


U.S. Environmental Protection Agency



Small Business Innovation Research

Success Stories





Technology performance data in this document are self reported by companies and have not been verified by EPA.

The Small Business Innovation Research (SBIR) Program is an important part of the Environmental Protection Agency's (EPA) research and development (R&D) efforts and it helps the Agency achieve its mission to protect human health and safeguard the natural environment. Through the SBIR Program, EPA makes awards to small, high-tech firms to help them develop and commercialize cutting-edge environmental technologies. The Program is intended to spawn commercial ventures that improve our environment and quality of life, create jobs, increase productivity and economic growth, and improve the international competitiveness of the U.S. technology industry. The technologies highlighted in this document illustrate some of the many commercial and technological successes fostered by EPA's SBIR Program.

History of the SBIR Program

The more than 23 million small businesses in the United States employ about 50 percent of the private workforce and develop most of the country's new technologies. Recognizing the tremendous potential of small businesses to help meet federal R&D goals, Congress passed the law creating the SBIR Program in the early 1980s. The purpose of this Act was to strengthen the role of small businesses in federally funded R&D and help

develop a stronger national base for technical innovation. An eligible small business is defined as a for-profit organization with no more than 500 employees, not dominant in the field of operation in which it is proposing, and has its principal place of business in the United States.

EPA's SBIR Program

EPA's SBIR Program is one of 10 federal SBIR Programs and works with similar programs in the U.S. Department of Energy, National Institutes of Health, U.S. Department of Agriculture, National Science Foundation, and U.S. Department of Transportation.

Since initiating its SBIR Program in the early 1980s, EPA has been supporting small business innovators in the development of technologies, products, and processes that are helping the Agency to achieve its strategic long-term goals. These goals include Clean Air and Global Climate Change, Clean and Safe Water, Land Preservation and Restoration, Healthy Communities and Ecosystems, and Compliance and Environmental Stewardship. SBIR technologies are helping to solve many of today's environmental problems and to equip our nation to address the complex environmental challenges of tomorrow. EPA issues annual solicitations for Phase I and Phase II research proposals from science- and technology-based firms. For Phase

I, EPA issues a Regular Solicitation and several Special Solicitations. The Regular Solicitation includes broad environmental topics such as water and wastewater management, air pollution control, monitoring, pollution prevention, safe buildings, and nanotechnology while the Special Solicitations focus on specific problems identified by EPA program offices, regional offices, and laboratories.

Phase I Solicitations are issued in March and close in May each year. Under Phase I, the scientific merit and technical feasibility of the proposed concept are investigated. EPA awards Phase I contracts of \$70,000 for 6 months. Those companies that successfully complete their Phase I research are eligible for Phase II funding.

The objective of Phase II is to develop and commercialize the technology. Competitive awards are based on the results of Phase I and the commercialization potential of the technology. In Phase II, EPA awards base contracts of \$225,000 for 2 years. EPA also offers two additional funding options to promote accelerated commercialization for firms with third-party financing and/or firms whose technologies have been accepted into one of EPA's verification programs such as the Environmental Technology Verification (ETV) Program.

Success Stories

Since its inception, EPA's SBIR Program has provided approximately \$100 million through more than 700 awards to small businesses to translate their innovative ideas into commercial products that address environmental problems. These innovations are the primary source of new technologies that can provide improved environmental protection at lower cost with better performance and effectiveness.

The highlights of many successful SBIR projects are included in this document. Success is demonstrated in many ways—commercially through product sales, establishment of commercial partners and collaborations, licensing, and follow-on funding from other sources including industry and other government agencies; and technologically through the receipt of R&D awards, patents, third-party testing, full-scale demonstration, and approval as a standard method. Many companies have adapted a technology platform to multiple applications to increase their market share and many have installations throughout the world. Equally as important, companies have shown innovation in addressing current and emerging environmental issues by developing technologies that monitor, treat, and prevent pollution, providing significant public health benefits.

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Arsenic Removal System for Point-of-Use/Point-of-Entry Drinking Water Systems

ADA Technologies, Inc.

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Littleton, CO 80127

Telephone: 303-792-5615

<http://www.adatech.com>

<http://www.amendedsilicates.com>

Environmental Problem

Arsenic contamination in groundwater poses a severe health risk to populations throughout the world. In the United States, the problem is most pronounced in the West, parts of the Midwest, and the Northeast. In response, EPA announced a tougher drinking water standard for arsenic, lowering the standard from 50 ppb to 10 ppb. This change is expected to impact 10% of the nation's community drinking water systems. Although several technologies are readily amenable to incorporation in large water treatment processes, fewer options are available for small water systems, particularly those serving fewer than 500 users.

SBIR Technology Solution

With support from EPA's SBIR Program, ADA Technologies, Inc., developed and commercialized a complete arsenic removal system for point-of-use/point-of-entry (POU/POE) drinking water systems. The unit combines a highly effective arsenic sorbent with an automatic shutoff feature that prevents overuse of the sorbent media. The unit features ADA Technologies' new Amended Silicate™

sorbent, a material that exhibits high capacity and the ability to remove both arsenite and arsenate, the forms of arsenic that commonly are found in well water. Tested in cooperation with Kinetico Incorporated, the system provides easy-to-maintain hardware for individual home use or deployment in small, centrally managed water systems.

ADA Technologies has continued to improve the performance of the Amended Silicate™ sorbent by modifying the formulation process. Amended Silicate™ recipes were compared to commercial granular ferric hydroxide (GFH). Small-scale column tests compared the performance of V8 (an Amended Silicate™ formulation) with GFH, with and without pretreatment processing. Columns were filled with equal volumes of the two sorbents, but because of the differences in bulk density, roughly four times more GFH was used by weight. Column life ranged from 3,500 to more than 5,000 bed volumes when tested with the arsenic challenge water at pH 8.5. Several electrochemical pretreatment options were tested. An electrocoagulation (EC) process removed arsenic to less than 10 ppb by itself but provided little benefit to the downstream sorbent columns, while use of acidic electrolyzed water pretreatment extended column life by approximately 30%.

Commercialization Information

Amended Silicate™ cost is estimated at \$0.50 to \$2.00/lb, depending on formulation and production volume. GFH costs are approximately \$3.00 to \$4.00/lb. ADA Technologies and CH2M Hill

(Denver, Colorado) formed a joint venture company, Amended Silicates, LLC, to promote, produce, and market Amended Silicate™ sorbents. The initial focus of the joint venture is commercialization of a mercury-specific form of Amended Silicates™ for mercury control from coal-fired power plants.

Isotherm tests have shown that the Amended Silicate™ can achieve seven-fold higher capacity versus commercial GFH on a mass basis (150% of the capacity on a volume basis) when tested in the arsenic challenge water. This, coupled with the lower estimated cost of the Amended Silicate™, indicates a clear economic advantage for the new sorbent. Electrochemical pretreatment can enhance the performance of arsenic sorbents, but the



ADA developed and commercialized an arsenic removal POU/POE drinking water system using Amended Silicate™ sorbents (pictured above with a dime to indicate scale).

economic value will depend strongly on incoming water quality. EC treatment may be suitable as a primary treatment process for arsenic removal and can be configured to remove silica from drinking water.

ADA Technologies also has secured follow-on funding through a U.S. Air Force SBIR award to field test Amended Silicate™ for use in small municipal systems. The company recently completed assembly of two pilot plants in collaboration with Kinetico, Incorporated.

Company History

ADA Technologies, a Littleton, Colorado-based firm, was founded in 1985 and has established a solid foundation of proprietary technologies to address a range of commercial opportunities. In October 2000, new ownership implemented a renewed focus on commercialization of technology through licensing, sale, joint ventures, and business manufacturing. ADA Technologies is establishing itself as a preeminent technology commercialization company through the development and implementation of processes to guide the entire technology commercialization cycle.

Amended Silicates, LLC, is a joint venture established between ADA Technologies and CH2M Hill to commercialize the sorbent technology. It represents a significant investment by both parties to take this SBIR technology forward into the marketplace. In addition to ADA Technologies' relationship with CH2M Hill on Amended

Silicate™ production, the company has teamed with Kinetico Incorporated (Newbury, Ohio), a major POU/POE hardware supplier, to address the issue of column design and aid with sensor integration activities. Partnering with an established hard-

ware provider is the most efficient method of introducing the technology into the marketplace.

SBIR Impact

- Arsenic contamination of drinking water poses a severe health risk to populations throughout the world.
- ADA Technologies developed and commercialized a complete arsenic removal drinking water system that features Amended Silicate™ sorbents.
- ADA Technologies' Amended Silicate™ sorbents can be produced at low cost from common starting materials, making them suitable for domestic and international applications where simple, inexpensive arsenic control is required.
- Isotherm tests demonstrated that ADA's Amended Silicate™ achieves arsenic removal that is seven times better than a leading competitor.

Mercury Sorbents and Carbon Black Derived From Waste Tires

Advanced Fuel Research, Inc.

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<http://www.afrinc.com>

Environmental Problem

The U.S. power generation industry relies heavily on coal, burning nearly 1 billion tons per year to provide heat and electricity. Burning coal, however, emits mercury into the air, where it contributes to air pollution and falls to earth again during rainfall, contaminating water supplies. Consumption of fish exposed to mercury in these contaminated sources can lead to many adverse health effects. One of the most effective methods of controlling mercury emissions from power plants is carbon injection, whereby activated carbon is injected into the flue gas stream exiting the boiler and adsorbed onto particulate matter that then is removed. The cost of commercially available activated carbon, however, is prohibitive (approximately \$0.40-\$0.50 cents/lb). Thus, low-cost carbons are extremely attractive for this application.

A promising new source for these low-cost activated carbons takes advantage of waste tires, which present their own serious environmental problem. Scrap tires are immune to biological degradation and thus present formidable disposal problems. Landfilling of the 280 million tires generated each year in the United States is an unacceptable solution. In addition to the continuous flow of waste tires, there are approximately 2-3 billion tires al-

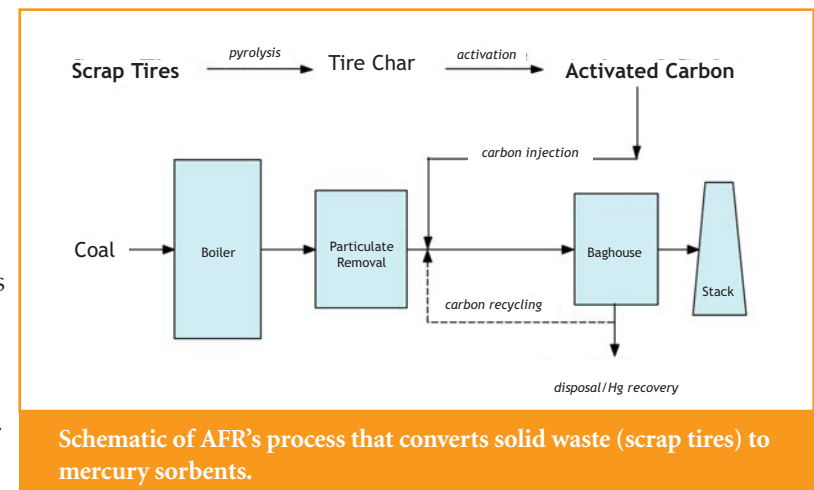
ready stored in piles throughout the country; illegal dumping also is a problem. The tires take up large amounts of valuable landfill space, provide breeding sites for mosquitoes and rodents, and present fire and health hazards. Tire pyrolysis (thermal decomposition into usable end products like steel, oil, and carbon black) is an effective method of disposing of scrap tires, but the economic leverage needs to be improved because the end products are of low quality compared to the virgin materials. This leveraging can be accomplished by producing value-added products such as carbon black, a high-value feedstock for the rubber industry, and activated carbon, which is used as a mercury sorbent in power plants.

SBIR Technology Solution

With support from EPA's SBIR Program, Advanced Fuel Research, Inc. (AFR), developed a technology to address both: (1) removal and recovery of mercury from combustion/incineration flue gas, and (2) reprocessing of waste tires into value-added products. AFR's approach is based on mercury adsorption on low-cost, sulfur-rich activated carbons derived from scrap tires. The sulfur added to tire rubber in the process of vulcanization makes the tire-derived sorbents particularly effective in mercury removal. The first step in the waste-tire processing scheme is pyrolysis, which involves thermal decomposition of tire rubber in an oxygen-free atmosphere. The solid product of pyrolysis (tire char)

subsequently is converted into activated carbon. The sulfur content increases during tire processing, which is believed to facilitate mercury-capture efficiency. The cost-performance characteristics of tire-derived carbons are excellent and more favorable than those of the benchmark commercial carbon, Norit FGD.

Two possible implementations of the process are envisioned: (1) sorbent injection into the flue gas duct (near-term applications), and (2) a patented regenerative scheme (long-term applications). AFR's technology for the removal of mercury from combustion/incineration flue gas, which is combined with the simultaneous utilization of massive amounts of solid waste (scrap tires), has applications for coal-fired power plants and municipal, medical, and hazardous waste incinerators.



Schematic of AFR's process that converts solid waste (scrap tires) to mercury sorbents.

In another SBIR-supported project, AFR developed a technology based on reprocessing tire-pyrolysis oils into virgin carbon black. In addition to manufacturing carbon black, this process also creates a market for the large stream of solid waste comprised of scrap tires. In addition, this process reduces the demand for fossil fuels, the conventional feedstock for carbon black manufacturing.

Commercialization Information

AFR has secured two patents for the mercury sorbent technology and was invited to participate in a full-scale Department of Energy/National Energy Technology Laboratory (DOE/NETL) evaluation of mercury-control technologies. The invitation was extended to AFR on the basis of data showing excellent performance characteristics of tire-derived sorbents combined with their exceptional cost-effectiveness. Participation in the DOE/NETL program is an important recognition of AFR's approach to mercury control and waste tire utilization. AFR currently is pursuing business arrangements for the production of ton quantities of tire-derived mercury sorbents.

Company History and Awards

Founded in 1980, AFR celebrated its 25th anniversary in early 2005. The East Hartford, Connecticut-based company has 14 employees at present. Through SBIR and industrial support, AFR has successfully developed a number of innovative laboratory and process control instruments and software products



that today are serving industrial and academic clients throughout the world. AFR received the U.S. Small Business Administration's prestigious Tibbetts Award in 2000 for exemplary achievement in commercializing technology developed with the

support of the SBIR Program. AFR's success has led to two spin-off companies: MKS Instruments On-Line Products Group and the newly formed Real-Time Analyzers, Inc.

SBIR Impact

- Mercury emissions from coal combustion and incineration of municipal and hazardous wastes and the disposal of scrap tires represent two serious environmental problems.
- AFR developed a novel technology for the removal of mercury from combustion/incineration flue gas while at the same time utilizing massive amounts of solid waste (scrap tires).
- Applications of this technology include use in coal-fired power plants and municipal, medical, and hazardous waste incinerators.
- AFR also has demonstrated the feasibility of making virgin carbon black from oils produced by waste-tire pyrolysis.

Ultralow NO_x Burner for Boilers and Process Heaters

Altex Technologies Corporation

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Environmental Problem

In many regions of the country, particularly the Northeast, West Coast, and Texas, ambient ozone levels exceed the standards established by EPA. A key precursor of ozone production, nitrogen oxides (NO_x), leads to acid rain and contributes to ground-level ozone and smog. NO_x is produced from burning fossil fuels in vehicles and in stationary sources such as power plants, waste incinerators, manufacturing plants, commercial buildings, and homes.

Boilers and process heaters, used in a wide range of applications such as industrial process heating, petroleum refining, and chemical manufacturing, consume approximately 37% of all gas used in industry and contribute a significant percentage to overall NO_x emissions. For those regions of the country that are in nonattainment of the ozone standard, reducing NO_x emissions effectively and economically is critical to their environmental quality. If NO_x is not reduced, oxidants can build up in the atmosphere and have detrimental effects on human health, particularly the lungs and eyes.

SBIR Technology Solution

With support from EPA's SBIR Program, the California Air Resources Board, and ST Johnson Company, Altex Technologies Corporation developed and commercialized an ultralow NO_x burner that reduces NO_x emissions to below 5 ppm (3% O₂ dry). The innovative burner, called the Ultra Reduced NO_x Burner (URNB), achieves low emissions while maintaining good flame stability and heat transfer characteristics. The URNB is applicable to a broad range of firetube and watertube boilers and process heaters.

The burner has been designed for natural gas fuel, with liquified petroleum gas (LPG) as the backup fuel. The URNB can be retrofitted to conventional boilers and process heaters, or incorporated into new equipment. No special mounting or air and fuel supply modifications are required, and the URNB consumes 11% less operating power than alternative ultralow NO_x burners. Unlike alternative ultralow NO_x burner technologies that use a single flame zone to cover all burner requirements, the URNB creates several flame zones to balance all burner performance criteria.

The URNB is a reliable and low-cost boiler and process heater emissions control option for nonattainment air quality regions in the United States. Given the 28 trillion ft³ of gas consumed in boilers and process heaters in the United States, it is estimated that a full deployment of the URNB could

reduce NO_x emissions by 36,000 tons/year and save facilities \$93 million/year. In comparison to postcombustion NO_x control devices that cost up to an additional \$20,000/ton of NO_x removed, the URNB could save facilities \$720 million/year.

Commercialization Information

The URNB was tested extensively by Altex Technologies in the laboratory and by a commercialization partner, ST Johnson Company, in the field. The laboratory tests covered system scales of 1MM Btu/hr, 4MM Btu/hr, and 13MM Btu/hr. The field test was successfully conducted at 25MM Btu/hr scale in a firetube boiler. The field tests utilized



The URNB, pictured above, is a reliable and low-cost boiler and process heater emissions control option for nonattainment air quality regions in the United States.

third-party EPA source testing equipment and procedures, and were supported by the California Air Resources Board, under its Innovative Clean Air Technology Program. The field test was successful, and the URNB now is being sold at scales from 4MM Btu/hr up to 40MM Btu/hr by ST Johnson Company.

Company History

Altex Technologies Corporation was founded in 1985 to research, develop, and demonstrate fuels and combustion system innovations that increase efficiency and reduce emissions at low cost. Altex Technologies is located in Sunnyvale, California, in the heart of Silicon Valley, where low emissions and low-cost burners are highly desirable. Altex Technologies works with manufacturers to implement successful energy and environmental technologies.

ST Johnson Company, the licensed manufacturer of the URNB, was founded in 1903, and is located in Oakland, California. The URNB expands the company's product line to include ultralow NO_x burners, as well as low NO_x and conventional burners, for markets outside nonattainment regions.

SBIR Impact

- Boilers and process heaters contribute significantly to overall nitrogen oxide (NO_x) emissions.
- Altex Technologies Corporation developed the Ultra Reduced NO_x Burner (URNB), a reliable and low-cost boiler and process heater emissions control option for nonattainment air quality regions in the United States.
- With full implementation of the URNB, NO_x could be reduced by more than 36,000 tons/year and costs to reduce NO_x could be reduced by \$93 million/year, relative to alternative burner technologies.
- The URNB is being sold at scales from 4MM Btu/hr up to 40MM Btu/hr by ST Johnson Company.

Real-Time Mercury Analysis: A Dry Sample Conditioning System

Apogee Scientific, Inc.

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Environmental Problem

Vapor-phase mercury emitted from the combustion of coal is recognized as a serious threat to the nation's air quality and public health. Mercury is a toxic, persistent pollutant that accumulates in the food chain. Concentrations of mercury in the air are usually low and of little direct concern; however, mercury in the air falls onto the Earth's surface through rain and snow and enters lakes, streams, and estuaries. Once there, mercury transforms to its most toxic form, methylmercury. Concentrations of methylmercury can build up in fish and animal tissues—people are exposed to mercury primarily by eating fish.

In March 2005, EPA directed coal-fired power plants to reduce mercury emissions by almost 22% in the next 5 years. In addition, several individual states have voiced the possibility of issuing their own mercury regulations. At this point, only two states, Massachusetts and Wisconsin, have issued mercury regulations; however, many other states, including New Jersey and Minnesota, are examining their own mercury regulations.

SBIR Technology Solution

With support from EPA's SBIR Program and the Electric Power Research Institute, Apogee Scientific, Inc., developed an advanced dry-catalytic gas sample conditioning system for use in the determination of in-duct mercury concentrations in coal-fired utility boilers. The Apogee Dry Sample Conditioning System (DSCS) represents a breakthrough in real-time mercury measurement technology. To date, the measurement of mercury concentrations in the exhaust streams of coal-fired utility boilers has been accomplished using wet-chemical impinger-based conditioning systems that are expensive to run and prone to problems. For real-time mercury monitoring to become a reality in terms of compliance monitoring, a dry-based sample conditioning system is a necessity.

The DSCS uses catalytic material in a reducing environment, created via the combustion of a hydrocarbon fuel, to ensure the complete conversion of all forms (species) of vapor-phase mercury to the elemental state (Hg^0). Current mercury detectors are only capable of measuring elemental mercury, and oxidized forms of mercury are very difficult to transport reliably.

An additional innovation was a modification to allow for operation at facilities where vapor-phase selenium compounds are present. The DSCS removes interference due to selenium compounds without adversely affecting the mercury measurements.

The DSCS takes the needed step towards reliability and automation to enable mercury monitoring for use as a compliance tool. The system removes the need for extensive labor and the costs associated with monitoring and managing a wet-chemical based sample conditioning system. Additionally, the system is inexpensive to operate and has been



Apogee's Dry Sample Conditioning System, pictured above, is a breakthrough in real-time mercury measurement technology.

shown to be very reliable. Apogee Scientific has tested the DSCS technology at a variety of power plants representing a large fraction of the modern coal-generation facilities in the United States. Testing occurred continuously for periods of between 1 to 3 weeks at each of four sites. Data were collected demonstrating the accuracy, stability, and robustness of the system.

Commercialization Information

The DSCS technology is continuing to be tested and refined by Apogee Scientific as a solution to mercury monitoring needs. Extensive testing is required to assure long-term stability and further refine the ultimate design. Although the system still is considered to be in a “beta” testing form, the promise of the technology already is being recognized. Apogee Scientific recently operated the DSCS at a utility facility for more than 3 months of continuous operation to demonstrate and evaluate the longevity and long-term durability of the system and design. Based on the strong results of this demonstration, Apogee Scientific has started entertaining the first commercial requests for this technology. The company plans to begin selling commercial units, and is actively seeking commercial partners to couple the system with other leading mercury monitoring technologies.

Company History

Founded in 1993, Apogee Scientific, Inc., is an advanced technology small business located in Englewood, Colorado. Apogee Scientific’s utility

experiences include real-time total, elemental, and oxidized vapor-phase mercury measurement services using state-of-the-art continuous emissions monitors that have been used at more than 30 power generation sites burning bituminous, subbituminous, or lignite coals. Apogee Scientific has developed a

patented flue gas extraction system that couples with a sample conditioning system, such as Apogee’s DSCS, followed by a commercially available elemental mercury monitor. The company has a staff of 10 and annual revenues of approximately \$1.5 million.

SBIR Impact

- Vapor-phase mercury emitted from coal combustion plants is a serious threat to the nation’s air quality and public health.
- Apogee’s Dry Sample Conditioning System (DSCS) was operated successfully at a utility facility for more than 3 months to demonstrate and evaluate the longevity and durability of the system and design.
- The technology removes the need for extensive labor and the costs associated with monitoring and managing a wet-chemical based sample conditioning system.
- Apogee’s DSCS is a needed step toward reliability and automation to enable mercury monitoring for use as a compliance tool.

Solid Scrubber for the Semiconductor Industry

ATMI, Inc.

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Danbury, CT 06810
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<http://www.atmi.com>

Environmental Problem

The rapid growth of the American microelectronics industry has spawned new environmental challenges associated with the processes used to prepare semiconductor chips, key components of many sophisticated electronic devices. Harmful chemicals including silane, phosphine, and arsine are used during semiconductor fabrication in a process called chemical vapor deposition (CVD).

Although most large companies have built facilities for handling these materials, smaller manufacturers have vented the gases into the atmosphere or used similarly unacceptable techniques. With increasing production, however, venting is no longer an option. The Emergency Planning and Community Right-to-Know Act designates silane, phosphine, and arsine as extremely hazardous chemicals used by the semiconductor industry; these chemicals also are regulated as toxic chemicals under the Clean Air Act.

SBIR Technology Solution

With support from EPA's SBIR Program, ATMI, Inc., developed an innovative solid scrubbing material

designed especially to reduce toxic air emissions from the semiconductor industry. With 30 times the capacity of activated carbon, the new material became the core of the Novapure Dry Scrubber System that was introduced into the market in 1991. The Novapure System has broad application in the electronics industry and in research and development institutions where small amounts of hazardous materials are routinely employed in CVD processes.

ATMI process scrubbers are smaller than traditional air pollution control equipment. Instead of a single large installation outside a fabrication plant, ATMI's abatement products are small enough to be located at each individual pollution source.

ATMI's scrubber system transforms these toxic gases into nonvolatile, benign solids through chemical adsorption. By neutralizing, solidifying, and concentrating hazardous effluent up to 20,000 times, this technology helps to eliminate toxic air emissions and minimize solid toxic wastes from small semiconductor manufacturers.

Commercialization Information

Since the award of this SBIR contract, ATMI has developed a family of novel vent gas scrubbers that are cost effective in reducing toxic air emissions from small quantity CVD processes as well as toxic air emissions released by semiconductor manufacturers. ATMI was granted four U.S. patents on its dry scrubber technology, and in just 3 years, the company's annual sales grew to nearly \$6 million.

To expand its environmental control equipment market, in 1994 and 1995 ATMI acquired the rights to alternative technologies, including wet scrubbing and combustion scrubbing. These acquisitions increased ATMI's annual revenues to nearly \$30



ATMI's Novapure Dry Scrubber System, designed to reduce toxic air emissions from the semiconductor industry, was introduced to the market in 1991.

million at that time. ATMI has since sold its Novapure Dry Scrubber technology to a division of Applied Materials, Inc.

ATMI is the largest supplier of point-of-use emission control equipment for the semiconductor industry in the world. This SBIR project led to the development of several new safety-related products for the semiconductor industry. One product, called the Safe Delivery Source[®], or SDS[®], that uses adsorbent materials similar to those of the dry scrubber system, eliminates the use of high-pressure toxic gases in the semiconductor industry. ATMI's SDS[®] Sub-Atmospheric Gas Delivery Systems represent the company's largest source of revenue.

Company History

In recognition of its outstanding achievements in technology innovation, ATMI received the Tibbetts Award in 1996. This award is presented by the U.S. Small Business Administration to companies associated with the SBIR Program that are models of excellence in the area of high technology. In 1997, the Danbury, Connecticut-based company was recognized as an Outstanding Small Business Enterprise by EPA. ATMI also was identified as one of America's 100 Fastest Growing Companies by *Individual Investor Magazine* in 2000, and ranked 63rd on Fortune's list of 100 Fastest Growing Companies. In 2002, ATMI was included in Business 2.0's list of Fastest Growing Companies, and made the Connecticut Technology Fast 50 List for the sixth time. Since 1987, when ATMI was awarded the EPA SBIR



Phase I contract, the company has grown from four employees working in a small garage in New Milford, Connecticut, to nearly 1,100 employees in numerous locations around the world. Revenues in

2001 were \$213 million. Originally called Advanced Technology Materials, Inc., the company changed its name to ATMI, Inc., in 1997.

SBIR Impact

- The rapid growth of the microelectronics industry has spawned new environmental challenges associated with the processes used to prepare semiconductor chips.
- This SBIR project led to the development of ATMI's Safe Delivery Source[®] (SDS[®]), which eliminates the use of high-pressure toxic gases in the semiconductor industry.
- ATMI's scrubber system transforms toxic gases into nonvolatile, benign solids through chemical adsorption.
- ATMI sold its successful Novapure Dry Scrubber technology to Applied Materials, Inc.

Enhanced Plasma Sterilized Filtration™ System: Improving Indoor Air Quality

Atmospheric Glow Technologies, Inc.

924 Corridor Park Boulevard

Knoxville, TN 37932-3723

Telephone: 865-777-3776

<http://www.atmosphericglow.com>

Environmental Problem

Indoor air quality (IAQ) is defined as the physical, chemical, and biological characteristics of indoor air. IAQ is influenced by a myriad of factors including the number of air exchanges between the indoor and outdoor environments, contamination arising from within the building or from the environment, and microbial contamination. Because it is estimated that people spend approximately 90% of their time indoors, both the public and private sectors are becoming increasingly aware of issues associated with poor IAQ. Furthermore, people who are the most susceptible to the effects of poor indoor air often are the same people who spent the greatest amount of time indoors. Examples include the very young, the elderly, and those suffering from chronic illnesses. EPA has ranked IAQ among the top five risks to public health.

SBIR Technology Solution

With support from EPA's SBIR Program, Atmospheric Glow Technologies, Inc. (AGT), developed and is actively commercializing its Enhanced Plasma

System (EPS) for IAQ. The EPS-IAQ, covered by four patents, is a multi-stage system that eliminates airborne microorganisms and certain chemicals using One Atmosphere Uniform Glow Discharge Plasma (OAUGDP®). The EPS-IAQ consists of an OAUGDP generator, a particulate filter for microorganism capture, a volatile organic compound (VOC) filter, and an ozone catalytic filter. Ancillary systems include the power supply and control system.

Air containing VOCs and microorganisms enters the system, where the contaminants are trapped and destroyed. The trap operates continuously and is designed to have a holding capacity that exceeds the expected loading between plasma treatments. The particulate filter uses off-the-shelf technology for high-efficiency capture. The plasma generator is energized periodically and creates reactive chemical species from the air. These species destroy trapped microorganisms as well as VOCs.

The fully automated EPS-IAQ is designed with flexibility and scalability in mind. It employs a simple modular design with a plasma generator at its core that is adaptable to room-sized or larger in-duct applications. EPS systems can be installed during new construction or easily retrofitted into existing facilities. By taking a modular design approach, AGT easily can reconfigure the EPS-IAQ to provide systems with or without ducted connections or direct, in-flight systems for fly-through destruction of organisms or chemicals.

Commercialization Information

The EPS-IAQ is in pre-production. AGT is completing engineering designs to meet specifications for a Tier 1 manufacturer. Initially, the targeted market will be the residential sector, providing a cost-effective means to remove and destroy microorganisms and reduce irritating VOCs from the indoor air while meeting the most rigid quality standards. AGT continues to advance the core plasma technology and is pursuing application areas in such diverse arenas as biotechnology, military and agricultural decontamination, aerodynamics, and materials processing for industry.



Diagram of AGT's Enhanced Plasma System for Indoor Air Quality, which destroys all types of captured microorganisms while reducing concentrations of airborne VOCs.

Company History and Awards

AGT is a science and engineering company that was founded in 2000. AGT became a publicly traded company in February 2004. The company's early research and development work was supported largely by the SBIR Program. To date, AGT has been awarded 15 SBIR projects totaling more than \$6 million. This funding has been used to further the development of AGT's atmospheric plasma technology. Located in Knoxville, Tennessee, AGT is housed in a 12,000 ft² facility with state-of-the-art chemistry, microbiology, physics, and plasma laboratories; a prototype development shop; and prototype manufacturing areas.



AGT has been internationally recognized with an *R&D Magazine* Top 100 Award, the University of Tennessee-Battelle Oak Ridge National Laboratories Subcontractor of the Year Award, the U.S. Small Business Administration Roland Tibbetts Award recognizing excellence in government contracting, and the Dawnbreaker Outstanding Commercial Achievement Award. AGT has just recently received its second R&D 100 Award for its first product in the biotechnology arena. The company and its products have been featured in periodical publications such as *Popular Science* and *R&D Magazine*.

SBIR Impact

- The U.S. Environmental Protection Agency has ranked indoor air quality (IAQ) among the top five risks to public health.
- Atmospheric Glow Technologies, Inc. (AGT), developed a cost-effective means of improving IAQ using atmospheric plasma—the Enhanced Plasma System for IAQ (EPS-IAQ).
- AGT's EPS-IAQ destroys trapped microorganisms and volatile organic compounds, and is engineered to meet the most rigid standards for indoor air quality.
- AGT is completing engineering designs to meet specifications for a Tier 1 manufacturer.

Membrane Technology for Reducing NO_x Emissions From Diesel Engines

Compact Membrane Systems, Inc.

325 Water Street

Wilmington, DE 19804

Telephone: 302-999-7996

<http://www.compactmembrane.com>

Environmental Problem

Nitrogen oxides (NO_x) lead to acid rain and contribute to unhealthy ground-level ozone and smog, often leading to severe respiratory problems among affected communities. Diesel engines produce unacceptably high levels of NO_x at high loads, and NO_x from nonroad diesel engines represents an increasing percentage of the environmental pollution in nonattainment regions (areas that do not meet primary environmental standards), where more than 90 million Americans live. Economical, easy-to-integrate solutions are needed to meet the NO_x reduction goals of the Clean Air and Clear Skies Acts.

SBIR Technology Solution

A promising new method of reducing NO_x emissions involves the recycling of exhaust gas in a process called exhaust gas recycle (EGR). EGR sends captured exhaust gas back into the combustion chamber of the engine, thereby increasing fuel economy and reducing emissions: a 25% EGR leads to a 50% reduction in NO_x. There are some problems, however, associated with the process, including: (1) extra pumping and cooling of the EGR stream, (2) engine wear from recirculating engine soot, and (3) high feed air water vapor lev-

els. These issues can be avoided by the use of nitrogen-enriched air (NEA), which reduces the diesel combustion temperature and, in turn, the amount of NO_x emitted in the engine exhaust. The NO_x reductions achieved through NEA are similar to those accomplished through the EGR process, while simultaneously avoiding the pumping, cooling, wear, and water vapor issues associated with EGR.

With support from EPA's SBIR Program, Compact Membrane Systems, Inc. (CMS), in cooperation with its commercialization partners, has developed stable fluoropolymer membranes to nitrogen enrich the turbocharged intake air to diesel engines. Cooled turbocharged air is processed by an NEA membrane to supply NEA to the diesel engine intake. NEA reduces the diesel combustion temperature; in turn, the amount of NO_x produced and emitted in the engine exhaust is greatly reduced.

CMS membrane modules are designed for very high flux, harsh operating conditions, stable performance, and production of NEA in the range of 79.5% up to 84%. As a result of EPA's SBIR funding and collaborations with downstream partners and commercial membrane manufacturers, CMS has made large advances in demonstrating and commercializing NEA membranes for NO_x reduction in diesel engines.

Commercialization Information

Working with major industrial gas companies (e.g., Praxair and Air Liquide) and their membrane divisions (IMS and MEDAL), CMS has produced large, commercial-sized membrane modules. In col-

laboration with Caterpillar, these large commercial-sized modules have operated successfully in excess of 1 million on-road miles on five Class 8 diesel trucks. Independent laboratory testing of the membrane systems showed them to have excellent fouling resistance to ingested dust and durability to an excess of 1 million pressurization cycles while operating at high temperature (85°C) and high pressure (30 psig). Caterpillar tests over a broad cycle showed that the membranes exceeded the target NO_x emission reduction of 50%.

CMS' successful field demonstration with Caterpillar in combination with ongoing support from EPA's SBIR Program has led to additional opportunities that presently are under commercial/developmental evaluation. At present, low-speed marine diesel



Membranes within the black housing mounted over the diesel engine pictured above generate NEA from cooled turbocharged air.

engines are being tested in support of installation of CMS membranes on Scandinavian ferries and ships for NO_x reduction.

The retrofitting of installed emergency generators with CMS NEA membranes is being evaluated, and the membranes show promise for creating cost savings from peak electric power rates. These additional programs have successfully completed the feasibility phase and CMS is receiving purchase orders for outfitting engines for initial fleet and field demonstrations.

Company History and Awards

CMS was founded in 1993, based on membrane technology acquired from E.I. DuPont. CMS is located in Wilmington, Delaware. CMS' focus is on the research, development, and commercialization of membranes and thin films composed of fluorinated polymers with exceptional gas transport properties and chemical resistance.

In 1998 and 2000, CMS received the Tibbetts Award as an Outstanding Small Business in the State of Delaware. This award is given by the U.S. Small Business Administration to firms judged to exemplify the best in small business innovation and research. The company's goal is to become, in combination with its partners, the world market leader of amorphous perfluoropolymer membranes for gas transport (including NEA). Although CMS products are focused on perfluoropolymers, the company serves a broad range of markets that can utilize the unique features of CMS membranes.



SBIR Impact

- Economical, easy-to-integrate solutions are needed to meet the nitrogen oxides (NO_x) reduction goals of the Clean Air and Clear Skies Acts.
- Compact Membrane Systems, Inc. (CMS), in cooperation with its partners, demonstrated that a high-productivity nitrogen-enriched air membrane can be used to reduce diesel engine NO_x emissions by 50%.
- Field tests have shown that these membrane systems are stable related to flux and selectivity and have excellent fouling resistance.
- CMS has successfully field demonstrated commercial-sized membrane modules with Caterpillar. In these on-road tests, the membranes exceeded the target NO_x reduction of 50%.

Phytoremediation of Arsenic-Contaminated Soils

Edenspace Systems Corporation

15100 Enterprise Court, Suite 100

Dulles, VA 20151-1217

Telephone: 877-961-8777

<http://www.edenspace.com>

Environmental Problem

Weathered lumber in decks, docks, playground equipment, and gardens can leach significant amounts of arsenic into soil and water, where it poses health risks to people and animals. By 1990, the United States used approximately 37 million lb of arsenic annually in the production of chromated copper arsenate (CCA), a wood preservative. Currently, there is no cost-effective method to clean up arsenic-contaminated soils. The levels of arsenic found in soil under CCA-treated decks have been as high as 20 times the background level and substantially above most state and federal standards.

Although EPA regulations now limit the use of CCA to the treatment of wood in forest products and other primarily nonresidential applications, the existing stock of CCA-treated wood products (containing more than 600,000 metric tons of arsenic) will continue to leach arsenic into the soil for years to come. *In situ* phytoremediation of contaminated soil could greatly reduce the amount of soil sent to hazardous waste landfills by collecting and concentrating the arsenic in a much smaller volume of plant biomass.

SBIR Technology Solution

With support from EPA's SBIR Program, Edenspace Systems Corporation developed an arsenic phytoremediation technology for *in situ* treatment of soils contaminated with CCA. With this technology, ferns accumulate arsenic in their harvestable fronds at levels up to 100 times the underlying soil concentration, facilitating efficient removal and disposal of CCA-derived arsenic while preserving topsoil. The plants then are harvested for recycling or landfill disposal.

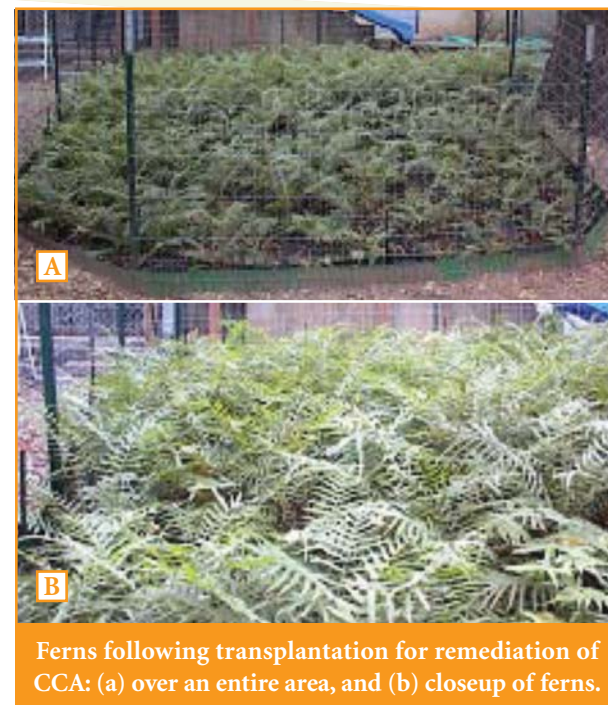
Edenspace Systems has demonstrated two methods using fluid extraction for concentrating and refining recovered arsenic for storage and future recycling, with recovery rates greater than 70%. Phytoextraction and recycling of CCA arsenic for reuse in industry offers two major benefits: (1) recapture and proper disposal of arsenic leached to the environment from CCA-treated lumber; and (2) reduced primary production (mining) of arsenic, thereby reducing the total level of anthropogenic arsenic in the environment.

This technology is scalable from very small sites (e.g., gardens) to large sites (e.g., lumber storage areas). An acres-wide storage site for CCA lumber can be treated with high-volume agricultural techniques, whereas a small area under a wood deck can be addressed using home gardening skills. Edenspace Systems is particularly interested in developing the technique for use by individual homeowners, enabling them directly and flexibly to address CCA risks in the "microenvironment" around their homes. EPA has indicated that

such activities are covered by the Household Waste Exclusion to the Resource Conservation and Recovery Act, allowing the ferns to be disposed of as ordinary waste in the same way that soil contaminated by lead-based paint may be disposed of, facilitating the reduction of environmental risk to the homeowner.

Commercialization Information

There is a strong customer interest in phytoremediation of soil arsenic deposited from CCA-treated wood, with a projected U.S. market of \$162-\$194 million



4 years after product introduction. Currently, there is no commercial competition for Edenspace Systems' CCA arsenic phytoremediation. For the foreseeable future, the innovation of this technology, combined with Edenspace Systems' existing intellectual property protection, should provide the company with an excellent competitive position.

Edenspace Systems is marketing the arsenic extracting fern under the trade name edenfern™. Sales of edenfern™ to government agencies, businesses, and homeowners totaled \$22,000 in the initial year of sales. Treatability studies are being conducted for six potential arsenic-contaminated sites, and a multiyear field cleanup is underway with the U.S. Army Corps of Engineers at Spring Valley in Washington, DC. Potential customers include wood treatment companies and distributors, homeowners, farmers, transportation and utility companies, schools, and other industry and government organizations.

Company History and Awards

Incorporated in Delaware in October 1998, and headquartered in Dulles, Virginia, Edenspace Systems Corporation is a leader in the commercial use of living plants in innovative systems to remove lead, arsenic, uranium, chlorides (salts), and other minerals from the environment. As of December 31, 2004, Edenspace Systems had 9 employees and revenues of \$1.1 million. Edenspace Systems owns or licenses 17 patents. In 2003, Edenspace announced a strategic partnership with Fujita Corporation, a large Japanese environmental contractor, to introduce Edenspace Systems' phytoremediation technology in Japan.

Current Edenspace Systems customers include EPA, the Departments of Agriculture and Energy, US Army Corps of Engineers, National Institutes of Health, state environmental agencies, universities, private companies, and homeowners in the United States and Japan. Edenspace Systems received the

1999 DaimlerChrysler Environmental Excellence Award for saving the automotive company more than \$1 million through a lead phytoextraction project.



SBIR Impact

- EPA regulations now limit the use of chromated copper arsenate (CCA), but the existing stock of CCA-treated wood products will continue to leach arsenic into the soil for years to come.
- Edenspace Systems developed an arsenic phytoremediation technology, using edenfern™, for *in situ* treatment of soils contaminated with CCA.
- No other method of arsenic remediation offers such great potential for recovering captured arsenic.
- Sales of edenfern™ were made to government agencies, businesses, and homeowners in the initial year of sales.

Hydrogen Peroxide Ballast Water Treatment System

Eltron Research, Inc.

4600 Nautilus Court South
Boulder, CO 80301-3241
Telephone: 303-530-0263
<http://www.eltronresearch.com>

Environmental Problem

During the last century, the problem of biological infestations and chemical contamination spread through waterways has been dramatically accelerated with the advent of modern high-speed freighters and their methods of ballast water exchange. Transport and discharge of contaminated ballast water constitutes a major route by which potentially invasive species are introduced into high-traffic marine and fresh waters worldwide. The discharge of marine vessel bilge and ballast water upon destination arrival can seriously contaminate the surrounding aquatic ecosystems with nonindigenous organisms, and grey/black water effluents with high biological oxygen demand (BOD).

The most problematic organisms to be controlled are bacterial, planktonic, and egg or larval stages of higher organisms. It is almost impossible, very expensive, and environmentally damaging to control/eradicate infestation of an invasive species once it is introduced into a waterbody. The introduction of the zebra mussel into the waterways of the Great Lakes provides a well-publicized and sobering example of both the economic and ecological costs associated with such invasions. Thus, prevention of

initial contamination by invasive species is the most practical approach to this problem.

SBIR Technology Solution

With support from EPA's SBIR Program, Eltron Research, Inc., developed a unique hydrogen peroxide (H_2O_2) generation technology into a turn-key, modular, flow-through water treatment system for bilge, ballast, and wastewater treatment. H_2O_2 is long known to be effective for disinfection and organic material oxidation. The core of this treatment system is Eltron Research's patented electrolytic technology that consumes only water, oxygen from air, and electricity.

A durable electrolytic cell design was developed for this treatment application that achieves the required H_2O_2 production rates and exceeded all expectations in performance during scale-up. Commercial production of the electrolytic cell modules demonstrated this technology's readiness for manufacture. A 3,000 gallon per hour system successfully demonstrated the modular scalability of treatment capacity.

Eltron Research's electrolytic technology produces H_2O_2 onsite and on-demand for about one-half the cost of the standard industrial production process based on power consumption and capital depreciation estimated over a 5-year period. Hydrogen peroxide water treatment with this new system is comparable in power consumption to the newest ultraviolet ballast water treatment systems, but provides the additional key benefits of organic destruction,

reduction of BOD, an estimated 30% reduction in capital costs, and a safe source of H_2O_2 .

Tests conducted by the Marine Biological Laboratory (Woods Hole, Massachusetts) in collaboration with Eltron Research demonstrated broad effectiveness of H_2O_2 to kill algae, fish, invertebrates, and planktonic and bacterial microorganisms. Introduction of 5-7 mg/L H_2O_2 into ballast water by Eltron Research's treatment system during vessel uptake is expected to provide effective treatment against biological organisms within the first 200-500 minutes of contact time. The corrosiveness of seawater with



Eltron Research developed a hydrogen peroxide water treatment system to mitigate marine vessel discharge of exotic, invasive organisms in bilge and ballast water.

this level of H₂O₂ was experimentally determined not to exceed that of natural dissolved oxygen, and thus is safe for ship-board use.

Commercialization Information

SBIR funding was utilized to transition Eltron Research's H₂O₂ production technology from the laboratory to a successful turn-key water treatment system ready for licensing. Ballast and bilge water treatment capacity and performance criteria of Eltron Research's H₂O₂ water treatment system have been examined with a leading U.S. marine equipment manufacturer. Other ship-board water treatment applications have been discussed and opportunities for field testing have been identified.

To date, Eltron Research's technology has been evaluated by a variety of potential end-users and manufacturing partners for applications that will benefit from the convenience, cost savings, and safety of onsite and on-demand H₂O₂ production. Ongoing efforts have produced a second-generation demonstration system for pilot-scale application testing and marketing.

Company History

Eltron Research, Inc., is an energy, chemical processing, environmental, and catalysis research company founded in 1982. The company is located in Boulder, Colorado, and currently employs 60 full-time staff members. Eltron Research is organized into five major technical areas: (1) Catalytic Membrane Reactors, (2) Catalysis, (3) Chemical

Sensors, (4) Electrochemistry, and (5) Material Science. The company's model for technology commercialization involves forming strategic relationships with large corporations to promote this process. SBIR projects at Eltron Research have generated well over \$100 million of non-SBIR support

from the resulting consortia, of which more than \$60 million is private-sector investment. Eltron Research believes this to be among the largest private-sector investments made in technology evolving directly from the SBIR Program.

SBIR Impact

- Transport and discharge of contaminated ballast water constitutes a major route by which potentially invasive species are introduced into high-traffic marine and fresh waters worldwide.
- Eltron Research developed a turn-key hydrogen peroxide (H₂O₂) water treatment system to mitigate marine vessel discharge of exotic, invasive organisms in bilge and ballast water.
- Eltron Research's unique electrolytic H₂O₂ production process consumes only water, oxygen from air, and electricity.
- This onsite and on-demand H₂O₂ production technology is economically competitive, convenient, and environmentally safe.

Nanofibers: A Novel Approach to Filtration

eSpin Technologies, Inc.

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Chattanooga, TN 37416
Telephone: 423-267-6266
<http://www.espintechnologies.com>

Environmental Problem

Indoor air contaminants, such as volatile organic compounds (VOCs), microorganisms, allergens, and other pollutants (e.g., tobacco smoke) pose serious health- and productivity-related problems for occupants of indoor spaces. These toxic compounds are complex mixtures of particles, 90% of which are smaller than 1 micrometer (μm) in diameter. These particles have hundreds of chemicals adsorbed onto their surfaces, including many known or suspected mutagens and carcinogens. Gaseous pollutants contain many irritants, toxic chemicals, and nitrogen oxides, which are ozone precursors, and can have negative environmental impacts. The minute size and the abundance of these toxins give them a greater opportunity to enter our bodies via air and water. As a result, the filter industry is looking for new filter media that can create effective barriers for particles smaller than $3 \mu\text{m}$ and adsorb pollutant gases.

SBIR Technology Solution

With support from EPA's SBIR Program, eSpin Technologies, Inc., developed and commercialized custom-made nonwoven membranes, whiskers, and 3-dimensional structures using nanofibers. These

fibers can be made from a variety of organic, inorganic, or biological polymers. Using a proprietary process, eSpin produces minute fibers that are 100-1,000 times smaller in diameter than fibers produced using conventional textile technologies. eSpin's nanofibers are 20-200 nm in diameter (about 1,000 times smaller than a human hair), have a very high surface area-to-mass ratio, and can be formed into sheet structures with very high porosity and tight pore size.

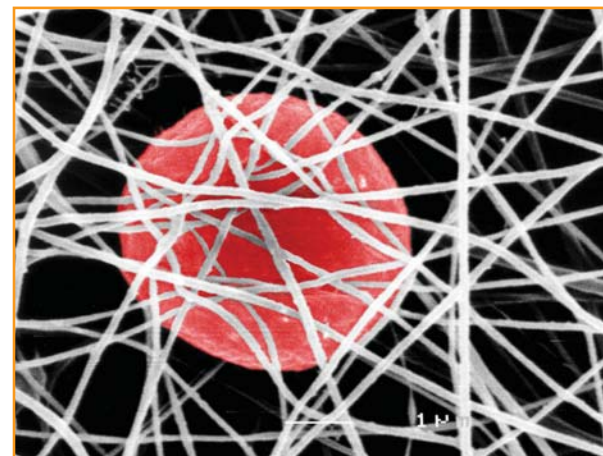
eSpin's SBIR-supported technology development specifically focuses on removing contaminants present in air by using nanomaterial-based air filtration technology. Applications include advanced media filters that stop particulates smaller than $3 \mu\text{m}$ and adsorb VOC gaseous pollutants. Enhanced VOC controls will allow benefits for the health and productivity of millions of U.S. workers.

Conventional fiber technology has reached its limits for producing commercially available monofilaments and is likely to produce fibers in the range of 10-50 μm , while nonwoven fibers produced by melt blown technology are in the range of 3-8 μm . Given this situation, filter manufacturers have been compelled to develop and use "exotic" media such as Teflon membranes. Use of Teflon membranes instead of fiber-based filters, however, increases the filter cost substantially, and such filters do not always perform well in field tests. Thus, a major challenge is overcoming the apparent $3 \mu\text{m}$ particle filtration barrier for a fiber-based filter that has a desirable high-capture efficiency at an affordable cost. eSpin produces nanofibers of unprecedented, unrivalled small diam-

eter with high surface area. Integrating such electrospun polymeric nanofibers with conventional filter media represents a unique opportunity to overcome the current threshold of filterable particle size barrier.

Commercialization Information

eSpin currently supplies nanofiber-based products for development efforts in many different industries, including filtration, performance textiles, energy storage, cosmetics, and others. The company's primary commercialization goal for air filtration applications is to develop and produce an efficient and reliable filtration technology for customers that has a low operating cost and meets or exceeds current



eSpin's nanofibers are 20-200 nm in diameter. This photo compares eSpin's nanofibers to a single blood cell.

Occupational Safety and Health Administration and environmental standards (in anticipation of future air filtration technology mandates). Research in this area resulted in technology that provides a cheaper and better way to clean breathable air by utilizing a highly efficient, cost-effective filter media application.

eSpin currently is working with companies that design and manufacture filtration products and exhaust systems to develop innovative products such as automotive air filters capable of filtering small particles with improved efficiencies of up to 500% compared to existing products. As a platform technology, eSpin's nanofibers have a broad range of market opportunities in traditional and emerging segments of industries such as filtration, aerospace, structural composites, health care, energy storage, cosmetics, and many others.

Company History

Founded in 1999, eSpin Technologies, Inc., is based in Chattanooga, Tennessee, and specializes in custom-engineered nanofiber production. The company has supplied nanofibers for developing unique applications such as clean room products, nanocomposites, filtration products, biomedical devices, and specialty fabrics, among others. eSpin's global partners include Fortune 500 corporations, government and military laboratories, research institutions, and select high-tech companies around the world.

eSpin has received grants and awards from several federal agencies for continued development of

nanofiber technology including EPA, National Science Foundation, Department of Energy, Department of Defense (U.S. Air Force), and National Institute of Standards and Technology. eSpin

Technologies has been featured in global industry publications such as *Nonwoven World*, *Chemical Engineering News*, and *Nature*.

SBIR Impact

- Indoor air contaminants pose serious health- and productivity-related problems for occupants of indoor spaces, and 90% of these contaminants are smaller than 1 μm in diameter.
- eSpin Technologies developed and commercialized custom-made nonwoven membranes, whiskers, and 3-dimensional structures using nanofibers that are 20-200 nm in diameter.
- Applications of this nanomaterial-based air filtration technology include media filters that stop particles smaller than 3 μm and adsorb VOCs.
- Market opportunities for these nanofibers include filtration, aerospace, structural composites, health care, energy storage, and cosmetics.

Replacement of Toxic Hexavalent Chromium in the Plating Process

Faraday Technology, Inc.

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Clayton, OH 45315

Telephone: 937-836-7749

<http://www.faradaytechnology.com>

Environmental Problem

Chromium in its hexavalent form (Cr^{+6}) is a hazardous chemical regulated under the Clean Air Act and designated by EPA as 1 of 17 “high priority” toxic chemicals. It is a known human carcinogen and emits a toxic mist at elevated temperatures. Chrome plating is used in a variety of heavy industrial applications to increase resistance to wear and corrosion on products such as cars and cutting tools, but Cr^{+6} plating produces hazardous air emissions. New installations of Cr^{+6} platers are banned in some states (including California), and existing Cr^{+6} platers have strict monitoring and control requirements and must report to the EPA.

SBIR Technology Solution

With support from EPA’s SBIR Program, Faraday Technology, Inc., has developed a safer, cost-competitive method of chromium plating, using trivalent rather than hexavalent chromium. In its trivalent form, chromium is not only a benign chemical, but an essential element of the human diet. Faraday Technology’s functional Cr^{+3} plating process is intended to replace entirely the toxic Cr^{+6} process. The pilot-scale technology is validating Faraday

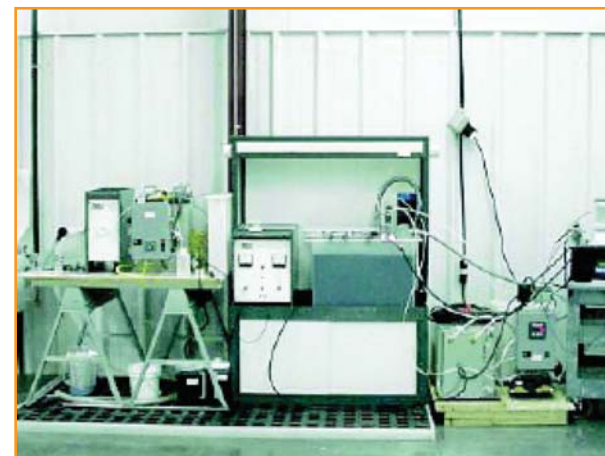
Technology’s electrically mediated Cr^{+3} plating process (the Faradayic™ Process) as a “drop-in” replacement for the use of Cr^{+6} plating. This manufacturing process validation is being executed with a large manufacturer of industrial pumps and the Naval Air Depot (NADEP) at Cherry Point, North Carolina.

Faraday Technology’s process uses pulse reverse-current electrolysis in conjunction with a reduced-cost Cr^{+3} plating chemistry and results in a reduced-cost, performance-based, functional Cr^{+3} plating process to replace conventional Cr^{+6} chromium plating. The process incorporates Faraday Technology’s EXCHANGE™ In-Process Recycling System (also developed under EPA SBIR Program funding) for effluent waste management—plating bath chemistry and rinse water. A controlled “alpha” test of the Faradayic™ Process was completed in a pilot-scale manufacturing cell designed and built by Faraday Technology. This test was conducted using strut rods provided by a Tier 1 automotive supplier.

Faraday Technology’s functional Cr^{+3} plating process demonstrates equivalent or superior plating rate, hardness, and current efficiency; will replace the conventional Cr^{+6} plating process; and will result in a more environmentally friendly and worker-safe plating process. The Faradayic™ Process demonstrates a thickness of 10 mils ($250\ \mu\text{m}$), a plating rate of $1.44\text{--}2.25\ \mu\text{m}/\text{min}$, and a bath cost of \$5.53 per pound of chromium; whereas conventional Cr^{+6} plating processes demonstrate a thickness of 6-10 mils ($150\text{--}250\ \mu\text{m}$), a plating rate of $0.76\text{--}1.27\ \mu\text{m}/\text{min}$, and a bath cost of \$4.81 per pound of chromium.

Commercialization Information

To date, Faraday Technology has secured \$381,940 in commercial revenue to support this pilot-scale activity. Additionally, the company is preparing samples for external evaluation by Concurrent Technologies Corporation and NADEP Cherry Point. Faraday Technology has a successful track record of technology commercialization, with numerous strategic technology alliances currently under contract and 60% of its annual sales coming from commercial sources. Faraday Technology has filed a patent application covering the unique use of electric field process control based on this SBIR-funded project.



A pilot-scale plating Cr^{+3} line is being operated at the Faraday Technology facility in Clayton, Ohio. This plating line is a small-scale version of a shop-floor full-scale line.

The Faradayic™ Process is being widely implemented by large private and publicly owned companies as well as various components of the U.S. Department of Defense with the following applications:

- Faradayic™ Industrial Coatings—such as functional chromium from a trivalent chromium bath.
- Faradayic™ Edge and Surface Finishing—for advanced engineering alloys, such as stainless steel, aluminum, nickel, titanium, and the like without toxic, exotic electrolytes.
- Faradayic™ Leveling—metallization without leveler-brightener additives for advanced electronics applications.
- Faradayic™ Environmental Countermeasures—electrically mediated systems for in-process recycling of rinse waters and plating bath chemistry.

The functional Cr⁺³ plating process supports the Faradayic™ Process technologies listed above by providing environmentally conscientious reclamation and reuse of process solutions.

Company History and Awards

Faraday Technology, Inc., is an electrochemical process technology development company focused on enhancing and commercializing the Faradayic™ Process, its platform electrochemical manufacturing technology. Founded in 1991, Faraday is located in Clayton, Ohio, and has established itself as a noteworthy applied research and development company with approximately 80



publications and more than 50 patents/patents pending. The company has been recognized with a number of awards, including: the U.S. Small Business Administration-sponsored Small Business/Enterprise Spirit Award, the State of Ohio Governor's Thomas Edison Emerging Technology Award,

the Affiliate's Society Council of Dayton Outstanding Technology Leadership Award, the Abner Brenner Silver Medal Award for a paper published in *Plating & Surface Finishing*, and the Ernst & Young Entrepreneur of the Year Award (High Technology Finalist for 2001).

SBIR Impact

- Hexavalent chromium (Cr⁺⁶) plating produces hazardous air emissions, and EPA has identified Cr⁺⁶ as 1 of 17 “high-priority” toxic chemicals and as a known human carcinogen.
- Faraday Technology developed a cost-competitive, environmentally beneficial trivalent chromium (Cr⁺³) plating process to replace Cr⁺⁶ plating.
- Faraday Technology's functional Cr⁺³ plating process demonstrates equivalent or superior plating rate, hardness, and current efficiency compared with Cr⁺⁶ plating.
- Faraday Technology has secured \$381,940 in commercial revenue to support commercialization of this technology.

Rapid Progesterin-Based Endocrine Disruption Screening Assay

Fort Environmental Laboratories

515 South Duncan Street
Stillwater, OK 74074
Telephone: 405-624-6771
<http://www.fortlabs.com>

Environmental Problem

The endocrine system is a complex network of glands and hormones that regulates many of the body's functions, including growth, development, and maturation, as well as the way various organs operate. In recent years, concerns have been growing that certain chemicals in food, water, and other environmental media may be inadvertently disrupting the endocrine systems of humans and wildlife. A variety of endocrine-disrupting chemicals (EDCs) already has been discovered, and there is strong evidence that chemical exposure has been associated with adverse developmental and reproductive effects on fish and wildlife in particular locations. Many of these potential EDCs are present in the marketplace, where approximately 100,000-150,000 chemicals currently are available as medications, fertilizers, pesticides, and other products; approximately 2,500 new chemicals are released each year.

Passage of the Food Quality Protection Act in 1996 as well as amendments to the Safe Drinking Water Act reflect the concerns that some of these chemicals may pose significant risks to the endocrine systems of humans and animals. To address these concerns, EPA has developed a screening program to

determine whether certain substances have an endocrine effect. Conventional toxicology and product safety testing is expensive and time-consuming; with increasing concerns regarding the presence of EDCs in the environment, the need for rapid and efficient standardized assays and other screening tests has dramatically increased.

SBIR Technology Solution

With support from EPA's SBIR Program, Fort Environmental Laboratories (FEL) modified, developed, and standardized assays to test substances that might disturb reproductive and developmental processes in animals by interfering with the endocrine system. A modified *Xenopus laevis* oocyte maturation germinal vesicle breakdown (GVBD) model based on the work of Pickford and Morris (*Environ. Health Perspect.*, 107:285-292, 1999) for rapid evaluation of EDCs was developed as a possible Endocrine Disruptor Screening Program (EDSP) assay for EPA. An amphibian lifecycle (XLCA) model using *Xenopus tropicalis* to evaluate EDCs that affect the development of the reproductive tract also was developed and evaluated for commercialization.

The 24-hour GVBD assay was designed to evaluate environmental progestins and androgens *in vitro*. The chronic exposure model using *X. Tropicalis* was designed to specifically evaluate the impact of EDCs on sexual differentiation and reproductive fitness. The assays were standardized and evaluated by conducting a preliminary validation study with a series of known EDCs, compounds found to be inactive, and chemicals with unknown activity. By standardizing and validating these model sys-

tems for screening EDCs, FEL will provide the scientific community, chemical and pharmaceutical industries, appropriate regulatory agencies, and ultimately the public with a versatile short-term pre-screening assay. Further, this model will enhance understanding of the significance of the effects of EDCs on the reproductive systems of amphibians.

The technical feasibility of these models for screening potential EDCs is high. Although more work will be required to validate the models, it appears to fit the criteria established for emerging assays that currently are being sought for the EDSP.



Fort Environmental Laboratories developed models for rapid evaluation of endocrine-disrupting chemicals on reproduction and development.

Commercialization Information

FEL's assay is relatively straightforward and could be commercialized following method standardization and validation. The models are capable of broadly screening compounds with widespread endocrine activity, including estrogens, progestins, and androgens, which is desirable for EDSP tests. Because the tests are relatively inexpensive compared to many of the other proposed screening tests and many compounds can be tested simultaneously, these models are ideal.

The *in vitro* oocyte GVBD and amphibian lifecycle models will provide the scientific community with a cost-effective, rapid, and reliable method of testing EDCs. The ability to rapidly and cost-effectively screen for and evaluate the mechanisms of EDCs is an attractive alternative to the current laborious and expensive testing systems used today. Increasing concerns over the finding of EDCs in the environment have dramatically increased the need for standardized assays. FEL is well-positioned to capitalize on this emerging market as a pioneer and leader in this field.

Company History and Awards

Fort Environmental Laboratories, an environmental toxicology consulting firm and laboratory, is the only commercial laboratory in the United States to specialize in the toxicological study of amphibians and reptilian species. Co-founded in December 2000 by Drs. Douglas and Deanne Fort and



located in Stillwater, Oklahoma, FEL occupies a unique market niche because of the significant increase in interest in the use of these animals, as well as many others, as indicators of environmental health. FEL won the sole 2002 National Tibbett's

Award from the State of Oklahoma for "National Small Business Research Excellence" and was a finalist for the "Most Promising New Business" award from Oklahoma City's Oklahoma Venture Forum in 2002 and 2003.

SBIR Impact

- The widespread finding of endocrine-disrupting chemicals (EDCs) in the environment has dramatically increased the need for standardized assays.
- Fort Environmental Laboratories (FEL) developed model systems using *Xenopus* for rapid evaluation of EDCs.
- The models developed can broadly screen compounds with widespread endocrine activity and are ideal for high-throughput testing.
- FEL occupies a unique market niche because of the significant increase in interest in the use of these amphibians as indicators of environmental health.

High-Efficiency Toxic Trace Metal Removal From Industrial Wastewater

Frontier GeoSciences, Inc.

414 Pontius Avenue North

Seattle, WA 98109

Telephone: 206-622-6960

<http://www.fgsdata.com>

Environmental Problem

Mercury is a harmful neurotoxin that is readily absorbed by the body from the surrounding environment, through the consumption of fish caught in mercury-contaminated waters as well as through inhalation of vapors from spills, incinerators, and industries that burn mercury-containing fuels. Exposure to mercury can permanently damage the brain, kidneys, and developing fetuses, and young children are particularly at risk. Heightened concern regarding the accumulation of mercury in the aquatic environment led EPA to lower the limit of mercury discharge levels for industries, and several states are considering requirements that mercury discharge levels be no greater than those in the ambient receiving waters. An effective treatment technology that will remove mercury and other toxic trace metals from industrial wastewater before it enters natural water systems is needed.

SBIR Technology Solution

With support from EPA's SBIR Program, Frontier GeoSciences, Inc., pursued the implementation of a toxic metal chelating agent, FGS-MCX. FGS-MCX exhaustively complexes most dissolved toxic trace metals of concern, including silver (Ag), cadmium

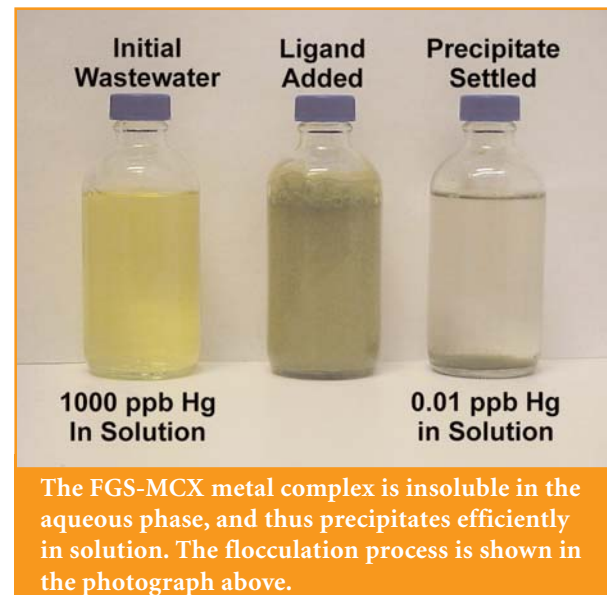
(Cd), copper (Cu), mercury (Hg), lead (Pb), selenium (Se(IV)), arsenic (As(III)), zinc (Zn), and thallium (Tl). In most cases, FGS-MCX has the ability to strip toxic trace metals from indigenous, competitive ligands, such as ethylenediamine tetraacetic acid (EDTA). The FGS-MCX/metal complex is insoluble in the aqueous phase and, thus, precipitates efficiently in solution. FGS-MCX complexes Hg greater than 99.9% from pH 1-12, and 99.999% from pH 3-6.

Toxicity studies of the binding reagent indicated that FGS-MCX is environmentally nontoxic. FGS-MCX preferably binds to lower valence state target metals such as As(III) and Se(IV). The FGS-MCX reagent has a binding hierarchy with typical target metals, in order of most preferred metals to least preferred: Hg > Ag > Cu, Ni > Cd, Pb > Co, Se(IV) > Fe > As > Zn > V > Tl > Cr. The particle formation of the FGS-MCX-metal complex was studied to ascertain the best separation strategy for high-flow process implementation. Reagent concentration at a fixed metal/FGS-MCX ratio had only a small effect on the aggregation kinetics, but increasing the FGS-MCX concentration sped up the aggregation process. Adding a salt also accelerates aggregation. In all cases, improved aggregation means better separation characteristics.

Commercialization Information

A batch pilot plant was constructed and still is under study for its applicability to low-volume laboratory environments. The pilot plant has processed more than 500 gallons of high-concentra-

tion toxic trace metal waste. The effluent was at least an order of magnitude below the local authority's discharge requirements. More than a dozen client sites have been characterized and tested for the applicability of FGS-MCX treatment. For example, natural gas-produced water and laboratory digestion waste were treated by a simple 50 ppm FGS-MCX addition. In the produced water case, the Hg was reduced from 9,569 $\mu\text{g/L}$ to 0.035 $\mu\text{g/L}$, 285-fold lower than the ocean discharge limit. The laboratory digest wastewater saw the Hg concentrations drop from 6,214 $\mu\text{g/L}$ to 16 $\mu\text{g/L}$, 12.5-fold lower than the municipal waste limit. The natural gas platform now uses MCX binding as the primary treatment method for a



million-gallons-per-day wastewater treatment system. Frontier GeoSciences also recently received a 64-ton order for FGS-MCX from Malaysia.

Additionally, the SBIR project directly resulted in a novel pilot online continuous analyzer being placed on a natural gas platform. FGS-MCX was demonstrated to work as a potential additive to wet scrubbers in the coal-fired power plant industry. EPA awarded additional funds to Frontier GeoSciences to pursue the feasibility of this application. Additional funds also have been obtained from an industrial partner that is a large natural gas producer.

Company History

Located in Seattle, Washington, Frontier GeoSciences, Inc., is an industry leader in trace metals analysis. With a state-of-the-art analytical laboratory and research facility, the company specializes in ultra-low detection of trace metals in multiple matrices. Frontier GeoSciences' mission is to provide the very best data to support clients' critical environmental and economic decisions. The company provides chemical solutions for the effective control of toxic metals to the environment. Frontier GeoSciences' scientists are widely published, and are worldwide experts in areas as diverse as mercury speciation and arsenic monitoring and remediation.

SBIR Impact

- The effluents of many industrial processes as well as surface and ground waters from historically polluted sites often contain unacceptably high levels of mercury and other toxic metals.
- Frontier GeoSciences implemented a toxic metal chelating agent, FGS-MCX, that strips metals from the natural ligand/metal complex.
- FGS-MCX binding is the primary treatment method for a million-gallons-per-day wastewater treatment system for a natural gas platform.
- FGS-MCX was demonstrated to work as potential additive to wet scrubbers in the coal-fired power plant industry.

New Coating Methods To Reduce Waste and Hazards in Plating

IonEdge Corporation

513 C, North Link Lane
Fort Collins, CO 80524
Telephone: 970-491-9942
<http://www.ionedge.com>

Environmental Problem

Electroplating is used for components and equipment in all fields of technology to protect materials against corrosion, improve surface properties, and achieve optimum decorative effects. A number of wastes that are hazardous to human health and the environment are commonly generated by the electroplating industry. Conventional physical vapor deposition (PVD) techniques, also known as vacuum coatings, have not been able to compete economically with electroplating in large-scale production. A substantial amount of coating material is wasted on chamber walls and fixtures, causing higher operating costs. Only vacuum-based techniques can deposit most metals and alloys, a large number of compounds and polymers, and ceramic or glassy materials on most types of solid surfaces. Therefore, conventional PVD techniques have established a niche in the semiconductor, optical, electronics, and several other high-technology fields.

SBIR Technology Solution

With support from EPA's SBIR Program, IonEdge Corporation developed dry plating methods that offer a substantial improvement over conventional

PVD techniques. Dry plating can be used for relatively thick (more than $5\ \mu\text{m}$) metal coatings. Dry plating production operation for commercial parts received for coating consists of degreasing, dry plating, and inspection process steps (eliminating several hazardous steps associated with electroplating). Dry plating uses two different methods based on the physical properties of the vapor material deposited: (1) the cadmium coating method; and (2) the chromium, aluminum, and other metals coating method, which is used above the melting point of about 650°C .

In the cadmium coating method, cadmium vapors are reflected from all directions so that the coating is uniformly three-dimensional. This is called zero-waste dry plating (Z-PVD) because there are no deposit accumulations on vessel walls and loading racks. The many advantages of the Z-PVD form of dry plating over conventional PVD include: (1) coating time is reduced from 1.5 hours to 15 minutes, (2) no emission of toxic cadmium particles, (3) no weekly downtime for hazardous wall scraping, (4) no frequent loading-rack chemical stripping, (5) zero waste and hazards, and (6) no embrittlement of high-strength steels.

For higher temperature melting materials, IonEdge developed the cathodic arc coating method. In this method, a target such as chromium is mounted on a cathode. The cathode-target pair is mounted in the vacuum vessel. An electric arc is struck between the vessel walls (anode) and the target (cathode). The arc instantaneously vaporizes a spot on the target and ejects vapors toward parts placed

on a table below the target. The arc spontaneously and randomly moves on the target, vaporizing the target surface continuously. As the arc current is increased, the vaporization and deposition rates increase.

The chromium, aluminum, and other metals method is capable of coating most metals on any vacuum-compatible solid substrate, conductive or nonconductive. This method can be used in decorative, electronics, electromagnetic interference shielding, and cutting-tool markets. Also, this method is technically capable of depositing precious metals such as gold, silver, and platinum.

Commercialization Information

Dry plating has been developed and commercialized by IonEdge Corporation over a period of 10 years. The technology has been developed primarily under funding from the EPA SBIR Program as an



IonEdge's dry plating process is cost competitive with conventional electroplating of various metals. Pictured above are products produced using IonEdge's PVD method.

alternative to existing electroplating for coating various metals on industrial objects. The cadmium coating method has received a U.S. patent, and the chromium, aluminum, and other metals (above 650°C) coating method has a U.S. patent pending; several more patents are anticipated.

The first commercial sale of IonEdge's dry plating process was to an aerospace customer who requested IonEdge to set up three additional processes to complete their plating line. The expanded plating line and processes have been certified for coating aerospace parts, and IonEdge continues to provide coating services to the aerospace industry. In 1 year, more than 50,000 steel components were cadmium dry plated on this plating line. These components now are in service in commercial airplanes, jet fighters, helicopters, and missiles.

IonEdge is preparing a business plan for expanding the dry plating line to increase the throughput by an order of magnitude (in the range of 2,000 parts of 1-inch size/hour). Simultaneously, a full commercial production plating line will be installed for high-volume parts processing (10,000 parts/hour), which will allow customers to evaluate the full economic benefits of the dry plating process.

Company History and Awards

IonEdge Corporation was founded in 1988, with the goal of developing environmentally safe coatings. The Fort Collins, Colorado-based company has a successful track record of inventing, developing, and commercializing novel waste-free coating

technologies. As a result of outstanding technological contributions over the years, IonEdge Corporation was awarded the 1998 Tibbetts National Award for its accomplishments under the SBIR Program. IonEdge also received the 1997 Franklin-

Jefferson award from the SBIR-West Regional Council.



SBIR Impact

- Several wastes such as mercury and chromium that are hazardous to human health and the environment are commonly generated by the electroplating industry.
- IonEdge Corporation developed a relatively simple, environmentally friendly, economical, physical vapor deposition (PVD) dry plating process.
- Dry plating eliminates solid wastes and hazardous chemicals and emissions from the plating process.
- Dry plating is cost competitive with conventional electroplating of chromium, copper, nickel, and various other metals and allows for a cost reduction in PVD coating.

Electrochemical Production of Potassium Ferrate

Lynntech, Inc.

7610 Eastmark Drive
College Station, TX 77840
Telephone: 979-693-0017
<http://www.lynntech.com>

Environmental Problem

Oxidizing agents such as chlorine, chlorine dioxide, hypochlorite, and ozone are used by many industries in the synthesis of fine chemicals and pharmaceuticals, as well as to treat hazardous industrial waste. Many of the currently available oxidants, however, require harmful starting materials and generate harmful byproducts. Because many of these oxidizing agents often have a detrimental impact on public health and the environment, new regulations are targeting many currently used oxidants as a problem that must be addressed. As a result, the industrial sector has been forced to identify, and put in use, environmentally friendly alternatives to traditional oxidizing agents. So far, however, a chemically effective alternative that could be affordably manufactured to meet the industry's needs has not been identified.

SBIR Technology Solution

With support from EPA's SBIR Program, Lynntech, Inc., developed a revolutionary new electrochemical method for the production of high purity, solid potassium ferrate (K_2FeO_4). Ferrate can exchange

any existing oxidizing agents (e.g., potassium permanganate, chlorine, peroxide, ozone, chromates, etc.) and can be applied in a wide range of applications for which environmentally benign oxidizers are needed (e.g., municipal disinfection, sterilization, decontamination, conversion coatings, etc.). Lynntech's process permits the bulk synthesis of highly crystalline K_2FeO_4 at one-tenth the cost of that required using conventional methods. Furthermore, the process is significantly more efficient than conventional electrochemical processes.

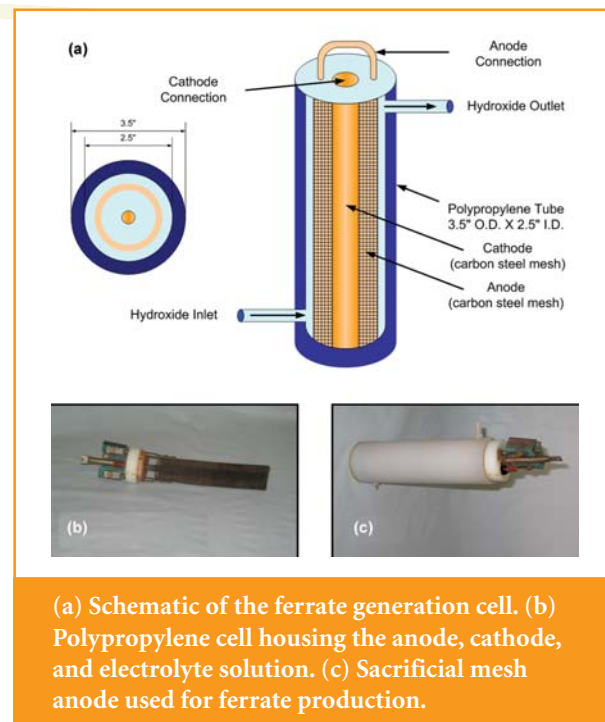
The use of a single chamber cell eliminates the need for expensive proton exchange membranes, and Lynntech's sodium hydroxide/potassium hydroxide electrolyte system allows for single-step production and separation of ferrate. Final ferrate purity is greater than 98%, the electrolyte can be recycled, and no potentially hazardous waste streams are produced. Online magnetic separation allows for continuous processing. Lynntech's process requires only low-cost stock chemicals, effectively lowering the cost of ferrate production.

This new process, which will facilitate the widespread use of ferrate, is cost competitive with other oxidants and is economically scalable for high volume, industrial synthesis. Furthermore, there are important treatment advantages, safety features of handling, and an absence of an environmental impact resulting from ferrate use. The unique single-chamber electrode configuration permits operation at a minimal cell voltage that significantly reduces operational costs and eliminates the need for expensive ion exchange membranes. The puri-

fied salt is nontoxic, environmentally benign, and safe to handle, making it an ideal replacement for traditionally used oxidants.

Commercialization Information

As a result of EPA's funding, Lynntech currently is involved in commercializing the electrochemically produced potassium ferrate salt. In general, the chemical marketplace is always trying to identify new environmentally friendly compounds. The need for low-impact oxidizing chemicals currently is seen in



the following industries: water and wastewater, nuclear and heavy metal waste remediation, organic synthesis (catalysts), metal finishing, and energy storage. Lynntech has teamed with one of the major worldwide chemical suppliers and has submitted samples for chemical quality analysis. Initial results meet the supplier's requirements for purity and Lynntech currently is generating a client base for the potassium ferrate salt product. It is anticipated that initial sales will begin in the next 6 months.

Company History

Lynntech, Inc., incorporated in 1987, is a privately owned company located in College Station, Texas. Lynntech develops scientific and engineering concepts and takes the resulting innovations to the marketplace. The company has a multidisciplinary staff of 153 scientists and engineers. Building on a core area of expertise in electrochemistry, Lynntech has developed products in the emerging markets of fuel cell test systems, proton exchange membrane fuel cells, and electrochemical ozone generations. In addition, Lynntech has successfully commercialized and spunoff two separate companies in the past year.

SBIR Impact

- Due to environmental concerns and stricter regulations, the industrial sector has been forced to adopt environmentally friendly alternatives to traditional oxidizing agents.
- Lynntech, Inc., developed a new electrochemical method for the production of high purity potassium ferrate (K_2FeO_4), an environmentally benign oxidizing agent.
- Lynntech's process permits the bulk synthesis of highly crystalline K_2FeO_4 at one-tenth the cost of conventional methods and is significantly more efficient than conventional electrochemical processes.
- Lynntech has teamed with a major worldwide chemical supplier to market their product.

Environmentally Friendly Conversion Coatings

Lynntech, Inc.

7610 Eastmark Drive
College Station, TX 77840
Telephone: 979-693-0017
<http://www.lynnotech.com>

Environmental Problem

The use of chemical conversion coatings on aluminum alloys to achieve long-term corrosion resistance of painted spacecraft and aircraft structures has found widespread military and commercial applications. The use of chemical conversion coatings that do not contain harmful chemicals is of particular interest to the U.S. Department of Defense, National Aeronautics and Space Administration, and other federal agencies. At the core of the problem is the demonstration of human health effects associated with exposure to hexavalent chromium. Because hexavalent chromium is a human carcinogen, concern exists not only about workplace exposure at high levels, but also environmental exposure at much lower levels.

This concern has produced a cascade of consequences, including: (1) increased liability for claims of workplace and environmental exposure; (2) increased costs for tracking inventories, monitoring emissions, reporting usage of chromium compounds, and disposal of solid wastes containing chromium; and (3) more stringent disposal limits for discharges of dissolved chromium in

wastewater. Therefore, environmentally acceptable alternatives for chromate conversion coatings that exhibit the same corrosion resistance as chromate coatings are needed.

SBIR Technology Solution

With support from EPA's SBIR Program, Lynntech, Inc., developed a fundamentally new conversion coating based on heteropolymolybdates, which belong to a class of compounds known as polyoxometalates. These species are remarkable for their molecular and electronic structural diversity. The use of heteropolymolybdates represents a significant departure from the use of molybdate ($\text{Mo}^{6+}\text{O}_4^{2-}$) as a conversion coating.

Tests of coatings prepared from formulations consisting of heteropolymolybdates and several important additives demonstrate exceptional corrosion resistance. Some coatings outperformed the chromate-based conversion coatings in electrochemical corrosion-resistance tests and passed a standard 14-day salt fog test.

The key to this technology is heteropolymolybdates. The primary effect of the hetero atom is an effective transformation of Mo(III) and Mo(IV) to stable Mo(V) and Mo(VI), thereby enhancing the formulation of conversion coatings on aluminum alloys. This unique characteristic provides an elusive self-healing capability. Surface spectroscopic studies indicate the presence of a stable reservoir of Mo(VI) in the oxide layer that acts in an analogous way to Cr(VI).

Commercialization Information

As a result of EPA's SBIR funding, Lynntech has made significant headway towards commercialization of this technology. Lynntech's conversion coatings are designed to be environmentally friendly, which lowers cost by eliminating hazardous waste disposal fees. Lynntech established collaborations with one of the leading aerospace contractors, as well as a leading supplier in the metal finishing



Aluminum 2024-T3 panels prepared with Lynntech conversion coating. No pitting is observed after 336 hours of salt fog spray testing.

industry. Through these collaborations, the company was invited to participate in a national study in search of chromium alternatives funded by the National Center for Manufacturing Sciences. In this study, Lynntech demonstrated two formulations that have the capability and potential to successfully replace chromium-based conversion coatings.

Company History

Lynntech, Inc., incorporated in 1987, is a privately owned technology development company located in College Station, Texas. Lynntech develops scientific and engineering concepts and takes the resulting innovations to the marketplace. The company has a multidisciplinary staff of 153 scientists and engineers. Building on a core area of expertise in electrochemistry, the company has developed products in the emerging markets of fuel cell test systems, proton exchange membrane fuel cells, and electrochemical ozone generation. In addition, Lynntech has successfully spunoff two separate companies in the past year.

SBIR Impact

- Because of the negative health effects associated with hexavalent chromium, alternatives for chromate conversion coatings are needed.
- Lynntech developed new environmentally friendly coatings based on heteropolymolybdates that outperformed chromate-based coatings.
- These coatings provide long-term corrosion resistance; can be applied by painting, dipping, or spraying; are compatible with existing processes; and lower costs by eliminating hazardous waste disposal fees.
- Lynntech is collaborating with a leading aerospace contractor and a supplier in the metal finishing industry to move this technology toward commercialization.

Recovery and Recycling of Valuable Feedstock From Plant Reactor Purge Gas

Membrane Technology and Research, Inc.

1360 Willow Road, Suite 103
Menlo Park, CA 94025-1516
Telephone: 650-328-2228
<http://www.mtrinc.com>

Environmental Problem

Oxygen-oxidation processes are used to produce a number of important chemical intermediates by selective catalytic oxidation of hydrocarbons in a reactor. Products include ethylene oxide, propylene oxide, vinyl acetate, and vinyl chloride, which are used to make major commodity and engineering polymers. All of these processes include an inert gas purge stream from the reactor. This purge stream is required to remove argon, which enters the reactor as a contaminant in the oxygen feed. Because argon does not react, the concentration in the reactor builds up unless it is purged. Currently, the purge gas is flared, resulting in a loss of approximately 450 million lb/year of the hydrocarbon feedstocks used in these processes in the United States.

For example, during the production of ethylene oxide, about 16 lb of ethylene are lost in the argon purge stream per ton of ethylene oxide produced (about 3.5 million tons of ethylene oxide are produced annually in the United States, representing a loss of 56 million lb/year of ethylene at a value of \$8.4 million per year). Incineration of the purge stream produces 440 million lb/year of carbon

dioxide plus the accompanying amounts of nitrogen oxides (NO_x). The argon purge stream clearly represents an important resource recovery and pollution reduction opportunity.

SBIR Technology Solution

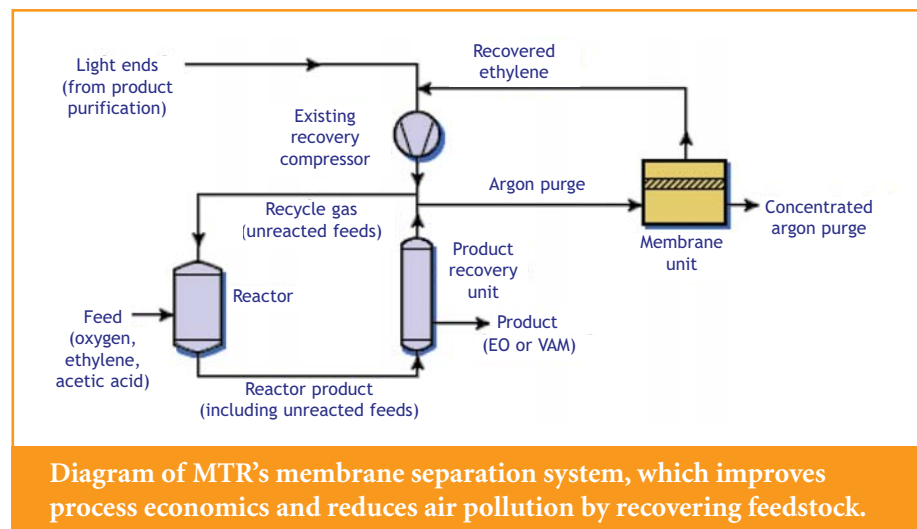
With support from EPA's SBIR Program, Membrane Technology and Research, Inc. (MTR), developed a membrane separation system to improve process economics and reduce air pollution by recovering feedstock. Selective membranes were developed to separate the hydrocarbon feedstock from the argon, so that the feedstock can be recycled to the reactor. The value of the recovered hydrocarbon is high, so a process payback time of 1-2 years is possible.

Ethylene-selective and argon-selective membranes can be used to economically recover ethylene from the argon purge stream from oxygen-oxidation reactors. Processes based on MTR's ethylene-selective silicone rubber membrane are superior to those using argon-selective membranes and can achieve 80% ethylene recovery with a system payback time of less than 1 year, provided sufficient compressor capacity is available in the plant. If additional compressors

are required, MTR's novel perfluorinated, argon-selective glassy membranes could be used to achieve a shorter payback period.

Commercialization Information

The annual revenue generated (ethylene value minus operating costs) by the membrane system is between \$200,000 and \$400,000 per year for a typical ethylene oxide plant. The addition of the membrane system is a simple retrofit and payback time typically is less than 2 years. To date, the development of this technology has resulted in the sale of three systems worldwide to recover ethylene from the argon purge stream in ethylene oxide and vinyl acetate plants. The current installed ethylene recovery capacity in these three systems is 2,100 tons/year.



Company History and Awards

MTR develops membranes, membrane modules, and membrane processes for industrial separations. The company was founded in 1982 as a research and development company and has been supplying membranes for commercial applications since 1990. Capabilities include membrane and module manufacturing, process and system design, project engineering, and commissioning services. MTR's administrative, research, and manufacturing facilities are located in Menlo Park, California. The company has sales offices in Houston, Texas, and Brussels, Belgium.

MTR's custom-designed membrane systems are employed at more than 100 petrochemical and natural gas processing plants throughout the world. The company's primary product lines include: VaporSep® technology for separating hydrocarbons from air and nitrogen, membrane-based natural gas treatment processes to control the hydrocarbon dewpoint of natural gas by removing higher (C3+) hydrocarbons, and PerVap® water treatment technology to recover flavor and aroma compounds in the food industry and to remove residual organic solvent contaminants from fine chemical process streams.



MTR received the 1997 Kirkpatrick Chemical Engineering Achievement Award for the successful commercialization of Vapor-Sep® membrane technology. The award, which is sponsored by *Chemical Engineering* magazine, honors

the best chemical engineering technology commercialized during the preceding 2 years.

SBIR Impact

- The purge stream from industrial reactors represents an important resource recovery and pollution reduction opportunity.
- Membrane Technology and Research, Inc. (MTR) developed a membrane separation system to improve process economics and reduce air pollution by recovering and recycling feedstock from the purge stream.
- The annual revenue generated by using the membrane system to recover feedstock is between \$200,000 and \$400,000 annually for a typical ethylene oxide plant.
- Three MTR systems are in use worldwide to recover ethylene from the argon purge stream in ethylene oxide and vinyl acetate plants, with an ethylene recovery capacity of 2,100 tons per year.

High-Speed Identification and Sorting of Plastic Resin Flake for Recycling

National Recovery Technologies, Inc.

566 Mainstream Drive, Suite 300
Nashville, TN 37228-1223
Telephone: 615-734-6400
<http://www.nrt-inc.com>

Environmental Problem

Postconsumer plastics have become a tremendous burden on waste disposal systems. Transport and disposal to landfills is very expensive because of the light weight and large volume. Disposal of plastics in landfills can be considered environmentally unsound because of their high resistance to degradation over time. EPA has recommended recycling of plastics as a preferred approach over incineration and landfill disposal. High-end recycled plastic resins typically are combined with virgin resins and used in manufacturing new products. To use these resins in new products, however, it is extremely important that the flake product during the recycling process be as pure and clean as possible. A large portion of recycled plastics is from postconsumer packaging materials, many of which contain mixed polymers. Mixed polymers do not recycle well, so they must be cleanly sorted to have a wide range of uses.

SBIR Technology Solution

With support from EPA's SBIR Program, National Recovery Technologies, Inc. (NRT), developed

FlakeSort™, a sorting system used for preparing a high-quality plastics resin material from recovered postconsumer plastics packaging materials. The FlakeSort™ system is the world's first sorting system designed to make high-accuracy, small particle, polymer-specific identifications and sorts in industrial feed streams of polymer flakes or pellets.

The FlakeSort™ system is a field-tested, industrial duty, computerized process combining leading-edge, polymer-specific infrared spectroscopic detection with proprietary high-speed identification algorithms to scan and classify polymer flakes or pellets fed through the unit at high volumes. The process employs precision air jet ejection to sort particles of a selected polymer or polymers from the feed stream using a binary sort approach. High-speed proprietary polymer-specific infrared spectroscopic sensing technology provides significantly improved performance over nonspecific technologies such as X-ray-based systems.

The system uses an array of specialized wavelength-dispersive infrared detectors to read spectral characteristics of plastic flakes as they pass at high speed through a detection zone. The infrared spectral information derived by the detectors is fed to an industrialized computing system for digitization and processing. The technology can spectrally measure and sort contaminants from up to 15,000 plastic flakes per second. The identification and sorting technology is independent of flake thickness, resulting in highly accurate performance. The system is designed for ease of use and incorporates a color touchscreen operator interface for presenting

operating status and diagnostics data and for accepting operator input. Additionally, the system incorporates modem connectivity, providing worldwide factory diagnostics and software upgrades.

Commercialization Information

The first FlakeSort™ system was sold and installed in the Midwest to NRT's Phase III partner during participation in the SBIR Program. This installation has provided a valuable test and evaluation site for the technology in a production setting. Lessons learned from this installation led to a more user-friendly second-generation product. These new units now are in operation and give excellent performance. Data show a measured 93%



Second-generation FlakeSort™ unit installed in a recycling facility near Venice, Italy.

reduction of polyvinyl chloride contamination in product resin from facilities that have used the system. The company has sold installations of the Flake-Sort™ system to plastics processing facilities in the United States and Europe. These systems operate on a continuous basis and each processes nominally 5,000 lb/hour of polyethylene terephthalate (PET) flakes.

Company History and Awards

NRT is a major worldwide supplier of automated bottle sorting systems using X-ray and infrared spectroscopic technology. Located in Nashville, Tennessee, NRT was formed in 1981 and has 14 full-time employees. The company owns or holds exclusive licenses for 21 U.S. patents and 5 foreign patents. Numerous other patents are pending or are in the application stage. NRT has won various awards, including EPA's Award for Outstanding Achievement by a Small Business Enterprise in 1991, and a Tibbett's Award for "Recognition of Outstanding Contributions to the SBIR Program" in 1996.



The majority of the world's recycled PET plastics are processed through sorting machines developed, manufactured, installed, and serviced by NRT. NRT inspection equipment is in operation at facilities in the United States, Canada, Mexico, Europe, Japan, and Australia. The company has agents in Europe and Japan, with approximately one-half of NRT's business being export.

SBIR Impact

- A large portion of recycled plastics is from postconsumer packaging materials that contain mixed polymers, which do not recycle well.
- National Recovery Technologies, Inc. (NRT) developed the world's first sorting system designed to make high-accuracy, small particle, polymer-specific identifications and sorts in industrial feed streams of polymer flakes or pellets.
- The FlakeSort™ system can spectrally measure and sort contaminants from up to 15,000 plastic flakes per second independent of flake thickness, resulting in highly accurate performance.
- The majority of the world's polyethylene terephthalate (PET) plastics are processed through sorting machines developed, manufactured, installed, and serviced by NRT.

Hand-Held Lead Paint Analyzer

NITON LLC

900 Middlesex Turnpike, Building 8
Billerica, MA 01821
Telephone: 978-670-7460
<http://www.niton.com>

Environmental Problem

Lead in paint has been associated with a number of environmental and health risks. Exposure of pregnant women to lead can result in premature birth, low birthweight, or spontaneous abortion. Lead exposure in infants and young children is correlated with decreased intelligence scores, and may lead to decelerated growth and hearing problems. Also, exposure of adults and children to high levels of lead may cause brain and kidney damage.

Lead-contaminated soil at residential and industrial sites poses numerous environmental, safety, and remediation problems. Depending on the source(s) of lead, the contamination may be highly localized or distributed extensively about a property. For example, if the main source of lead is external house paint, then the lead in soil is expected to be highest near the dripline of the house and decrease rapidly away from the structure. Conversely, if the lead source is from a nearby industry or large lead abatement project, the soil contamination may be pervasive throughout the property. Only a thorough site assessment involving a detailed sampling pattern will produce an accurate contamination profile of such sites.

SBIR Technology Solution

With support from EPA's SBIR Program, NITON LLC developed and commercialized a unique instrument to detect lead in paint, soil, and air. In 1994, NITON introduced the first ever one-piece X-ray fluorescence (XRF) spectrometer, the NITON XL-309 Lead Paint Analyzer. In 2004, NITON introduced the newest generation of this device, the XLp 300 Series Lead Analyzer. This portable, hand-held analyzer provides rapid lead analysis for inspections, risk assessments, and screening.

The NITON XLp 300 Series Lead Analyzer is compact, lightweight, and battery operated. It produces rapid, accurate measurements of lead and can be equipped with the capability to be used for numerous applications, including: (1) lead in paint, independent of the composition, thickness, and substrate of the paint; (2) lead in soil for site characterization, clearance screening, and remediation quality control; (3) lead in dust wipes for lead inspection, risk assessment, and site clearance; and (4) lead on filters for tracking workers' exposure to harmful airborne lead. The device weighs 3 lb, including battery pack, and has an integrated touchscreen display.

The device uses a ^{109}Cd source to measure the concentration of lead in paint, even when covered by 50 or more layers of non-lead paint of unknown thickness and composition. This results in no substrate correction and simple, point-and-shoot operation on any surface. Positive/negative classifications are displayed automatically when 95 percent confi-

dence is achieved, and the results are continuously displayed and updated. In some cases, results are obtained in as little as 1 second with no inconclusive ranges. The XLp 300 Series Lead Analyzer complies with both National Institute for Occupational Safety and Health (NIOSH) Method 7702 and Occupational Safety and Health Administration (OSHA) OSA 1 for airborne-lead monitoring and with EPA Method 6200 for lead-in-soil screening.

NITON participated in the "Evaluation of Field Portable Measurement Technologies for Lead in Dust Wipes" conducted by EPA's Environmental Technology Verification (ETV) Program to evaluate



NITON's XLp 300 Series Lead Analyzer, pictured above, can measure the concentration of lead in paint even when covered by 50 or more layers of non-lead paint of unknown thickness and composition.

the performance of commercially available field analytical technologies for analyzing dust wipes for lead. Data from the XL-300 series showed excellent agreement with the estimated lead value for the range of samples analyzed, with very few false negative results.

Commercialization Information

Since receiving SBIR funding, NITON's lead paint analyzers have become the industry standard for lead-in-paint analysis, and the devices have evolved into complete lead analyzers. In addition to its XL-309 lead analyzer, NITON manufactures XLI and XLT series XRF analyzers for a wide variety of analysis applications. To date, more than 6,000 portable NITON analyzers are in use every day worldwide in applications ranging from lead paint detection to quality control of alloy materials in manufacturing. NITON ships more than 1,000 new instruments each year.

Companies using NITON analyzers include Northrup Grumman Space Technology, Lockheed Martin Aerospace, Boeing Aerospace, Exxon/Exxon Mobil, British Petroleum, Chevron/Texaco, Eli Lilly, Sanyo Electronics, and General Motors. A number of government agencies (e.g., EPA, NIOSH, OSHA) also are using NITON's devices.

Company History and Awards

NITON LLC was founded in 1987 and has offices in Billerica, Massachusetts; North Kingstown, Rhode Island; Bend, Oregon; Munich, Germany; and Hong Kong. The company was a finalist for

the 1994 Discovery Award and was awarded its first R&D 100 Award for its significance in miniaturization and mainstreaming of portable XRF technology, based on the XL-309. NITON also received the Lead Tech Product of the Year Award in 1995, and won another R&D 100 Award in 2003 for its XLT and XLI analyzers. NITON became

the largest portable XRF manufacturer in the world, and based in large part on the success of its analyzers, the company was purchased by Thermo Electron Corporation in 2005.

SBIR Impact

- Lead in paint has been associated with a number of environmental and health risks, with pregnant women and young children most at risk.
- NITON developed and commercialized a portable, handheld analyzer that provides rapid lead analysis for inspections, risk assessments, and screening.
- NITON's XLP 300 Series Lead Analyzer uses a ¹⁰⁹Cd source to measure the concentration of lead in paint, even when covered by 50 or more layers of non-lead paint of unknown thickness and composition.
- Since receiving SBIR funding, NITON's lead paint analyzers have become the industry standard for lead-in-paint analysis, and more than 6,000 portable NITON analyzers are in use every day worldwide.

Affordable Manufacturing of High Surface Area Iron Powder for Remediation

OnMaterials, LLC

1425 Russ Boulevard, Suite T-107E

San Diego, CA 92101

Telephone: 760-670-4530

<http://www.z-loy.com>

Environmental Problem

Toxic chemicals contaminate soil and groundwater in numerous locations worldwide. These compounds, including chlorinated hydrocarbons and transition metal compounds, are now affecting aquifers that supply drinking water. Adverse health effects associated with exposure to these chemical compounds include damage to the nervous system, liver dysfunction, and an increased cancer risk.

Traditional remediation protocols often are prohibitively expensive, leave behind toxic byproducts, and are difficult to implement, particularly when addressing a deeply embedded contaminant phase. Alternative remediation techniques involve treating the contaminant phase in the subsurface. These *in situ* methods include the injection of zero-valent metal particles, typically iron, into the ground. The metal sustains an electrochemical reaction that converts the toxic materials into innocuous products. Commercially available iron particles typically are coarse, with dimensions of a few micrometers to a millimeter or larger. When injected underground, these large metal particles are held back by soil particles before they reach the contaminant phase.

SBIR Technology Solution

With support from EPA's SBIR Program, OnMaterials, LLC, developed a scalable manufacturing process to produce affordable, submicrometer and nanocrystalline zero-valent metal powders. This work led to the development of Z-Loy™, a non-aqueous zero-valent metal suspension. The discrete particle size is advantageous because other nanocrystalline zero-valent iron (NZVI) particles, prepared by chemical precipitation or thermal reduction, typically are aggregated into larger particles that hinder underground mobility.

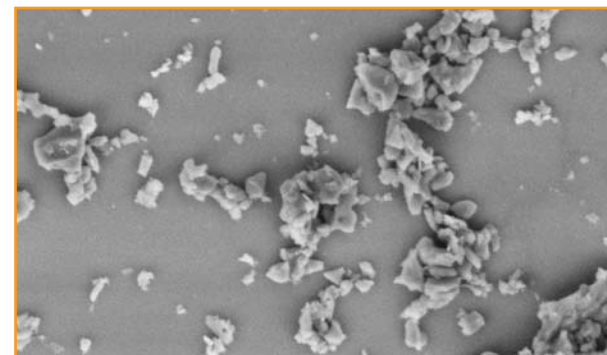
Engineered and manufactured in the United States, Z-Loy™ provides the remediation community a zero-valent metal with small, discrete particles that enable underground mobility to remediate deeply embedded substances. Z-Loy™ particles have highly reactive surfaces that enable the rapid elimination of toxic substances without producing toxic daughter products. Z-Loy™ offers a metallic surface area of approximately 15 m²/g; this provides exceptional reactivity because reaction kinetics scale with surface area. A first-order measure of reactivity is obtained by making a 10 g/L aqueous suspension (10 g particulate matter in 1 L of water) and measuring the oxygen reduction potential (ORP). ORP quantifies the ability of the metal particles to accomplish electrochemical reduction; a large negative value is indicative of a reactive material. Due to its high metallic surface area, Z-Loy™ exhibits values between -800 and -900 mV as compared to approximately -200 mV for conventional iron pow-

ders. These values provide a nonincremental improvement in reduction potential.

Laboratory microcosm studies using gas chromatography show the rapid and near-complete elimination of aqueous-phase chlorinated hydrocarbons from very concentrated solutions. Additionally, the resulting reaction products consist primarily of innocuous, nonchlorinated gaseous hydrocarbons with little or no toxic chlorinated byproducts formed.

Commercialization Information

The exceptional reactivity of Z-Loy™ has been independently corroborated by prospective customers in laboratory experiments. This has led to subsurface injections, the largest of which occurred



Scanning electron microscope micrograph showing the discrete, submicrometer and nanocrystalline particles of Z-Loy™ zero-valent iron powder.

at a 1,1,1-trichloroethane-contaminated facility in Edison, New Jersey. This pilot injection used pneumatic fracturing in fractured bedrock and pressurized injection in overburden material to emplace 1,400 lb of Z-Loy™ in the subsurface. Underground mobility was verified by the visual observation of iron at monitoring wells 15 feet away from the injection site at two vertical intervals. This far exceeded the 8-10 feet expectations, and thus diluted the 2-3 g/L targeted Z-Loy™ loading. Even so, electrochemical activity was verified by the reduction of ORP from slightly positive values to nearly -400 mV at a monitoring well approximately 35 feet from the injection point. A second phase injection of 8,000 lb at the Edison site is scheduled. This will be one of the largest injections of NZVI to date.

OnMaterials has tailored the Z-Loy™ product line to meet particular remediation requirements. Three different categories of zero-valent iron materials currently are available with properties engineered to address site-specific needs: Z-Loy™, Z-Loy™ Flake, and Z-Loy™ LA. Presently, synthesis capacity is about 1 ton per day and will increase as demand requires.

Company History

OnMaterials, LLC, a privately held company, specializes in the synthesis and processing of technical powders, including ceramic and metal nanopowders. The company was formed in 2000 and offers technical support services designed to minimize

risk and reduce costs associated with the development and implementation of custom applications, products, and processes. OnMaterials' research and

development operations are located in San Diego, California, and its Z-Loy™ manufacturing operation is located in Longmont, Colorado.

SBIR Impact

- Toxic chemical substances, including chlorinated hydrocarbons and transition metal compounds, contaminate soil and aquifers that supply drinking water.
- OnMaterials developed Z-Loy™, a nonaqueous zero-valent metal suspension that enables underground remediation of toxic substances.
- Current synthesis capacity is approximately 1 ton per day.
- OnMaterials has successfully emplaced 1,400 lb of Z-Loy™ at a contaminated site in New Jersey. A second phase injection of 8,000 lb at this site is scheduled.

A Novel Liquid and Gas Pipeline Leak Detection System

Ophir Corporation

10184 W. Belleview Avenue, Suite 200

Littleton, CO 80127

Telephone: 303-933-2200

<http://www.ophir.com>

Environmental Problem

Methane is one of the most serious greenhouse gases contributing to irreversible climate change. The contribution of methane emissions from leaking pipelines and the expected increased throughput through the pipelines prompted the natural gas industry to set a goal of reducing emissions by 50% by 2010. The integrity of the pipelines is critical to the safety of the gas transportation infrastructure. The U.S. natural gas pipeline industry spends approximately \$50 million annually to comply with the U.S. Department of Transportation's increasingly stringent inspection regulations. Current legislation requires that more than 300,000 miles of transmission pipeline be inspected at least once a year. The reduction of detrimental greenhouse gas emissions and the compliance with pipeline integrity management regulations may be attained by using a device to detect liquid and gas pipeline leaks.

SBIR Technology Solution

With support from EPA's SBIR Program, Ophir Corporation has developed and demonstrated an optical remote sensing product, duoThane[®], for

detecting and potentially reducing the emission of methane from fossil fuel sources such as natural gas and oil processing as well as from production and transmission operations. duoThane[®] independently and simultaneously detects methane and ethane, the primary constituents of natural gas.

Ethane emissions provide an excellent means of detecting and locating leaks in crude oil pipelines. The system has sufficient speed and sensitivity to enable cost-effective stationary surveys over gas and liquid pipelines. At a fenceline monitoring distance of 600 m, the duoThane[®] detection sensitivity is 50 ppb for methane and 33 ppb for ethane.

The duoThane[®] sensor employs the optical technique of active gas correlation radiometry, which uses an active infrared source and an optical, spectral correlation detection method. The duoThane[®] system can be employed in a stationary scenario directly over the transmission pipeline or downwind of the pipeline. The system also can be used to detect leaks from pipelines constructed under waterways. Currently, there is no efficient method for monitoring liquid pipeline leaks that emanate from pipes under waterways such as streams and rivers.

The duoThane[®] system also has been demonstrated for liquid pipeline application through an oil-on-water test on natural oil seeps in the Santa Barbara Channel off the coast of California. The ship-mounted duoThane[®] system successfully detected both methane and ethane in this demonstration.

duoThane[®] significantly reduces the costs associated with natural gas pipeline inspections, provides superior leak detection, and results in fewer false alarms than achievable with the current industry-standard inspection methods. The benefits of this remote sensing system are threefold: (1) methane emission reduction, (2) improved pipeline safety, and (3) reduced gas and liquid industry pipeline operating costs.

Commercialization Information

There is both national and international interest in the ground-based duoThane[®] system, as well as in an airborne natural gas leak detection device developed through U.S. Department of Energy (DOE) funding. duoThane[®] has been successfully demonstrated on operational natural gas transmission



duoThane[®] transmitter and receiver mounted on an oil spill clean-up vessel demonstrating the effectiveness of detection of leaks from pipelines that run under waterways.

pipelines with El Paso Pipeline Group and Williston Basin Interstate Pipeline Co., Inc. The sensor successfully detected the presence of methane and ethane in the case of a compromised pipeline and in calibrated leak scenarios.

Alyeska Pipeline Services Company, a large oil pipeline services company, co-funded a demonstration of Ophir's technology with the EPA. Alyeska continues to show interest in this system for the detection of leaks from pipelines under waterways. In addition, Ophir presented this duoThane® system for the liquid pipeline leak detection application at the Alaska Department of Environment and Conservation Best Available Technologies Conference in May 2004. Ophir is targeting this market by instrumenting aircraft with duoThane® to enable leak detection measurements for the lines that currently are inspected visually.

Company History

Ophir Corporation, based in Littleton, Colorado, and founded in 1980, focuses on research, development, and production of optical remote-sensing instrumentation for the atmospheric sciences. Ophir has been very successful in commercializing sensor technologies through the SBIR Program, and the company has commercialized optical, remote-sensing technologies with gross revenue from commercial sales exceeding \$45 million. Ophir's primary products are the Pilot Alert System (a laser-based radar system currently flown on the B-2

Stealth Bomber) and duoThane®. Ophir has been recognized for outstanding performance by the U.S. Small Business Administration, the Small Business

High Technology Institute, and the Northrop Grumman Corporation.

SBIR Impact

- Methane is one of the most serious greenhouse gases contributing to irreversible climate change.
- Ophir Corporation developed and demonstrated duoThane® for detecting methane emissions from leaking pipelines.
- duoThane® has the potential to reduce methane emissions, improve pipeline safety, and reduce gas and liquid industry pipeline operating costs.
- The system also can be used to detect leaks from pipelines constructed under waterways.

Innovative Ultraviolet Light Source for Disinfection of Drinking Water

Phoenix Science & Technology, Inc.

27 Industrial Avenue

Chelmsford, MA 01824

Telephone: 978-367-0232

<http://www.phoenixsandt.com>

Environmental Problem

Water contamination causes a wide range of diseases. The main objective of disinfecting drinking water is to reduce the number of waterborne pathogenic organisms to safe levels and lower the risk of exposing the public to disease. Although disinfection methods range from chemical to physical, the many disadvantages of chemical disinfectants, specifically chlorine, have led to increased interest and use of ultraviolet (UV) light as an alternative. The use of high doses of chlorine to disinfect water leads to the production of carcinogenic and mutagenic chloro-organics. These chloro-organics persist in the environment and are not destroyed by dechlorination methods that reduce chlorine residuals. Consequently, alternative disinfection techniques are becoming more widely used. Of the more than 200,000 community drinking water systems in the United States and Canada, more than 2,000 use UV disinfection systems.

UV light disinfection is a well-established technology; mercury lamps have been commercially available for decades. The presence of mercury in these lamps, however, is an environmental concern.

Additionally, the cost of the high doses of electrical power required to operate mercury UV lamps reduces the attractiveness of using this technology. A cost-effective, environmentally friendly method of disinfecting drinking water is needed.

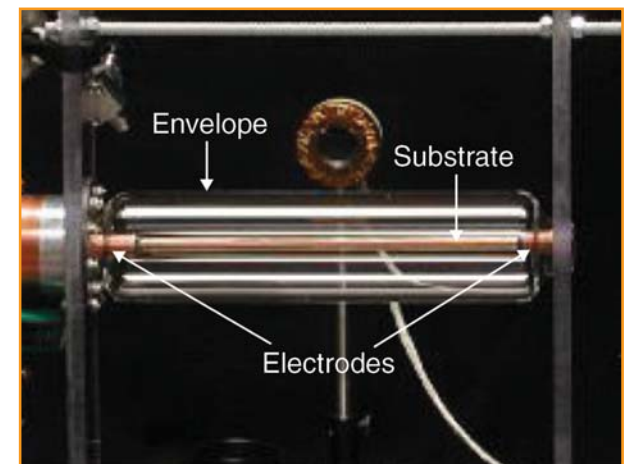
SBIR Technology Solution

With support EPA's SBIR Program, Phoenix Science & Technology, Inc. (PS&T), demonstrated the efficacy of its patented pulsed "Surface Discharge" (SD) lamp to improve disinfection of drinking water. In an SD lamp, a high-power electrical pulse is discharged along the surface of a dielectric substrate, generating a light-emitting plasma along its surface. The SD lamp is free of mercury, a major concern with commercial UV lamps currently in use, and has a higher inherent UV efficiency than medium-pressure mercury lamps, so that electrical costs of a commercial system will be less.

UV light inactivates microorganisms by causing photochemical damage to nucleic acids. Absorption of UV energy, mostly in the 220-300 nm wavelength range, produces new bonds between adjacent nucleotides, creating double molecules or dimmers that prevent replication and result in cell death. The amount of cell damage depends on the dose of UV energy absorbed by a microorganism and its resistance to UV light.

Tests conducted as part of this SBIR project in collaboration with water treatment researchers at Duke University show that, in addition to higher UV efficiency, the SD lamp has a significantly higher

inactivation rate, on a per-dose basis. Research to date indicates that this is due to a combination of the high intensity of the SD light pulses, which can produce thermal effects, along with spectral differences in the UV output. The combination of higher inherent UV efficiency and higher inactivation rates of the SD lamp make it especially suitable for disinfecting drinking water. This has the potential to make UV disinfection practical for use with all microbes.



Phoenix Science & Technology, Inc.'s pulsed surface discharge lamp (shown above) disinfects drinking water using a pulsed electric discharge that generates a light-emitting plasma along the surface of a substrate.

Commercialization Information

PS&T is collaborating with major water treatment companies to use SD UV lamps as replacements for commercial mercury lamps. Trojan Technologies, Inc., has provided mercury lamps for use in comparative testing and is working with PS&T to implement a cost-effective SD lamp system into their product line. The current SD lamp has been designed to allow direct replacement in existing water treatment systems. The next steps are to develop a reactor optimized for the SD lamp's UV spectrum and high intensity, demonstrate disinfection of drinking water, and develop a commercial prototype.

Company History

Phoenix Science & Technology, Inc., was founded in 1994 and is located in Chelmsford, Massachusetts. The company carries out research and develops innovative pulsed light and sound sources, as well as related pulse power components. PS&T works with leading researchers in application areas to develop a quantitative scientific basis for the performance of its technologies. PS&T licenses its technology, collaborating with manufacturers and end users to commercialize its technologies.

PS&T employs 12 people and has a fully equipped laboratory where it has developed underwater acoustic sources, the SD lamp in an Advance Technology Program sponsored by the National

Institute of Standards and Technology, and used the lamp for paint stripping and water treatment in programs sponsored by EPA, the U.S. Department

of Housing and Urban Development, and the National Science Foundation.

SBIR Impact

- Although drinking water disinfection methods range from chemical to physical, the many disadvantages of chemical disinfectants, specifically chlorine, have led to increased interest in the use of ultraviolet (UV) light as an alternative.
- Phoenix Science & Technology, Inc. (PS&T), demonstrated improved disinfection of drinking water with its new pulsed surface discharge (SD) UV lamp.
- The new lamp inactivates standard microbes with one-half to two-thirds the dose needed from standard UV mercury lamps, is mercury free, and may lower the cost of disinfecting drinking water.
- PS&T is collaborating with major water treatment companies to use SD UV lamps as a replacement for commercial mercury lamps.

Vehicle-Mounted Natural Gas Leak Detector

Physical Sciences Inc.

20 New England Business Center
Andover, MA 01810
Telephone: 978-689-0003
<http://www.psicorp.com>

Environmental Problem

In the United States, significant resources are devoted annually to leak inspection of natural gas transmission and distribution pipelines. Leakage surveys are critical to maintaining the integrity and safety of the nation's pipelines and gas distribution systems. Gas utility companies are actively seeking remote detection technology to improve the efficiency and reduce maintenance costs of leak detection. To perform detection surveys, a service person must enter a property and walk the entire length of the service line (from the main to the service entry point of the building). If these surveys could be done at a distance, either from the sidewalk or as a drive-by operation, significant savings could be achieved. Mobile leak detector technology would help the United States prepare to address a large, aging, and expanding natural gas pipeline system.

SBIR Technology Solution

With support from EPA's SBIR Program, the U.S. Department of Energy, Northeast Gas Association, and Health Consultants, Inc., Physical Sciences Inc. (PSI) developed the Remote Methane Leak

Detector (RMLD). This technology uses an optical detector that does not need to be located within the gas leak plume. The leak detection device is based on tunable diode laser absorption spectroscopy.

Remote detection of specific gases is achieved by projecting a laser beam through the air to a target (such as grass, foliage, or buildings). A fraction of the laser beam is scattered from the surface and returned back to the source where it is collected and focused onto a detector. Gas molecules in the air path will absorb specific frequencies of light in a unique pattern as dictated by their structure and spectroscopy. Because the laser beam can be easily scanned over the survey area, the presence of leaks can be quickly determined or eliminated.

The RMLD is a handheld device intended for use in walking pipeline leak surveys. The device, about the size of a breadbox, also can be mounted on top of a vehicle. The laser beam can be projected from the road or sidewalk above the path of the pipeline to the home and indicate the presence or absence of gas. If gas is detected, the survey crew then would walk the length of the pipeline to locate the leak. Because most surveys are negative, the tool would eliminate the need to walk along these pipes, reducing survey times (it takes only seconds to make each measurement) and enabling more efficient use of manpower.

The RMLD can be used to remotely determine the presence of natural gas inside a building or confined space. The RMLD also could be a valuable

tool for use by first responders to determine if an area or building is safe for occupation or to locate the source of a leak after a natural disaster causes a pipeline rupture. PSI recently conducted a successful test of its prototype mobile natural gas detector, which demonstrated the ability to spot natural gas leaks from a distance of up to 30 feet from a vehicle moving at speeds approaching 20 mph. The device can detect methane plumes with concentrations comparable to those of a pilot light as far away as 100 feet. The RMLD has been successful at locating all types of leaks under a variety of field conditions.



PSI's handheld remote natural gas detector can be used for walking pipeline leak surveys and also can operate from a moving vehicle.

Commercialization Information

The prospect of replacing currently available gas detectors that deploy technologies such as flame ionization units and combustible gas indicators with a laser-based device that can rapidly survey off-road pipelines has great appeal to leak detection companies. A conservative estimate indicates that members of NYSEARCH—a premier natural gas research, development, and demonstration program—can save more than \$1 million annually if a remote gas leak detector is developed and implemented. Preliminary estimates for walking survey operations have projected savings in the range of 25-40%. Health Consultants, Inc., and PSI worked together to build pre-commercial instruments in the spring of 2004, and NYSEARCH companies field tested the device. Health Consultants, Inc., and PSI will begin production of the RMLD in 2005, and will market the detector to the natural gas industry. Health Consultants, Inc., estimates that 3,000 units, valued at approximately \$50 million, will be sold by 2010. This SBIR project has led to more than \$1 million in additional funding to bring this technology to the commercial market.

Company History

Founded in 1973, PSI is located in Andover, Massachusetts, 30 minutes north of Boston. The company has satellite offices in Sterling, Virginia, and San Ramon, California. PSI generates approximately \$25 million in revenue annually, with 80% of this revenue stemming from contracts with the U.S. government. The company's core technologies have been developed with more than \$250 million

of federal and industrial funding. The SBIR Program has played a pivotal role in PSI's technical and commercial success, and has been responsible for a family of intelligent instrumentation products based on proprietary electro-optical and electromechanical technologies. PSI focuses on providing contract

research and development services in a variety of technical areas to both government and commercial customers. The company develops advanced technologies for aerospace, energy, environmental, manufacturing, and medical applications.

SBIR Impact

- Significant resources are devoted annually to leak inspection of natural gas transmission and distribution pipelines.
- PSI developed the Remote Methane Leak Detector (RMLD), which extends the range of remote detection of natural gas leaks in distribution and transmission pipelines.
- The RMLD can identify natural gas leaks from a distance of up to 30 feet from a vehicle moving at speeds approaching 20 mph.
- The technology could save one group of gas companies more than \$1 million annually.

Portable Field Decontamination Unit

PlasmaSol Corporation

614 River Street
Hoboken, NJ 07030
Telephone: 201-216-8680
<http://www.plasmasol.com>

Environmental Problem

The ability to clean organic contaminants from a surface has many applications, ranging from semiconductor manufacturing to homeland defense, where surface decontamination following a chemical or biological attack is critical. Surfaces that potentially need to be cleaned include circuit boards, historical and legal documents, art and architecture, and medical instruments. A convenient method of cleaning surfaces at the microscopic level, however, without damaging them or using harsh, dangerous, or environmentally unfriendly chemicals, is a challenging problem. Plasma cleaning is one method of removing organic contaminants or oxidation layers, but traditional systems are often complicated, capital-intensive, and require exposure to dangerous chemicals.

SBIR Technology Solution

With support from EPA's SBIR Program, PlasmaSol Corporation developed a surface contaminant destruction system that sterilizes surfaces in an affected building following a chemical/biological attack. PlasmaSol's technology is scalable and portable—it can be transported throughout a building to decontaminate flat and odd-shaped surfaces. In contrast to traditional plasma cleaning systems

that require vacuum systems, PlasmaSol developed a decontamination system that operates at atmospheric pressure and is lightweight, portable, nondestructive to the contaminated substrate, and eliminates the need for exposure to harsh and dangerous chemicals.

PlasmaSol's decontamination process replaces current complicated and capital-intensive systems with a low-cost, low-maintenance system providing rapid, nontoxic, low-temperature performance. The modular design of PlasmaSol's nonthermal plasma technology permits the installation of only the desired capacity, with the option of adding functionality or capacity at a later time. This greatly reduces the footprint, allowing such decontamination to be located in remote and challenging locations.

The man-portable plasma cleaner weighs approximately 15 lb. The handle is a telescoping pole that can extend out to 5 feet and has a swivel attachment that allows the user to adjust the angle of the plasma emitter. This approach has numerous advantages over conventional decontamination methods, such as no exposure to toxic chemicals, and it leaves contaminated substrates intact and reduces/eliminates the need to dispose of hazardous wastes. The power supply and gas delivery system are located on the handle of the device.

Commercialization Information

The nondestructive nature, combined with the sterilization performance of this innovation, makes it an excellent candidate for use as a decontamination technology for sensitive items in which the use of harsh solvents or autoclave sterilization is unfea-

sible (i.e., circuit boards, historical and legal documents, art and architecture, medical instruments). PlasmaSol is developing approaches to use its technology against not only routine bacteria, viruses, and allergens, but also terrorist-released chemical



Demonstration of the plasma cleaner to treat horizontal and vertical surfaces.

and biological pathogens. The technology application is being pursued in collaboration with various government agencies in addition to EPA.

Company History

Based in Hoboken, New Jersey, PlasmaSol Corporation was established in 2000 to develop processes and applications for a unique low-temperature, room-pressure plasma invented by scientists at Stevens Institute of Technology. Starting with an exclusive license to this technology, PlasmaSol has developed additional intellectual property for effective surface treatment, engine emissions, and air control quality as well as sterilization.

PlasmaSol builds on successful research and development in the field of air cleaning, sanitizing, and sterilizing. Notable clients and collaborators include EPA; the National Aeronautics and Space Administration; Defense Advanced Research Projects Agency; U.S. Army Research, Development and Engineering Command; National Institute of Justice; the Oklahoma City National Memorial Institute for the Prevention of Terrorism; Stevens Institute of Technology; the University of Medicine and Dentistry of New Jersey; and others. In 2003, the company developed a process for medical instrument sterilization using the plasma as a gas generator to produce a transient biocide based on active chemical radicals. The system was designed around the conventional medical tray container used to hold instruments during sterilization, storage, and transport to the area of final use, such as an operating room.

SBIR Impact

- Cleaning contaminated surfaces at the microscopic level without using environmentally unfriendly chemicals is a challenging problem.
- PlasmaSol Corporation developed a scalable and portable surface contaminant destruction system that sterilizes surfaces in an affected building following a chemical/biological attack.
- The decontamination system operates at atmospheric pressure, is lightweight, and is nondestructive to the contaminated substrate.
- The technology could replace current complicated and capital-intensive systems with a low-cost, low-maintenance system providing rapid, nontoxic, low-temperature performance.

Measurement System for Determining Particulate Matter Pollution

Rupprecht & Patashnick Co., Inc.

26 Tech Valley Drive
East Greenbush, NY 12061
Telephone: 518-452-0065
<http://rpco.com>

Environmental Problem

On a typical day, a person can inhale more than 10 million microscopic and submicroscopic particles with each breath; these particles are emitted from motor vehicles and industrial sources, resuspended by the wind, or formed in the atmosphere from gaseous pollutants. The particles occur in a wide range of shapes and sizes, and although individual particles are invisible to the unaided eye, the collective effect of high concentrations of these particles in the environment can have a variety of adverse effects. Only in the past 10 years have scientists begun to understand the magnitude of the health effects associated with particulate air pollution (see <http://www.ioe.ucla.edu/publications/report01/ParticulateAirPollution.htm>). Particulate pollution has been linked to reductions in lung function, increased hospital and emergency room admissions, and premature deaths. The Natural Resources Defense Council estimates that 64,000 premature deaths may be attributable to particulate pollution each year. Epidemiological studies indicate a linear relationship between exposure to particulate pollution and effects, but scientists have not been able to identify a threshold below which health effects do not occur. An ambient particulate matter (PM) mass measurement system is needed.

SBIR Technology Solution

With support from EPA's SBIR Program, Rupprecht & Patashnick Co., Inc. (R&P) developed the Series 8500 Filter Dynamics Measurement System (FDMS™) to account for both the volatile and non-volatile components of PM and report the combination as a mass concentration result. The device measures the volatile portion of the sample independently from the total incoming sample and uses this fraction in calculating the PM mass concentration. The device provides a new PM measurement approach that offers the ability to quantify more representatively PM mass concentration as it exists in ambient air.

The FDMS™ system takes into account the dynamics of PM that has been deposited on a sample collection filter and how that material behaves over time. It is designed to provide high-quality, representative PM mass concentration readings for both short-term averages (1 hour) and 24-hour averages. The system's basic output consists of running 1-hour average mass concentrations (in $\mu\text{g}/\text{m}^3$) of PM_{10} (particles smaller than $10\ \mu\text{m}$), $\text{PM}_{2.5}$ ($<2.5\ \mu\text{m}$), or PM_1 ($<1\ \mu\text{m}$), updated every 6 minutes. It also computes the base mass concentration and reference mass concentration over the same averaging times.

The FDMS™ instrument computes its running PM mass concentration average based on independent measurements of the base and reference mass concentrations. To accomplish this, the FDMS™ unit constantly samples ambient air and uses a switching valve to change the path of the main flow every 6

minutes. The sampling process consists of alternate base and purge (filtered) to reference air streams passing through the exchangeable filter in a tapered element oscillating microbalance mass sensor.

During the base sampling periods, the sample air stream passes through the sample filter for determining the base level of PM mass in the atmosphere. During the base sample periods, the sampled gases are diverted through a chilled filter to remove and retain the ambient PM mass, including semi-volatile material. The FDMS continuously measures the change in mass on the sample filter, correcting the measurement during the base periods with the reference measurement periods, reporting the final ambient PM mass levels.



The Series 8500 FDMS™ unit has been selected by the California Air Resources Board as a California Approved Sampler for both $\text{PM}_{2.5}$ and PM_{10} .

Commercialization Information

The California Air Resources Board (CARB) evaluated the FDMS™ in Bakersfield, California, during a time of year when particulate nitrate concentrations are particularly high and ambient temperatures are at their lowest. Based on the results, the CARB selected the device as a California Approved Sampler for both PM_{2.5} and PM₁₀ as part of standards promulgated in June 2003. Whether for routine monitoring, regulatory monitoring, mapping, forecasting, or air quality index applications, the FDMS™ unit is the most accurate, precise, representative PM monitoring instrumentation available today.

Company History and Awards

Since its incorporation in 1981, R&P has commercialized a number of technologies in the form of advanced instrumentation to address critical measurement needs of customers around the world. The East Greenbush, New York-based company has experienced substantial growth over the years with an average growth rate during the 1990s of more than 25% per year. R&P specializes in the development, manufacture, and marketing of technology-leading products for applications that require accurate mass measurement or particle characterization.



Customers include air pollution monitoring networks, diesel engine manufacturers, power companies, and catalyst producers. Due in part to the successful development of its particulate monitoring instruments, R&P was purchased by Thermo Electron Corporation in 2005.

R&P was awarded the ISO 9002 certification in early 1996 and the ISO 9001 designation in May 1997. R&P has been named by *R&D Magazine* as a 2004 R&D 100 Award winner in partnership with the National Institute for Occupational Safety and Health, the Bituminous Coal Operators' Associa-

tion, the United Mine Workers of America, and the National Mining Association. In addition, R&P and two government laboratories jointly received a 2003 R&D 100 Award for a technology that monitored the venues of the 2002 Salt Lake City Winter Olympic Games for bioaerosols.

SBIR Impact

- An ambient particulate matter (PM) mass measurement system that fully accounts for the nonvolatile and volatile PM fractions when computing PM mass concentration is needed.
- Rupprecht & Patashnick Co., Inc.'s (R&P) Series 8500 Filter Dynamics Measurement System (FDMS™) unit accounts for both the nonvolatile and volatile components of PM.
- The California Air Resources Board selected the FDMS™ as a California Approved Sampler for both PM_{2.5} and PM₁₀.
- R&P customers include air pollution monitoring networks, diesel engine manufacturers, power companies, and catalyst producers.

Gas-Phase Bromination for Cost-Effective Mercury Control

Sorbent Technologies Corporation

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<http://www.sorbenttechnologies.com>

Environmental Problem

Mercury becomes airborne as a pollutant when coal and other substances burn and falls from the atmosphere into lakes and rivers, where it is absorbed by microbes that are in turn eaten by fish. Mercury is especially damaging to the brains of developing fetuses and young children as a result of eating tainted fish. In late 2000, EPA officially determined that the regulation of mercury emissions from U.S. power plants is “both appropriate and necessary.” In March 2005, EPA directed coal-fired power plants to reduce mercury emissions by almost 22% in the next 5 years. For those plants without flue gas desulfurization—by far the largest segment of the market—the dominant control method is expected to be activated carbon injection. The least expensive mercury control technology to retrofit onto these plants is the injection of a mercury-capturing sorbent material into the ductwork ahead of the plants’ particulate removal systems.

SBIR Technology Solution

With support from EPA’s SBIR Program and the U.S. Department of Energy, Sorbent Technologies Corporation developed an inexpensive, proprietary

treatment for powdered activated carbon sorbent-gas-phase bromination that increases its cost-effectiveness for mercury control by about 300%. Brominated powdered activated carbon (B-PAC™) can cut the cost of mercury compliance at power plants to approximately 25% of that of competitive products or technologies. Utility capital costs are virtually nil with the technology.

B-PAC™, a halogenated sorbent, has consistently demonstrated high mercury removal rates at relatively low injection levels across a wide variety of coals and configurations. Sorbent Technologies has tested the injection of B-PAC™ into power plant flue gases for mercury removal at seven different power plants. These plants have burned bituminous, subbituminous, lignite coals, and blends and include testing with cold-side electrostatic precipitators (ESPs), hot-side ESPs, spray dryers, and fabric filters. Mercury removal performance at these sites has been observed to vary between 70% and 98%, at sorbent consumption costs of approximately \$2,000 to \$20,000 per lb of mercury removed, considerably less costly than previous technologies. B-PAC™ injection is now being tested on an increasing number of full-scale coal-fired power plant flue gas streams, all with similar positive results.

In addition, the company has developed a special version of its mercury sorbents for plants that sell their fly ash into concrete applications. Sorbent Technologies also is working on a version for plants with hot-side ESPs, two particularly difficult, high value-added market niches.

Commercialization Information

In recent years, Sorbent Technologies has been scaling up its proprietary B-PAC™ brominated powdered activated carbon technology, demonstrating it at three coal-fired boiler sites. Data from a number of diverse power plant trials show that simple B-PAC™ injection ahead of an existing particulate collector can be a comparatively inexpensive, yet uniformly effective mercury emission reduction strategy. With B-PAC™, high-performance, low-cost power plant mercury control is now commercially available. By the end of the decade, revenues of more than \$100 million are expected as the company supplies B-PAC™ to utility customers. Sorbent



B-PAC™ has consistently demonstrated high mercury removal rates at relatively low injection levels across a wide variety of coals and configurations.

Technologies can inexpensively use a mobile sorbent injection trailer to perform full-scale trials for utilities ahead of any permanent installations, allowing companies to “try before they buy.”

Company History and Awards

Sorbent Technologies Corporation is located in Twinsburg, Ohio, and has been working on mercury control from flue gas streams for more than 8 years. Sorbent Technologies is currently one of only four companies that has demonstrated full-scale utility sorbent injection mercury control and is the only one using its own advanced sorbent. The company completed the world's first and only dedicated utility sorbent production plant in the summer of 2004. This plant can profitably and continuously supply approximately eight utility boilers at present. The company had more than \$2.5 million in revenues in 2002, and more than \$5 million in 2003, with more than \$300,000 in profits. Sorbent Technologies Corporation received a 2004 Bronze Medal Award from the *Environmental Business Journal*.



SBIR Impact

- EPA directed operators of coal-fired power plants to cut mercury emissions by almost 22% in the next 5 years.
- Sorbent Technologies Corporation developed an inexpensive, proprietary brominated powdered activated carbon sorbent for mercury removal.
- Brominated powdered activated carbon (B-PAC™) can cut the cost of mercury compliance at power plants to approximately 25% of that of competitive products or technologies.
- By the end of the decade, revenues of more than \$100 million are expected as the company supplies B-PAC™ to utility customers.

Nanoparticle-Anchored Plasticizers

TDA Research, Inc.

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Environmental Problem

Plasticizers are small, often volatile molecules added to hard, stiff plastics to make them softer and more flexible. Phthalate plasticizers are not directly bound to polymers such as polyvinyl chloride (PVC) and can leach out of the plasticized material. From environmental, health, and safety perspectives, the loss of plasticizers to the surrounding medium—whether air or soil in the environment, saliva in the mouth of an infant, or pharmaceutical solutions passing through intravenous tubing—is unacceptable and commercially undesirable. Due to their known toxicity, the European Union banned three phthalates and restricted three more from toys and other child care items. PVC is the second largest plastic sold, and plasticizers are the highest volume additive for PVC.

SBIR Technology Solution

With support from EPA's SBIR Program, TDA Research, Inc., developed a system that softens plastics by forming a polymer nanocomposite that does not become brittle and contaminate its surroundings by leaching its plasticizer. Polymer

nanocomposites are a combination of a polymeric host matrix and additive particles that are smaller than 100 nm. Properly designed nanoparticles can be dispersed into a polymer, and the unusual behavior of the polymer at the nanoparticle surface can change the overall bulk physical properties of the composite. There is a synergistic effect of combining nano-particles with polymers that is well beyond the sum of the properties of both phases, and revolutionary improvements in the properties of the resulting composite materials can be achieved.

Plasticizers change the properties of a polymer by increasing the free volume between polymer chains, allowing more chain movement, which translates to more flexibility of the softened plastic. TDA has shown that plasticizers anchored to nanoparticles can soften PVC but cannot escape from the polymer. Although the nanoparticles resisted efforts to migrate out of the polymer, the nanocomposite PVC exhibited a lower glass transition temperature, tensile strength, and modulus, indications of the formation of a softer, more plasticized material. Both rigid and traditionally plasticized PVC formulations showed increased plasticization with the addition of TDA's nanoparticles.

The addition of TDA's nanoparticles resulted in the additional benefit of increased plasticizer permanence. In PVC formulations plasticized with dioctylphthalate, the addition of small (2-5%) amounts of TDA's nanoparticles significantly decreased the percent of plasticizer lost to air, activated carbon, and aqueous and organic solvents. This improved

retention feature decreases the amount of phthalate leaching from plasticized materials and could increase the service lifetimes of soft PVC materials.

Commercialization Information

As a result of EPA's SBIR funding, TDA made significant advances in areas vital to commercializing hybrid nanoparticles. TDA's nanoparticles are designed to be inexpensive and attractive to the commodity polymer materials market. TDA scaled up production of nanoparticles from the gram to



Pictured above is the device used to synthesize TDA's nanoparticle-anchored plasticizers, which soften polyvinyl chloride (PVC), keep plastics soft longer, and do not escape.

the kilogram scale and developed preparative methods that are environmentally benign and can be carried out with simple “bucket chemistry” techniques. TDA established ongoing collaborations with several commercial partners and has extended this technology to other plastics. In addition to the anchored plasticizer nanoparticles developed for PVC, TDA also gained knowledge that allowed for the development of additional applications, such as impact modifiers and nanoparticles as carriers for colorants and antimicrobials.

Company History

TDA Research, Inc., was founded in 1987 and is located in Wheat Ridge, Colorado. The company carries out research and development for proprietary technology in advanced materials and chemical processes that it can either manufacture or license. TDA employs 65 individuals, nearly all with degrees in either chemistry or chemical and mechanical engineering (two-thirds of whom have advanced degrees). In the past 2 years, in partnerships with major companies that are leaders in their fields, TDA successfully commercialized the large-scale manufacture of fullerenes and a direct oxidation process that removes and recovers sulfur from natural gas. TDA also commercialized electronically conducting polymers that are made easier to process because they disperse in organic solvents.

SBIR Impact

- From environmental, health, and safety perspectives, the loss of plasticizers to the surrounding medium is unacceptable and commercially undesirable.
- TDA developed a system that softens plastics by forming a polymer nanocomposite that does not become brittle and contaminate its surrounding medium by leaching its plasticizer.
- TDA’s nanoparticles are designed to be inexpensive and attractive to the commodity polymer materials market.
- TDA established ongoing collaborations with several commercial partners and has extended this technology to other plastics.

Upflow Filters for Rapid and Effective Treatment of Stormwater

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Environmental Problem

Stormwater has been identified as one of the major sources of surface water pollution by EPA. To prevent further contamination to surface water bodies, stormwater needs to be treated at the source. A number of studies have linked pollutants in stormwater runoff with specific sources, such as paved parking lots and gas stations. Runoff from paved parking areas, storage areas, and gas stations can be contaminated with concentrations of many critical pollutants. These paved areas generally contribute most of the pollutant loadings of toxicants to stormwater. Numerous manufacturers have developed proprietary devices to treat stormwater runoff at these critical source areas. These devices have been designed to treat one or more common stormwater pollutants such as solids, metals, oil and grease, nutrients, or bacteria; however, very few have been designed to treat all of the pollutants in a single device.

SBIR Technology Solution

With support from EPA's SBIR Program, USInfrastructure, Inc. (USI), developed an upflow filter technology that is a low-cost, low-maintenance fil-

tration system for stormwater treatment. Stormwater filters with a mixed sand/organic media operated in an upflow mode have the potential to eliminate many of the disadvantages associated with conventional downflow stormwater filters. The main drawback of downflow filtration is the frequent clogging of the filters and the regular maintenance that is integral to long-term downflow operation. In locations where the filter is receiving large suspended solids loadings, the filter size must be large to have a long filter run before maintenance. To reduce the large filter surface area, the stormwater runoff must be pretreated to remove the solids loading prior to entry to the filter. One alternative to pretreatment would be to operate the filters in an upflow mode.

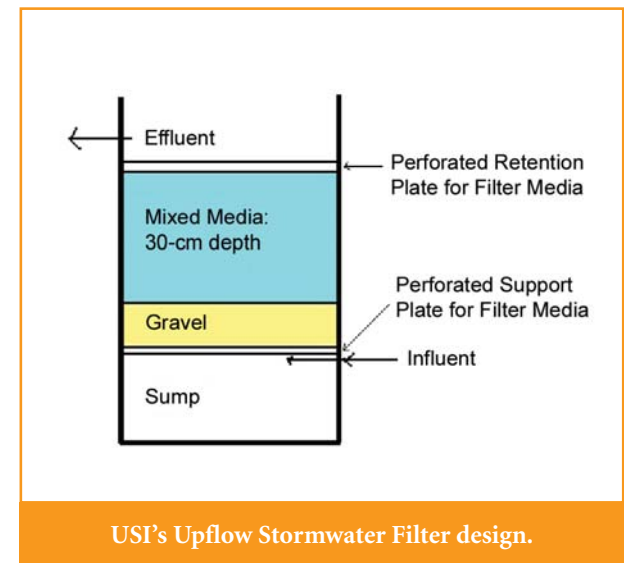
USI's upflow filter is designed so that it is easily adapted to fit in inlets of different sizes. The upflow filter sizes can be changed to fit a specific site's needs. The upflow filter eliminates degradation of performance due to filter clogging that is a weakness of all existing filtration competitor technologies. Therefore, maintenance costs are low compared to downflow filters. Additionally, this filter setup does not require electricity at individual installation locations. The upflow filter is basically a catch basin insert, designed to be compact and inexpensive for easy installation and maintenance. Stormwater enters through a grated inlet. Heavier particles settle in the sump, and the water enters the filter through a screen, leaving all of the debris behind. The water is pushed upwards through the filter media and then downwards, and finally, into an effluent pipe. The primary advantage to this approach is that stormwater passes through the fil-

ter media twice, and heavier particles settle before they can enter the filter because of the sump at the bottom of the filter.

Based on the laboratory testing performed to date, USI believes that stormwater filters with a mixed sand/organic media and operated in an upflow mode can solve many of the problems found in conventional downflow stormwater filters.

Commercialization Information

USI's patent application currently is under review by the U.S. Patent Office, and the company knows of no other patents for this particular technology. Additionally, USI's technology has been accepted



into EPA's Environmental Technology Verification (ETV) Program. USI is collaborating with Hydro Compliance Management, Inc., located in Ann Arbor, Michigan. This company will license the process and be responsible for marketing it. Hydro Compliance Management also will provide maintenance services to filter owners. USI and Hydro Compliance Management have identified a number of commercialization opportunities, including "hot spot" areas such as drains downstream from dumpsters, material storage areas, truck loading/unloading areas, and fueling operations; municipalities in urban areas that will have to begin implementing programs to reduce pollutant runoff from their facilities; and government-owned entities required to obtain permits and implement controls for defined industrial activities.

Company History

USI is an employee-owned professional engineering firm that was founded in 1994. USI currently has approximately 260 employees. The company's corporate headquarters is located in Birmingham, Alabama. USI's primary expertise is planning, designing, program management, and construction management for projects related to environmental engineering, water and wastewater management, water resources, watershed studies and management, natural gas lines, transportation, asset management, civil design, construction management, geographic information systems, and information technologies. USI has offices across the United States and in New Delhi, India. USI clients include EPA; the U.S. Army Corps of Engineers; the Department of the Navy; Alabama, Tennessee,

Georgia, and Oklahoma Departments of Transportation; and a variety of state, municipal, and private clients.

SBIR Impact

- Runoff from paved parking areas, storage areas, and gas stations can be contaminated with many critical pollutants, and these areas contribute most of the pollutant loadings to stormwater.
- USI developed an upflow filter with a mixed sand/organic media that has the potential to solve many of the problems associated with conventional down-flow stormwater filters.
- One advantage of USI's filter is that stormwater passes through the filter media twice, and heavier particles settle before they can enter the filter, minimizing clogging.
- USI is collaborating with Hydro Compliance Management, Inc., which will license the process, be responsible for marketing it, and provide maintenance services to filter owners.

Arsenic Removal From Drinking Water Systems Using a Novel Hybrid Sorbent

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Environmental Problem

The presence of dissolved arsenic in contaminated groundwater has emerged as a major concern for drinking water supplies on a global scale. Sources of dissolved arsenic in groundwater include natural geochemical contamination through soil leaching, combustion of fossil fuels, and inorganic arsenic, which occurs as As(III) or As(V) in drinking water and poses a great threat to human health. Exposure to higher levels of arsenic in drinking water can lead to thickening and discoloration of skin; nausea and diarrhea; decreased production of blood vessels; and skin cancer and tumors of the bladder, kidney, liver, and lung. As a result of the problems associated with arsenic exposure, EPA passed a regulation to lower the arsenic concentration from 50 ppb to 10 ppb in drinking water. More than 4,000 water utilities serving approximately 20 million people will need corrective action to comply with the new regulation.

SBIR Technology Solution

With support from EPA's SBIR Program, VEEtech, P.C., in collaboration with Lehigh University, developed a family of polymeric-inorganic hybrid sor-

bents, known as HIX, that can selectively capture all forms of arsenic and other co-contaminants from drinking water. HIX can be used in a fixed-bed configuration without the need for any pre- or post-treatment. HIX also can be regenerated and reused for many cycles of operation, thus yielding a very low life cycle cost of treatment. The regenerant can be stabilized and disposed of as nonhazardous waste. HIX is accepted by EPA for the simultaneous removal of arsenic and multiple co-contaminants from drinking water.

HIX exhibits the following characteristics for removal of arsenic in drinking water: (1) excellent mechanical strength and attrition resistance; (2) selectivity towards both As(III) and As(V); (3) requires no pre- or post-treatment (e.g., pH); (4) does not alter the electrolytic quality of treated water; (5) generates no fines or pressure drops during long-term column operation; (6) can treat up to 40,000 bed volumes of water per cycle and can be regenerated up to 20-30 cycles of operation; and (7) can remove multiple contaminants such as radium, uranium, and perchlorate along with arsenic.

A majority of the small- and medium-sized drinking water utilities require an arsenic removal system that is easy to operate, low cost, needs minimal operator attention or training, is forgiving towards fluctuations in feed compositions, does not require frequent regeneration or disposal, and requires minimal start-up time. A fixed-bed HIX arsenic removal system meets all of these desirable attributes and is ideal for use by the small- and medium-

sized utilities that are most affected by EPA's 10 ppb standard for total arsenic.

Although the primary focus of the HIX technology is the removal of arsenic from drinking water, it also can be selectively applied to separate a host of heavy metal contaminants from other aqueous streams, such as fly ash and coal pile leachate from electric generating stations, and wash water and drainage from mining operations. Both of those streams contain several heavy metal contaminants that will require treatment to meet increasingly stringent discharge standards. In addition, this system will remove natural uranium from drinking water sources. The technology can be configured as



HIX, developed by VEEtech, P.C., is a family of polymeric-inorganic hybrid sorbents that can selectively capture all forms of arsenic and other co-contaminants from drinking water.

a permanent or mobile system. The basic components are one or two columns and a small number of tanks and pumps. The HIX system also can be retrofitted as a polishing unit downstream of the existing water distribution system.

Commercialization Information

Based on the results of pilot studies, EPA selected VEETech's HIX technology for demonstration at a site in Lake Isabella, California. This will be the first full-scale commercial HIX system built. Commercialization of the HIX-based fixed-bed arsenic removal technology can benefit the numerous drinking water utilities affected by arsenic concentrations in excess of the maximum concentration limit. The simplicity, versatility, and cost of the HIX technology are expected to play a significant role in the environmental compliance of drinking water suppliers.

The technology has very good export potential to the countries suffering from acute arsenic toxicity. The ability of HIX to simultaneously remove arsenic and other co-contaminants (e.g., uranium, radium, chromium) from aqueous sources is beginning to garner attention and may set this media apart from its competition.

Company History

VEETech, P.C., is a certified 8a organization with locations in Cary, North Carolina; Aiken, South Carolina; and Philadelphia, Pennsylvania. Founded in 1996, the company provides environmental

engineering, consulting, construction, and remediation services to a variety of clients, including the U.S. Army Corps of Engineers, North Carolina Department of Transportation, South Carolina Department of Health and Environmental Control, Georgia Power Corporation, and Lucent Tech-

nologies, Inc. VEETech, also has created a technological niche in implementing cost-effective pollution control technologies, such as BIOSORPTION®, an advanced form of biofiltration that treats a wide variety of volatile organic compounds.

SBIR Impact

- The presence of dissolved arsenic in contaminated groundwater has emerged as a major concern for drinking water supplies on a global scale.
- VEETech, developed a family of polymeric-inorganic hybrid sorbents, known as HIX, that can selectively remove all forms of arsenic and other co-contaminants from drinking water.
- A fixed-bed HIX arsenic removal system is ideal for use by the small- and medium-sized utilities that are most impacted by EPA's 10 ppb standard for arsenic.
- Based on the results of pilot studies, EPA selected VEETech's technology for full-scale demonstration at a site in Lake Isabella, California.

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