi-component hydrogen storage material	A reversible hydrogen storage material that shows improved performance at low temperatures compared with binary systems such as MgH_2-$LiNH_2$.	Research complete; seeking to license.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,790,013	09/07/10	Safe Hydrogen, LLC	Storing and transporting energy	A method for safely storing and transporting energy in the form of hydrogen. Hydrogen is released from water by a process such as electrolysis. The released hydrogen is then stored and transported in a metal hydride slurry, which can be mixed with water to release the hydrogen at an end-use location.	No longer being used.
7,781,109	08/24/10	Sandia National Laboratory	Hydrogen storage and integrated fuel cell assembly	A system in which housings for hydrogen storage materials are located in close proximity to a fuel cell stack. Heat generated from operation of the fuel cell stack is used to help drive the endothermic dehydrogenation reactions for releasing hydrogen from the storage materials.	Being used in continuing research at SNL.
7,754,641	07/13/10	General Electric Company	Hydrogen storage material and related processes	A hydrogen storage material consisting of a complex hydride and a borohydride catalyst. The catalyst improves the hydrogenation and dehydrogenation kinetics of the complex hydride.	No longer being used.
7,736,531	06/15/10	Los Alamos National Laboratory	Composition and method for storing and releasing hydrogen	A chemical hydrogen storage system that couples an endothermic reaction (which releases hydrogen) to an exothermic reaction to achieve overall thermodynamic neutrality.	Being used in continuing research at LANL.
7,713,506	05/11/10	Los Alamos National Laboratory	Metal aminoboranes	Metal aminoboranes of the formula $M(NH_2BH_3)n$ have been synthesized. The aminoboranes can be dehydrogenated to form hydrogen and a reaction product. The reaction product can react with hydrogen to form a hydrogen storage material.	Being used in continuing research at LANL.
7,678,362	03/16/10	Universal Oil Products, LLC (UOP, LLC)	High density hydrogen storage material	A hydrogen storage material that is a combination of $LiBH_4$ with MH_x, wherein greater than about 50% of M comprises Al.	Being used in ongoing research.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,666,807	02/23/10	Savannah River National Laboratory	Hollow porous-wall glass microspheres for hydrogen storage	Coated hollow glass microspheres are used as part of a hydrogen storage system. The hollow glass microsphere wall defines a series of pores. The pores facilitate the placement of a hydrogen storage material within the interior of the hollow glass microsphere. The porosity of the hollow glass microspheres is modified by either altering or reducing the overall pore size or by coating the individual hollow glass microspheres. The hydrogen storage material is sealed within the interior of the hollow glass microspheres. The coating or the controlled pore size enables the selective absorption of hydrogen gas through the walls of the hollow glass microsphere while isolating the hydrogen storage material encapsulated therein from other external gases and fluids.	No longer being pursued.
7,645,902	01/12/10	Los Alamos National Laboratory	Acid-catalyzed dehydrogenation of amine-boranes	A method of dehydrogenating an amine-borane using an acid-catalyzed reaction. The method may be used to generate hydrogen for portable power sources such as fuel cells.	Being used in continuing research at LANL.
7,625,547	12/01/09	Ford Motor Company	High density hydrogen storage material	A hydrogen storage material that is a combination of $LiBH_4$ with MH_x, wherein greater than about 50% of M comprises Ti, V, Cr, Sc, Fe, or combinations thereof.	Being used in ongoing research.
7,608,233	10/27/09	Sandia National Laboratory	Direct synthesis of calcium borohydride	A method for directly preparing an alkaline earth metal borohydride, i.e. $Ca(BH_4)_2$, from the alkaline earth metal hydride and the alkaline earth metal boride. The calcium borohydride product can be used to reversibly store and release hydrogen.	Being used in continuing research at SNL.
7,544,837	06/09/09	Los Alamos National Laboratory	Base metal dehydrogenation of amine-boranes	A method of dehydrogenating an amine-borane using a base metal catalyst. The method may be used to generate hydrogen for portable power sources such as fuel cells.	Being used in continuing research at LANL.
7,521,037	04/21/09	Brookhaven National Laboratory	Regeneration of aluminum hydride	The invention provides methods and materials for the formation of hydrogen storage alanes, AlH_x, where x is greater than 0 and less than or equal to 6 at reduced H_2 pressures and temperatures.	No longer being pursued.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,402,234	07/22/08	Idaho National Laboratory	Polymeric hydrogen diffusion barrier, high-pressure storage tank so equipped, method of fabricating a storage tank and method of preventing hydrogen diffusion	An electrochemically active hydrogen diffusion barrier which comprises an anode layer, a cathode layer, and an intermediate electrolyte layer, which is conductive to protons and substantially impermeable to hydrogen.	No licenses issued and no internal research being done with this patent.
7,384,574	06/10/08	Savannah River National Laboratory	Hydrogen storage material and process using graphite additive with metal-doped complex hydrides	A hydrogen storage material having improved hydrogen absorption and desorption kinetics is provided by adding graphite to a complex hydride such as a metal-doped alanate. The incorporation of graphite into the complex hydride significantly enhances the rate of hydrogen absorption and desorption and lowers the desorption temperature needed to release stored hydrogen.	Research complete; seeking to license.
7,306,780	12/11/07	Sandia National Laboratory	Method of generating hydrogen gas from sodium borohydride	A compact solid source of hydrogen gas, where the gas is generated by contacting water with micro-disperse particles of sodium borohydride in the presence of a metal catalyst, thus generating hydrogen gas.	Licensed to Nanodetex but license was terminated.
7,303,736	12/04/07	Lawrence Livermore National Laboratory	Nanostructured materials for hydrogen storage	A system for hydrogen storage comprising a porous nanostructured material with hydrogen absorbed on the surfaces of the porous nanostructured material. The system of hydrogen storage comprises absorbing hydrogen on the surfaces of a porous nanostructured semiconductor material.	Research complete; seeking to license.
7,250,386	07/31/07	Energy Conversion Devices, Inc.	Quantum limit catalysts and hydrogen storage materials	A quantum limit catalyst comprised of atomic aggregations whose dimensions correspond to the quantum limit. The electronic interactions possible in the quantum limit results in modifications to the electron density at catalytic sites that improve the catalytic properties.	No licenses issued and no internal research being done with this patent.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
7,191,602	03/20/07	Lawrence Livermore National Laboratory	Storage of H_2 by absorption and/or mixture within a fluid medium	A hydrogen storage method, apparatus and system having a fluid mixture. At predetermined pressures or temperatures within a fixed volume, the fluid mixture can store a high density of hydrogen molecules, wherein a predetermined phase of the fluid mixture can be withdrawn from the substantially fixed volume for use as a vehicle fuel or energy storage having reduced or eliminated evaporative losses, especially where storage weight, vessel cost, vessel shape, safety, and energy efficiency are beneficial.	Part of an emerging hydrogen storage technology.
7,160,530	01/09/07	National Renewable Energy Laboratory	Metal-doped single-walled carbon nanotubes and production thereof	A method for the production of single-walled carbon nanotubes that can be used for reversibly storing hydrogen at ambient conditions with low energy input requirements.	Being used in research at NREL but there are no licensees.
7,094,387	08/22/06	Savannah River National Laboratory	Complex hydrides for hydrogen storage	Melting a mixture of sodium aluminum hydride mixed with titanium under a combination of heat and pressure to provide a fused hydrogen storage material.	Being used in research at SRNL but there are no licensees. Part of an emerging storage technology.
7,052,671	05/30/06	Safe Hydrogen, LLC	Storage, generation, and use of hydrogen	Operation of a hydrogen generator with a composition of a carrier liquid, a dispersant, and chemical hydride. A regenerator recovers elemental metal from byproducts of the hydrogen generation process.	No longer being pursued.
6,918,382	07/19/05	Energy Conversion Devices, Inc.	Hydrogen powered scooter	A scooter powered by a hydrogen fueled internal combustion engine utilizes an on-board metal-hydride hydrogen storage unit and the storage unit may be heated with an exhaust stream from the engine to help liberate the embedded hydrogen.	No licenses issued and no internal research being done with this patent.
6,793,909	09/21/04	Sandia National Laboratory	Direct synthesis of catalyzed hydride compounds	Method of producing complex hydride compounds comprising mechanically milling powders of a simple alkali metal hydride material with a metal and a titanium catalyst compound followed by high-pressure hydrogenation.	Being used in research at SNL but no licensees.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,787,229	09/07/04	University of Central Florida	Three-dimensional carbon fibers and method and apparatus for their production	A novel three-dimensional (3D) carbon fiber which is original (or primary) carbon fibers (OCF) with secondary carbon filaments (SCF) grown thereon, and, if desired, tertiary carbon filaments (TCF) are grown from the surface of SCF forming a filamentous carbon network with high surface area. The methods and apparatus are provided for growing SCF on the OCF by thermal decomposition of carbonaceous gases (CG) over the hot surface of the OCF without use of metal-based catalysts. The thickness and length of SCF can be controlled by varying operational conditions of the process. An optional activation step enables one to produce 3D activated carbon fibers with high surface area. The TCF growth on SCF is by thermal decomposition of carbonaceous gases over the hot surface of the SCF using metal catalyst particles.	Research complete; seeking to license.
6,787,007	09/07/04	Idaho National Laboratory	Polymeric hydrogen diffusion barrier, high-pressure storage tank so equipped, method of fabricating a storage tank and method of preventing hydrogen diffusion	Electrochemically active hydrogen diffusion barrier made of an anode layer and a cathode layer, each including a polymer material conductive to protons and substantially impermeable to hydrogen. There will also be a voltage source operably coupled to the anode layer and the cathode layer and a catalytic material interface between at least one of the anode layers and the electrolyte layer and the cathode layer.	Not licensed and no research being done at INL with this patent.
6,746,496	06/08/04	Sandia National Laboratory	Compact solid source of hydrogen gas	A compact solid source of hydrogen gas, where the gas is generated by contacting water with micro-disperse particles of sodium borohydride in the presence of a catalyst, such as cobalt or ruthenium.	Licensed to Nanodetex but license was terminated.
6,708,502	03/23/04	Lawrence Livermore National Laboratory	Lightweight cryogenic-compatible pressure vessels for vehicular fuel storage	A lightweight, cryogenic-compatible pressure vessel for flexibly storing cryogenic liquid fuels or compressed gas fuels at cryogenic or ambient temperatures.	Part of an emerging hydrogen storage technology.
6,616,891	09/09/03	Energy Conversion Devices, Inc.	High capacity transition metal based hydrogen storage materials for the reversible storage of hydrogen	A reversible transition metal-based (including titanium, vanadium, chromium, and manganese) hydrogen storage material can store up to 4 wt.% hydrogen and reversible delivering up to 2.8 wt.% hydrogen at temperatures up to 150 °C.	Being used in ongoing research at Vodik Labs LLC.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,593,017	09/09/03	Energy Conversion Devices, Inc.	High capacity calcium lithium based hydrogen storage material and method of making the same	Nonreversible metal hydrides can be used to store and release hydrogen. A nano-crystalline, calcium lithium-based hydride can store up to 5% hydrogen by weight. The metal hydrides can be ground to a fine power to facilitate hydrogen transportation and storage.	No licenses issued and no internal research being done with this patent.
6,528,441	03/04/03	Savannah River National Laboratory	Hydrogen storage composition and method	A hydrogen storage material based on a metal hydride dispersed in an aerogel prepared by a sol-gel process.	No longer being pursued.
6,471,935	10/29/02	University of Hawaii	Hydrogen storage materials and method of making by dry homogenation	A method of making such reversible hydrogen storage materials by dry doping is also provided and comprises the steps of dry homogenizing metal hydrides by mechanical mixing, such as crushing or ball milling a powder, of a metal aluminum hydride with a transition metal catalyst.	Being used in ongoing research.
6,418,962	07/16/02	Johns Hopkins University	Low cost compressed gas fuel storage system	A compressed gas vehicle fuel storage system comprised of a plurality of compressed gas pressure cells supported by shock-absorbing bumpers positioned within a low-cost, shape-conforming container.	No longer being used.
6,321,775	11/27/01	Johns Hopkins University	Compressed gas manifold	A compressed gas storage cell interconnecting manifold including a thermally activated pressure relief device, a manual safety shut-off valve, and a port for connecting the compressed gas storage cells to a motor vehicle power source and to a refueling adapter.	No longer being used.
6,262,328	07/17/01	Savannah River National Laboratory	Container and method for absorbing and reducing hydrogen concentration	A method for absorbing hydrogen from an enclosed environment.	Being used in research at SRNL but no licensees.
6,257,360	07/10/01	Johns Hopkins University	Compressed gas fuel storage system	A compressed gas vehicle fuel storage system comprised of a plurality of compressed gas pressure cells supported by shock-absorbing foam positioned within a shape-conforming container.	No longer being used.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
6,017,600	01/25/00	Lawrence Livermore National Laboratory	Method for forming a bladder for fluid storage vessels	Lightweight, low permeability liner for graphite epoxy composite compressed gas storage vessels. The liner is composed of polymers that may or may not be coated with a thin layer of a low permeability material, such as silver, gold, or aluminum, deposited on a thin polymeric layer or substrate, which is formed into a closed bladder using torispherical or near torispherical end caps.	No licenses issued and no internal research being done with this patent.
5,965,482	10/12/99	Savannah River National Laboratory	Composition for absorbing hydrogen from gas mixtures	A hydrogen storage composition that defines a physical sol-gel matrix having an average pore size of less than 3.5 angstroms, which effectively exclude gaseous metal hydride poisons while permitting hydrogen gas to enter.	Being used in research at SRNL but no licensees.
5,798,156	08/25/98	Lawrence Livermore National Laboratory	Lightweight bladder lined pressure vessels	A lightweight, low permeability liner for graphite epoxy composite compressed gas storage vessels. The liner may be used in most types of gas storage system and is applicable for hydrogen, gas mixtures, and oxygen used for vehicles, fuel cells or regenerative fuel cell applications, high altitude solar powered aircraft, hybrid energy storage and propulsion systems, lunar or Mars space applications, and other applications requiring high cycle life.	No licenses issued and no internal research being done with this patent.
5,411,928	05/02/95	Savannah River National Laboratory	Composition for absorbing hydrogen	The composition comprises a porous glass matrix, made by a sol-gel process, having a hydrogen-absorbing material dispersed throughout the matrix. The glass matrix has pores large enough to allow gases having hydrogen to pass through the matrix, yet small enough to hold the particles dispersed within the matrix so that the hydrogen-absorbing particles are not released during repeated hydrogen absorption and desorption cycles.	Being used in research at SRNL but no licensees.
5,296,438	03/22/94	Savannah River National Laboratory	Dimensionally stable metallic hydride composition	The invention relates to a metallic hydride composition that can undergo repeated hydrogen absorption and desorption cycles without disintegrating, and a process for making such a composition.	Research complete; seeking to license. Part of an emerging storage technology.

Storage Patents Status

Patent Number	Award Date	Organization	Title	Description	Status
5,198,207	03/30/93	Safe Hydrogen, LLC	Method for the preparation of active magnesium hydride-magnesium hydrogen storage systems, which reversibly absorb hydrogen	Method for the preparation of active magnesium hydride-magnesium-hydrogen storage systems, which reversibly absorb hydrogen, with addition of a catalyst for the absorption of hydrogen with the formation of hydride.	No longer being pursued.

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