RESEARCH AWARDS & GRANTS

U.S. DEPARTMENT OF DEFENSE

Aerosol Collection Technology (Army 2003 SBIR Phase 2)
Michael McNamee (PI) 480-813-4884, mcnamee@padtinc.com
Phoenix Analysis & Design Technologies, Tempe, AZ, www.padtinc.com
Contract Number: DAAD13-03-C-0022
Award Amount: $730,153
13MAR03 - 13MAR05

PADT proposes to develop two particle collection and concentration devices, one designed for 600 LPM, and another for the 100-LPM-or-less class. Both configurations will be optimized for 2-10 micron particle collection efficiency, power consumption, size, cost, and weight. The design arrangement to be developed is comprised of a custom inlet, a novel collection chamber, and a continuous gas-to-liquid concentration mechanism. An autonomous, 'point-into-the-wind,' iso-kinetic inlet will be used to maximize the inlet collection efficiency for difficult sampling conditions, such as shipboard sampling. The aerosol collection and concentration mechanism being studied exhibits the combined behavior of an impactor, cyclone, and centrifuge. The gas-to-liquid concentrator will consist of a recirculating liquid injection and recovery system. A preconditioning impactor and screen stage is used to remove large particles. Construction of the first prototype is ongoing at this time. Primary focus has been, and will continue to be, placed on developing the high flow-rate collector. Late-stage efforts will modify this design for low flow-rate applications. The proposed designs could have application in Army and other Joint Services activities, the Office of Homeland Defense, U.S. Postal Service, and Environmental Protection Agency. Civilian applications exist in areas such as pollution monitoring, environmental monitoring, hazard detection, and medical settings. Interest has been expressed concerning coupling a smaller version of this device with a biosensor application for airborne particulate toxicity detection.

All-Optical Terahertz Spectrophotometer for Biological Detection (CBD 2004 SBIR Phase 1)
Dr. Aniruddha Weling (PI) 781-684-4640, aweling@foster-miller.com
Foster-Miller, Inc., Waltham, MA, www.foster-miller.com
Contract Number: FA8650-04-M-5419
Award Amount: $69,957
19APR04 - 19OCT04

Contemporary portal security systems based on X-ray and magnetic screening are seriously limited in their capabilities for detecting a wide variety of potentially dangerous materials, e.g., weapons made out of ceramics, plastics, or composites; explosives; and substances associated with chemical, biological and nuclear weapons. Coherent THz radiation coupled with phase coherent electro-optic detection imaging (CTI) presents significant potential as an advanced safe, non-ionizing, invasive sensing technology probe for both personnel and packages with no health risks, sub-millimeter spatial resolution, and with enhanced capabilities for compositional analysis and automated recognition of CBW threats. Foster-Miller proposes to design and develop an "All-Optical" laser-based CTI Coherent THz Spectrometer (OCTS) based on highly efficient nonlinear optical THz generation and detection system that incorporates the opto-electronic generation of spectrally agile continuous wave (CW) THz radiation coupled with phase-coherent detection using non-resonant electro-optic (EO) sampling. Combined with efficient software algorithms that perform image deconvolution and target recognition, such a system will permit real-time interrogation of packages and personnel in complementary transmissive and reflective modes. Phase I will demonstrate the efficacy of the OCTSI by (1) building integrating component technologies into a compact table-top system to that can perform rapid and accurate detailed spectroscopic studies measurements of various harmful substances and (2) developing appropriate signal processing software and hardware for the detection and identification of concealed on biological materials over the widest possible THz frequency range.

Automated Individual Real-Time Toxic Exposure Monitoring (AIRTEM) System (Air Force 2004 SBIR Phase 2)
Marina Temchenko (PI) 781-684-4154, mtemchenko@foster-miller.com
Foster-Miller, Inc., Waltham, MA, www.foster-miller.com
Contract Number: FA8650-04-C-6468
Award Amount: $749,662
18JUN04 - 18OCT06

In this Phase II SBIR program, Foster-Miller proposes to aid in the detection of chemical warfare agents (CWAs) through development of a novel diagnostic device. The proposed effort will build upon the successes of the Phase I program, which resulted in the identification of biomarkers indicating the exposure of human cells to two CWAs. As a result of the Phase II program, a prototypical device, the Automated Individual Real-time Toxic Exposure Monitor (AIRTEM), will be fabricated and its ability to detect the presence of biological analytes indicating the exposure of human cells to target CWA will be demonstrated.

Automated Polychlorinated Biphenyl (PCB) Analyzer for Solid Waste Material using SPME/GC/MS (Navy 2004 SBIR Phase 1)
Dr. Venkat Mani (PI) 814-234-7074, vmani101@yahoo.com
American Analytical, State College, PA, http://americananalytical.us
Contract Number: N65538-04-M-0131
Award Amount: $70,000
13MAY04 - 13NOV04

The main goal of this Phase I SBIR proposal is to demonstrate the feasibility of developing an automated method that can be used in the field to identify and quantify polychlorinated biphenyl compounds (PCBs) present in solid materials, e.g., felt gasket, faying material, paint, electric power cable insulation, and many rubber products. Solid Phase Microextraction (SPME) has been shown to be effective in the determination of the concentration of PCBs in liquids. In this modified SPME technique, new stable fibers with nanoparticles will be developed for efficient and selective absorption of PCBs. Modified fiber holders will be developed to automate the accurate determination of the presence and concentration of PCBs in solid materials. This will be a quick, reliable, cost-effective, and portable device that can be operated in the field by a single person with minimum training. The sensitivity reached with this technique is 5-700 parts per trillion (EPA regulation 50 parts per million) in an extraction time of only 50 minutes. The sensitivity, extraction parameters, and time for analysis will be improved. This proposal will also enable the separation and quantitation of toxic PCB congeners and highly toxic polychlorodibenzofurans (PCDF) and dioxins produced from PCBs. This proposal combines SPME with portable GC and/or GC/MS for automated PCB analysis.

Bio-Inspired Sensor Systems (DARPA 2004 SBIR Phase 1)
Dr. Tat H. Tong (PI) 937-320-1877, tongth@crgrp.net
Cornerstone Research Group, Inc., Dayton, OH, www.CRGrp.net
Contract Number: W31P4Q-05-C-R030
Award Amount: $99,000
08NOV04 - 18JUL05

Cornerstone Research Group, Inc. (CRG) proposes the use of bio-inspired sensing concepts to develop novel, low-cost polymer composite sensors for military as well as commercial applications. CRG will investigate the design and fabrication of sensors with the use of conducting polymer composite, drawing inspiration from known biological sensing mechanisms reported in the literature. The use of polymer composite materials to fabricate sensors will lead to significant cost saving due to greater versatility, flexibility, and fault tolerance of polymeric materials, compared with silicon. The employment of a bio-inspired sensing mechanism will lead to novel sensing capability, such as the possibility of multi-functionality, and improved performance, with greater sensitivity and room-temperature operation.

A Compact Raman and Fluorescence Detector for Rapid Detection of Chemical Leaks (DoD MDA 2004 SBIR Phase 1)
Dr. Drew L'Esperance (PI) 949-553-0688, dlesperance@metrolaserinc.com
Metrolaser, Inc., Irvine, CA, http://www.metrolaserinc.com
Contract Number: HQ0006-04-C-7064
Award Amount: $99,927
19MAY04 - 19NOV04

Chemical leaks from chemical oxygen iodine lasers (COIL) in aircraft release toxic gases that can endanger the flight crew. We propose to develop an optical sensor to detect four toxic gases used in COIL systems: iodine, chlorine, hydrogen peroxide, and ammonia. In addition, the proposed sensor will monitor oxygen levels in the aircraft. The proposed sensor will apply a combination of Laser-Induced Fluorescence and Raman to detect the gases at concentrations well below their permissible exposure levels (PELs), and trigger an alarm when the concentrations exceed the PEL. The innovation of the proposed sensor is to use a single laser source for all of the gases, facilitating the development of a rugged, compact system that can be deployed in an airplane. The proposed sensor will have distinct advantages over conventional sensors that rely on chemical reactions between the target gases and a sensitive element. It will operate even when exposed to high concentrations of hazardous chemicals, it will not be harmed by decompression, and its warm-up time will be shorter than existing gas sensors. The Phase I work plan consists of defining the measurement requirements, estimating signal levels, constructing a proof-of-concept breadboard, performing laboratory experiments, and establishing a calibration procedure.

Compact Submillimeter-Wave Spectrometers for Biological and Chemical Sensing (Army 2004 SBIR Phase 1)
Dr. David Porterfield (PI) 434-297-3257, porterfield@virginiadiodes.com
Virginia Diodes, Inc., Charlottesville, VA, www.virginiadiodes.com
Contract Number: W911NF-04-C-0019
Award Amount: $120,000
15DEC03 - 14JUN04

The goal of this proposal is to develop frequency domain terahertz spectrometers for chemical and biological sensing based on compact and reliable all-solid-state components. VDI's novel integration technology allows full waveguide band performance without mechanical tuners as well as unprecedented source power and detector sensitivity for room temperature operation. A prototype spectrometer will be developed and tested with precalibrated samples. The spectrometer technology will be shown to be highly compact and portable.

Compact Submillimeter-Wave Spectrometers for Biological and Chemical Sensing (Army 2004 SBIR Phase 2)
Dr. David Kurtz (PI) 434-297-3257, kurtz@vadiodes.com
Virginia Diodes, Inc., Charlottesville, VA, www.virginiadiodes.com
Contract Number: W911NF-04-C-0141
Award Amount: $729,997
04OCT04 - 03OCT05

The ultimate goal of this research is to create a militarily viable terahertz technology suitable for use in portable spectrometers for point and stand-off detection of explosives and chemical and biological threat agents. To achieve this goal, VDI will develop a compact and reliable terahertz spectrometer based on a revolutionary new solid-state diode technology. This technology is based on highly integrated GaAs-on-dielectric circuits that are used to translate the functionality of lower frequency systems to the terahertz band.

Continuous, On-Line, Low-Cost Monitor to Detect Arsenic in Water (Air Force 2004 SBIR Phase 1)
Rex M. Harper (PI) 207-799-9133, w1rex@megalink.net
Brims Ness Corp., Millinocket, ME, www.brimsness.com
Contract Number: FA9300-04-M-1002
Award Amount: $99,912
11MAY04 - 11FEB05

The EPA has imposed a maximum contaminant level for arsenic at 10 ppb, which poses a tough standard for a significant number of the nation's community drinking water systems. One major issue relates to how the utility knows when the filtration media has saturated with the removed arsenic and needs regeneration or replacement. The current method of monitoring the filtration system effectiveness involves taking water samples periodically and submitting those samples to labs using wet chemistry methods. That process has shortcomings. An improved method entails the use of a continuous, on-line, low-cost monitor that automates the process. A solution for that requirement employs a sensor device known as a quartz crystal microbalance (QCM) that vibrates at 10 million cycles per second. When chemistries are applied to the crystal surface that are selective for arsenic, the vibrations slow down, signaling the presence of the contaminant. Technical issues that will be addressed are, (a) the sensor must be selective for arsenic, (b) the signal must be amplified to be responsive at 1 ppb, (c) the system must be reliable, low-cost and low maintenance. An added benefit is that the system can be readily adapted to detect arsenic at a well head.

CW Indicating Chromophore for Decontamination Operations (CBD 2004 SBIR Phase 1)
Dr. Martin Leuschen (PI) 405-372-9535, mleuschen@nomadics.com
Nomadics, Inc., Stillwater, OK, www.nomadics.com
Contract Number: W911NF-04-C-0042
Award Amount: $70,000
20APR04 - 19OCT04

Nomadics is currently working with a novel chemical weapon indicating chromophore (CWIC) that can make CW agent contamination literally glow in the dark. Developed by Professor Tim Swager at MIT, CWICs will allow equipment to be quickly and easily examined to show any areas of contamination, making targeted decontamination manageable. Nomadics' experience in developing remarkably sensitive and selective sensors from fluorescent materials will facilitate the quick development of a fast surface contamination detection system. When exposed to CW agent simulants, CWICs react to become fluorescent under UV stimulation. The CWICs have been proven against surrogates and will soon be tested against actual agents. In the proposed effort, we will implement a system employing CWICs to indicate whether an area is contaminated by chemical agents. An especially important feature of these chromophores is that it has been shown to be responsive only to chemicals that are in fact hazardous even if they are not typically considered CW agents. Similarly, because the CWICs respond only to reactive materials, they are not subject to interference even from compounds that normally serve as surrogates for CW agents. Thus, the proposed work should lead to development of an effective system for assessing CW agent contamination.

Detection of Liquids on Surfaces using Long Wave Infrared Hyperspectral Imaging Spectroradiometer (Army 2003 STTR Phase 2)
Michele Hinnrichs (PI) 805) 688-2088, patinc@patinc.com
Pacific Advanced Technology, Santa Ynez, CA (www.patinc.com) with Southwest Research Institute, San Antonio, TX
Contract Number: DAAD13-03-C-0073
Award Amount: $492,332
15SEP03 - 15SEP05

Chemical warfare agents with their low vapor pressure can stay on a surface for long periods of time and pose a serious threat to anyone coming into contact with the surface. A standoff sensor that can visualize and identify such a threat is of great interest to the US military. Pacific Advanced Technology (PAT) has a technology with the capability of standoff detection and the potential for identification of these chemical agents on different surfaces; however, the phenomenology is not well understood and work needs to be done to better characterize and analyze these threatening agents on different surfaces with different illumination conditions. During the Phase I effort, PAT demonstrated that chemical agent simulants have different spectral signatures than interferants, such as motor oil and water, in the longwave (8 to 11 microns) infrared spectral region. During Phase II, a hyperspectral imaging system with a cooled detector array, coupled to embedded real time processing of the hyperspectral image, will be developed. Numerous data collections of various types of simulants and interferants under different illumination, plus incident angle imaging, allow a better understanding of the phenomenology and thus enable the fielding of instruments that are highly reliable for this application. A handheld chemical/biological warfare remote imaging system being developed for this program can be used for gas-phase detection, such as bio-aerosols and chemical warfare agents. It can be applied to the commercial market to monitor gas pipeline leaks and for leak detection in gas, oil, and chemical refineries.

Development of a Detector Using Fluorescent Coated Filters (Army 2003 STTR Phase 2)
Dr. Senerath Palamakumbur (PI) 978-606-2600, spalamakumbura@sensera.com
Sensera, Inc., Chelmsford, MA (www.sensera.com) with the Univ. Of Central Florida, Orlando
Contract Number: DAAD19-03-C-0066
Award Amount: $749,999
19JUN03 - 19JUN05

Sensera Inc., in collaboration with the University of Central Florida (UCF), proposes to build sensor filters with fluorescent detection for the preconcentration and detection of Biological Warfare Agents (BWAs). These filter-based detection systems allow for continuous monitoring of BWAs in reservoirs, lakes and rivers. During Phase I, Sensera and UCF developed and demonstrated two sensor filter membranes that change fluorescent signals in the presence of BWA simulants without the need of user intervention. In Phase II, the team will further optimize the filter membranes and incorporate them as an array in an actual filter housing. A prototype detection device for both filter types will be built, and the arrays will be characterized for their detection limit, response time, reproducibility, cross reactivity and response to interferents. Software to decode the array signals and indicate the presence of agents will also be configured. Live agent testing will be performed at Battelle for final verification of the sensor prototype. The proposed detection system can be adapted to many commercial applications, such as: environmental and water-quality monitoring; food-quality monitoring; viral and bacterial pathogens detection for medical diagnostics; and hazardous material emergency response units.

Direct Toxin-Specific Biowarfare Detector (Army 2004 STTR Phase 1)
Dr. Anastasia Bogomolova (PI) 727-723-3006, anastasia.bogomolova@verizon.net
Fractal Systems, Inc., Safety Harbor, FL (www.fractalsystemsinc.com) with the University of South Florida, Tampa
Contract Number: W911NF-04-C-0068
Award Amount: $99,997
16JUL04 - 31JAN05

Several potent cytotoxins, such as ricin, can be lethal with very low dose exposure. Current immunochemical detection methods for such toxins are slow and expensive. Recent research resulted in the discovery of peptides that bind selectively to these lethal toxins, particularly ricin, and could replace the traditional monoclonal antibody used in immunochemical detection. This innovative approach will use a peptide-modified conductive polymer with biorecognition and biomimetic properties for binding to ricin in Phase I. The binding of peptide to ricin will induce a change in the electrical properties of the conductive polymer. Electrochemical AC and DC techniques will register the changes in situ, corresponding to the active peptide-toxin recognition. We will synthesize and characterize the novel ricin-specific detection material and focus on sensitivity and speed of recognition using ultrathin films on interdigitated electrode arrays. In Phase II, other derivatives will be synthesized for specific recognition of other toxins toward creating multi-specific detector arrays in a credit card-like format. This work will be carried out in collaboration with the Center for Biological Defense at the University of South Florida (Tampa), which is properly equipped to carry out the necessary testing toward a Phase III implementation of the technology.

Disposable Chemical Detection (Navy 2004 SBIR Phase 2)
Edward Locke (PI) 757-431-2260, elocke@kandmenvironmental.com
K&M Environmental, Inc., Virginia Beach, VA, www.kandmenvironmental.com
Contract Number: M67854-04-C-5018
Award Amount: $597,927
16JAN04 - 16JAN06

Since the end of the Gulf War, significant concern regarding the health and safety of the solders and sailors has been raised. It is clear that the potential for exposure to hazardous chemicals due to chronic and acute environmental threats from the poor environmental practices of host nations, as well as collateral damage from warfare and terrorism, is faced by deployed soldiers and sailors every day. The ideal solution for the service member is a sensitive, selective, durable, and lightweight badge with no external power requirement to provide an immediate visual indication of the presence of a hazard. In Phase I of this project, a prototype multi-sensor format badge was developed for this purpose. Using proprietary K&M technology, colorimetric chemistries were developed and tested for the detection of toxic industrial contaminants (TICs) of high or extreme priority listed in the USACHPPM TG 230A. TIC multi-sensor combinations were evaluated for cross-interferences and shelf-life stability. The second phase of this effort is directed toward assessment of the service-life stability in realistic field environments, modification of chemistries to eliminate false positive and false negative interferences, and evaluation of the performance of the multi-sensor arrays in the presence of potential field interferents.

Efficient Frequency Conversion and Optical Amplification to Improve Detection of Chemical and Biological Agents (Army 2004 STTR Phase 2)
Dr. Stuart A. Kingsley (PI) 614-799-0664, skingsley@srico.com
Srico, Inc., Columbus, OH (http://www.srico.com) with the University of Dayton, Dayton, OH
Contract Number: W911SR-04-C-0099
Award Amount: $749,555
23SEP04 - 23SEP06

There is a need to improve the sensitivity of chemical and biological sensing LIDAR systems so that standoff distances can be increased. LIDAR sensing systems have to cover ranges of 50 m to 20 km; however, their sensitivity is limited by the need to keep the laser transmitter power below the eye-safe limit. We propose to use Periodically-Poled Stoichiometric Lithium Niobate (PPLN) for improved frequency conversion efficiency in shifting received 3 to 5 micron mid-wave band LIDAR signals to the 1.5 micron optical telecommunications band. At 1.5 microns, commercial fiber optic amplifiers and detectors may be conveniently employed to ensure shot-noise limited detection and significantly improved signal-to-noise ratio. The optical gain stages may be based on Erbium Doped Fiber Amplifier or Raman Fiber Amplifier technologies. Such amplifiers are capable of producing gains of more than 40 dB with Noise Figures of less than 6 dB. The combination of the new tunable frequency conversion device with optical amplification and other system improvements will result in greater than 20 dB improvement in signal-to-noise ratio and will, therefore, triple the standoff measurement distance, reduce signal processing time, and offer greater frequency agility.

Enhanced Buried Explosive Detection System (Army 2004 SBIR Phase 2)
Dr. John Lovell (PI) 303-792-5615, john.lovell@adatech.com
ADA Technologies, Inc., Littleton, CO, www.adatech.com
Contract Number: W911QX-04-C-0006
Award Amount: $729,998
05NOV03 - 05NOV05

In this 3-Phase program, ADA Technologies proposes to develop and demonstrate a novel, active trace explosives sampling system/method that will be easily adapted for use with existing commercially available explosive detection sensors. This will lead to a generic-interface sampling device that will directly couple with currently deployed trace explosives detection sensors. The active sampling system has been shown in the Phase I project to amplify the signature of trace explosives on soil by two to three orders of magnitude. In the Phase II project, ADA will combine the active sampling system with a leading trace explosive sensor to create a system that will operate at a walking pace and will detect the trace explosives and explosive related chemicals that are associated with buried landmines. The combined system will be demonstrated in operational testing at a minefield test area.

Fast Laser Pulse Shaping for Molecular Control and CB Detection (Army 2004 STTR Phase 1)
Dr. Marcos Dantus (PI) 517-355-9715, dantus@msu.edu
Biophotonic Solutions, Inc., Okemos, MI (biophotonicsolutions.com) with Michigan State University, Contract & Grant Administration, East Lansing, MI
Contract Number: W911NF-04-C-0094
Award Amount: $99,855
03AUG04 - 15FEB05

Monitoring the air for potential chemical and biological agents (from terrorist threats or from industrial contamination) has become a necessity. Our proposal objective is to develop device capable of fast (1 second), accurate (even in a chemically complex environment), robust (stand alone, closed-loop, and portable), and reproducible sensing. Operationally, the device interfaces with a commercially available femtosecond pulsed laser and mass spectrometry module. The device operates on the principle of molecular control based on shaped laser fields. Using genetic-algorithm (GA) search methods, a series of laser fields are determined to unequivocally identify each chemical or biological agent of interest. The stand-alone unit monitors for suspected chemical agents. Multiple electromagnetic fields increase the accuracy of chemical identification a million-fold compared to available sensor methods. Upon positive identification, the unit contacts a command center. The goal for phase I will be to demonstrate that differently shaped laser fields produce uniquely different fragmentation mass spectra and that such fields can be determined for each chemical or biological sample. Phase II of the project will concentrate on the development of a field-ready, stand-alone module capable of detection of contaminants at part per billion levels even in the presence of a chemically complex environment.

Fast Response Chemical Sensor for Landmine Multi-Detector Device (Army 2003 SBIR Phase 2)
Dr. Leonid Krasnobaev (PI) 781-246-0700, leonid@implantsciences.com
Implant Sciences Corp., Wakefield, MA, www.implantsciences.com
Contract Number: W909MY-04-C-0002
Award Amount: $729,903
18NOV03 - 18NOV05

In Phase I, Implant Sciences Corp. (ISC) constructed an early prototype cyclone vapor sampling system with an integrated surface heater to extract explosives and ERC vapors from soil samples and to deliver the extracted vapors to a chemical detector. The physical design of the cyclone unit and its operating parameters were highly optimized. Currently, the cyclone module excludes particulates from the collected sample vapors, which is helpful in minimizing contamination of the detector, and can operate in crosswinds of up to 4 mph without significant loss of sample vapors to the ambient air. With the prototype sampling system interfaced to ISC's ultra-sensitive Laser IMS system, the ability to detect ppm ppb concentrations of TNT and RDX in two types of soil was demonstrated in a response time of less than one second. In Phase II, the design of the cyclone unit and the sample heater will be further optimized for a portable unit, and all components will be combined and modified as necessary to work as a complete system and to minimize size, weight and power consumption. This technology can be used to create a rapid-response chemical detector system to confirm or disprove the presence of buried land mines with a false-positive response rate substantially lower than those of currently employed portable explosives detectors.

Field Chemical Analysis Tool (Navy 2003 SBIR Phase 1)
Dr. Cy Herring (PI) 217-328-0481, cy@caviton.com
Caviton, Urbana, IL, caviton.com
Contract Number: M67854-03-C-1092
Award Amount: $69,999
07AUG03 - 07FEB04

Emission spectroscopy based microdischarge sensors will be adapted to a gas chromatography system for the rapid detection of chemical agents in the field. These systems will be tested to determine optimum column length for seperation and integration time. Microdischarge detectors are rapid, real-time sensors, capable of sub-parts per billion detection of a wide range of atomic and molecular species. They are ideal as gas chromatography detectors due to their small size and low flow requirements, a potential shortcoming of other available technologies. Additionally, these detectors provide a wealth of spectroscopic data, providing for accurate determination of chemicals present in air, with little chance of false alarms. The entire detection system will be self-contained, battery-operated, and robust enough for field deployment in its final form. Portable chemical analysis in a hand-held, rugged package will provide a safe effective source of chemical agent detection for protection of the warfighter. A portable, hand-held, hazardous chemical sensor will also be applicable for hazmat and fire department use, as well as for the screening of mail and luggage, and security monitoring of buildings. The technology also will be applicable to any situation where size and portability requirements are placed on a chemical analysis tool, such as in environmental site surveying, characterization, and monitoring.

Hand-Held, Standoff Chemical-Biological Hazard Detector (DoD SOCOM 2004 SBIR Phase 2)
Matthew Roberts (PI) 703-299-0252, cre299@aol.com
CRE, Inc., Alexandria, VA
Contract Number: USZA22-03-C-0041
Award Amount: $747,530
01JUL03 - 01APR04

Prototype two SORAD units based on a design developed in Phase I to meet SOF requirements and conduct the following research with the integrated hardware and software. - Conduct a Military Utility Assessment (MUA) with SOF personnel to assess human factors for man portable, standoff sensors and refine conceptual user interface from phase I design. - Test SORADS in austere SOF environments to ensure passive infrared technology supports SOF operational needs. - Experiment with SOF unique target requirements to include classic chemical warfare agents; toxic industrial chemicals; and precursors for counter-proliferation and counter-narcotics. - Conduct research to support specific SOF missions utilizing passive infrared spectrometers.

Improved Filters for Chemical Warfare Agent Detectors (CBD 2004 SBIR Phase 2)
Hamed Borhanian (PI) 978-606-2600, hamedb@sensera.com
Sensera, Inc., Chelmsford, MA, www.sensera.com
Contract Number: FA8650-04-C-6528
Award Amount: $749,898
27SEP04 - 28MAY06

During Phase I of this program, Sensera developed filters for the JCAD and LCAD detection systems that allow more efficient passage of nerve agents. Sensera's filters are superior to PTFE in that they allow improved permeation of nerve agents.

Improved Kit for Chemical Detection (Army 2004 STTR Phase 2)
Dr. Keith LeJeune (PI) 412-209-7298, klejeune@agentase.com
Agentase LLC, Pittsburgh, PA (www.agentase.com) with Battelle Technical Support Operations, Columbus, OH
Contract Number: W911NF-04-C-0118
Award Amount: $748,474
31AUG04 - 12SEP05

Agentase LLC has previously demonstrated that its technologies for enzyme polymerization can be used to detect nerve agent chemical weapons. That endeavor has resulted in a fielded product used by DoD, the U.S. intelligence community, and emergency first responders. User feedback, while positive, suggests that an expansion of the sensor's detection capabilities beyond nerve agents would greatly improve upon the product's utility. The completed Phase I STTR effort clearly shows that Agentase's enzyme-based chemical detection technology can be used to detect not only nerve agents, but also blood agents, blister agents, and a variety of toxic industrial chemicals, such as cyanide. Each of these chemistries has been adapted into a simple pen-like construct for inclusion within a kit of sensors for hazardous chemicals. The proposed Phase II effort is directed at developing individual pen-like sensors that detect target chemicals at concentration below levels that represent an immediate danger to life and health. Sensors will be extremely easy to use without training, respond to contamination within seconds, and be highly resistant to potential forms of chemical and environmental interference that can be problematic for conventional detection equipment.

In-Line, Real-Time monitoring of Arsenic in Drinking Water (Air Force 2004 SBIR Phase 1)
Dr. Mehran Pazirandeh (PI) 607-272-0002, mehranp@agavebio.com
Agave Biosystems, Inc., Austin, TX, www.agavebio.com
Contract Number: FA9300-04-M-1001
Award Amount: $100,000
11MAY04 - 11FEB05

In this Phase I project, Agave BioSystems proposes a novel approach for the development of a rapid and sensitive detection system for arsenic in drinking water based on the bioluminescent protein aequorin. The simplicity and ruggedness of this technology has the potential for providing low cost, on-line, real-time monitoring for arsenic as part of a treatment plant process control system. Aequorin is a unique calcium-sensitive photoprotein originally isolated from the jellyfish Aequorea aequorea. In nature, when aequorin is in the presence of calcium, it triggers the chemical reaction that results in the production of light. Agave BioSystems proposes to engineer a genetically modified aequorin that is capable of generating light in the presence of arsenic by replacing the aequorin calcium binding sites with arsenic binding sites. This will result in a specific and rapid arsenic detection mechanism. Subsequently, the engineered molecule will be integrated into a self-contained biosensor for the rapid, and sensitive detection of arsenic in drinking water.

In-Situ Aquatic Biomonitoring Toxicity Alarm (Army 2003 SBIR Phase 1)
Ryan Moody (PI) 919-405-3993, rmoody@nektonresearch.com
Nekton Research LLC, Durham, NC, www.nektonresearch.com
Contract Number: DAMD17-03-C-002
Award Amount: $119,989
13DEC02 - 10NOV03

A mobile platform is proposed for aquatic in situ toxicant detection featuring living biosensors. This platform or biosensor suite comprises a sentinel species biosensor, water quality monitoring sensors, and a water sampler. The biosensor suite will be deployable as an integrated sensor package on the Ranger TA (Toxic Alarm), a 10 lb micro-UUV. The proposed effort will include system design, fabrication, sensor integration, multi-sensor fusion, and lab and field trials. The proposed system will enable a mobile, man-portable aquatic biological early warning system to become a reality. Multi-agent capabilities being developed in other efforts will enable dynamic retasking of groups of the proposed platform to rapidly and accurately characterize the extent of a toxicant contamination in aquatic settings. The initial target military application is an early warning system to detect chem/bio contamination of drinking water sources for forward deployed troops prior to filtration by reverse osmosis water purification units and tactical water purification systems.

In-Situ Aquatic Biomonitoring Toxicity Alarm (Army 2003 SBIR Phase 2)
Ryan Moody (PI) 919-405-3993, rmoody@nektonresearch.com
Nekton Research LLC, Durham, NC, www.nektonresearch.com
Contract Number: DAMD17-03-C-0020
Award Amount: $726,471
31JAN04 - 31JAN06

A mobile platform is proposed for aquatic in situ toxicant detection featuring living biosensors. This platform or biosensor suite comprises a sentinel species biosensor, water quality monitoring sensors, and a water sampler. The biosensor suite will be deployable as an integrated sensor package on the Ranger TA (Toxic Alarm), a 10 lb micro-UUV. The proposed effort will include system design, fabrication, sensor integration, multi-sensor fusion, and lab and field trials. The proposed system leverages Phase I accomplishments and will enable a mobile, man-portable aquatic biological early warning system to become a reality. Multi-agent capabilities being developed in other efforts will enable dynamic retasking of groups of the proposed platform to rapidly and accurately characterize the extent of a toxicant contamination in aquatic settings.The proposed technology will have military and civilian benefits. The initial target military application is an early warning system to detect chem/bio contamination of drinking water sources for forward-deployed troops prior to filtration. In civilian applications, the technology has applications in homeland defense and environmental monitoring. Homeland defense applications include monitoring for toxicants in drinking water reservoirs on a periodic basis or in the event of suspected tampering. Environmental monitoring includes detection and localizing toxicants in public bodies of water, particularly populated beaches.

Isothermally Amplified Proximity Ligation Assays for Biothreat Agents (Army 2004 STTR Phase 1)
Dr. Jeffrey A. Cook (PI) 512-632-6010, jcook@echotechnical.com
Echo Technical, Cedar Park, TX (www.echotechnical.com) with University of Texas at Austin, Office of Sponsored Projects
Contract Number: W911NF-04-C-0090
Award Amount: $99,884
30JUL04 - 31JAN05

Echo Technical and the Ellington Lab at the University of Texas at Austin have performed initial testing of a demonstration biosensor capable of using aptamer-based receptors (Biological Reconfigurable Interface Electronics For Classification and Analysis of Selected Elements, or BRIEFCASE). We propose to adapt a recently developed technology, proximity ligation assays, to a field-deployable device based on the BRIEFCASE to perform rapid, specific, hypersensitive detection and identification of the unique protein biosignatures of biothreat agents. To date, the proximity ligation assay has relied on polymerase chain reaction (PCR) for signal amplification. While PCR has previously been adapted to fielded devices, these devices have tended to be relatively bulky, in part because of the hardware required for thermal cycling. To simplify reagent addition and ultimately the device itself, we will instead utilize isothermal amplification reactions that are as sensitive as PCR but require only a single addition of reagents to amplify nascent signals. This new technique, isothermally amplified proximity ligation assay (IAPLA), and an IAPLA-based biosensor prototype will be demonstrated to support goals identified for sensitivity, miniaturization, and field deployability, with feasibility demonstrated by the end of Phase I.

LCP-Based Packaging of Exposed MEMS Sensors (DARPA 2003 SBIR Phase 2)
Michael Kranz (PI) 256-533-3233, mkranz@morganres.com
Morgan Research Corp., Huntsville, AL, www.morganres.com
Contract Number: MDA972-03-C-0094
Award Amount: $490,822
24JUL03 - 30SEP04

Over many years of development, the microelectronics industry yielded a broad set of advanced microelectronics packaging techniques. These techniques have been designed to increase the reliability of microelectronic devices under harsh operating conditions by isolating the devices from the environment. However, these techniques are unsuitable for environmental MEMS sensors that require exposure to the environment. Humidity sensors and chemical sensors are two examples of MEMS sensors requiring this exposure. To meet the packaging needs of these devices, new package designs, packaging materials, and packaging techniques are required. The first phase of this SBIR effort resulted in package designs based on new materials and packaging techniques that will enhance the reliability of exposed MEMS sensors. Phase I performed materials compatibility studies, developed package designs and concepts, and conducted experiments to verify aspects of concept feasibility. Phase II will develop engineering prototype packages suitable for environmental testing and screening, as well as result in packaged MEMS sensors exposed to the environment.

Long Wave Infrared Acousto-Optic Materials:Development of Novel Materials for the Fabrication of LWIR (8-12 micron)Acousto-optic Tunable Filters for I (Army 2004 SBIR Phase 1)
Dr. Sudhir Trivedi (PI) 410-668-5800, strivedi@brimrose.com
Brimrose Corp. of America, Baltimore, MD, www.brimrose.com
Contract Number: W911QX-04-C-0043
Award Amount: $70,000
04DEC03 - 03JUN04

We propose to develop novel anisotropic materials that can be used to fabricate acousto-optic tunable filter (AOTF)-based spectral imaging systems in the LWIR (8 to 12 micron) spectral region. AOTFs are very attractive for multispectral and hyperspectral applications such as the detection of targets, backgrounds, and stand-off chemical and biological agents. Tellurium dioxide (TeO_2) is the most commonly used AOTF material, and it has a spectral transmission range of 0.35-5.0 micron. Chemical agent infrared absorption/emission primarily occurs in the 8-12 micron wavelength region. Currently, there is no technologically matured material for AOTF imaging in this wavelength range. We propose to investigate the mercurous halides (Hg_2Cl_2 and Hg_2Br_2) and tellurium (Te) for this purpose. These materials can be processed at relatively low temperatures, are nonhygroscopic, have high acousto-optic figure of merit (M_2), high birefringence, and relatively high transmission in the 8-12 micron spectral range. This long-wave infrared (LWIR) region technology is relevant to the detection of buried mines.

Miniature CBR Sensor with Combined Sampler and Terahertz Spectroscopy (Navy 2004 SBIR Phase 2)
Joseph Birmingham (PI) 360-694-3704, joe@microet.com
Microenergy Technologies, Inc., Vancouver, WA, www.microet.com
Contract Number: N00164-04-C-6035
Award Amount: $599,914
24MAY04 - 24MAY06

MicroEnergy Technologies in conjunction with vdW Design (at the University of Wisconsin-Madison) has demonstrated feasibility of developing a unique, non-intrusive chemical and biological agent detection system during Phase I. Current detection techniques rely on systems that are intrusive, expensive, slow, or unreliable. The non-intrusive Terahertz (THz) CBR detection approach demonstrated during phase I will enable reduced shipboard workload for functions (such as examining packages delivered to Navy ships) and will increase the ship's protection against asymmetrical threats. The objective of this proposal is to develop a portable solid-state device to interrogate shipboard hazards with Terahertz (THz) energy to determine the presence of chemical and biological hazards. While the initial focus is on screening packages, the proposed system is safe for people screening, and when afloat, the THz system can be used to alarm against airborne threats. During Phase I, we demonstrated the efficacy of the novel combination of microstructured aerosol and gas collector with an all-electronic THz spectrometer to non-invasively detect simulants of hazardous chemical vapors and biological pathogens. The participants have substantial experience in every aspect of the novel combination of filtration and detection, including air sampling for CB agents, surface sampling, and optical spectroscopy. During Phase II, we will focus on development of a portable prototype for demonstration with biological agents in a certified agent lab.

Nanoporous Metallic Structures for Concentrating Hazardous Vapors (Army 2004 STTR Phase 1)
Dr. Jane F. Bertone (PI) 781-769-9450, bertone@eiclabs.com
EIC Laboratories, Inc., Norwood, MA (http://www.eiclabs.com) with Johns Hopkins University, Baltimore, MD
Contract Number: W911SR-04-P-0080
Award Amount: $99,999
12AUG04 - 12AUG05

Air toxins must be rapidly and accurately detected. The trace concentrations (generally ppb) that must be detected usually require sensitive analytical laboratory equipment, whereas rapid and continuous field monitoring is preferable. A filter that rapidly concentrates the contaminants into a small sample volume and can be directly interrogated using a noninvasive, stand-alone device is desired. In this program, EIC Laboratories and Johns Hopkins University will develop novel nanoporous metallic substrates that can simultaneously concentrate the hazardous material into a small volume and then serve as the sample for optical evaluation. The techniques of Surface-Enhanced Raman (SERS) and Surface-Enhanced Infrared (SEIR) spectroscopy can both provide ppb levels of detection for analytes adsorbed to roughened metal substrates. EIC has already demonstrate 5 ppb detection of explosive vapors on portable equipment in military field tests. In the current program, nanoporous gold will be produced through novel nanosynthetic and metallurgic procedures. The physical characteristics of the substrates, their adsorption coefficients for hazardous materials of interest, and SERS and SEIR spectra will be collected. The optimal substrates will be further developed and demonstrated in an air handling system that can emulate building flow rates.

Nanostructured Substrates for Surface-Enhanced Raman Scattering (Air Force 2003 STTR Phase 1)
Dr. Jane Bertone (PI) 781-769-9450, bertone@eiclabs.com
EIC Laboratories, Inc., Norwood, MA (www.eiclabs.com) with Clemson Univ., Office of Sponsored Programs, Pendleton, SC
Contract Number: F49620-03-C-0060
Award Amount: $99,997
02SEP03 - 02SEP04

The proposed program aims to demonstrate nanoengineered metal surfaces which will reproducibly enhance the Raman scattering of chemical and biological agents while still providing selective detection at trace concentrations. Two main categories of nanoscale architecture will serve as the basis for the proposed substrates: colloidal crystal templated superstructures and self-organized arrays of engineered Ag nanocrystals, the latter under development by Clemson University. The 9-month Phase I technical program goal is to evaluate the ability of these two types of nanostructured surfaces to act as reproducible SERS substrates for the detection of chemical and biological species relevant to CBW protection at low levels with a high degree of selectivity. The Phase II program will build upon the Phase I results, improving the chemical selectivity of the nanoparticles and lowering the detection limits of the substrates through surface modification. During phase II, we will pursue the development of a fieldable SERS spectrometer by incorporating substrates into the modular probe of a commercial portable Raman system. SERS promises to be a universal detector for trace constituents in air and water. It will have wide applications for monitoring water supplies, sensing air pollutants, monitoring facilities for possible chemical and biological terrorism, and incorporation into air reconnaissance platforms. Further applications are anticipated for screening for disease markers and toxins in clinical samples.

A Novel, Microfabricated, Electro-Immuno, Integrated Sensor-Sampler for Bioagent Collection and Detection (Navy 2004 SBIR Phase 2)
Kapil Pant (PI) 256-726-4871, jls@cfdrc.com
CFD Research Corp., Huntsville, AL, www.cfdrc.com
Contract Number: M67854-04-C-5020
Award Amount: $599,935
13JAN04 - 13JAN06

We propose to develop and demonstrate a compact, low-cost, low-power, high-sensitivity, integrated sensor-sampler that provides vastly superior performance while concomitantly achieving drastic size/weight reduction. The overall device is expected to be of shoebox size, to operate with AC/DC power, to generate <30dB of noise, and to target a sample-to-answer time of <5 minutes. The Phase I project successfully demonstrated concept development, design, and integration of three major components: (a) high-efficiency, high-viability, low-power electrostatic capture of bioagents from air, (b) high selectivity advanced electrokinetics-based method for intelligent discrimination of particulates, and (c) high-sensitivity, readily multiplexable bead-based immunoassay detection. Physical prototypes were microfabricated and experimentally proven. During Phase II, we will partner with Micronics Corporation to enable fast, accurate and reliable quantitative analysis of chem-bio agents in complex samples using microfluidic technology. First, the personal-sized electrostatic sampler will be engineered for >90% capture of targeted particulates in liquid medium. Next, the advanced electrokinetic separation and bead-based immunoassay will be optimized and integrated with Micronics' state-of-the-art Microcytometer(TM) cartridge. This extremely sophisticated cartridge will feature on-chip reagent storage and lysing of cells, and is fully integrated with a miniaturized, portable flow cytometer. The air sampler will be seamlessly interfaced with this microfluidic detection system. Waste will be contained on-chip for safe disposal, with minimal user training required. Detailed performance assessment with biosimulants and HVAC pollutants will be carried out.

Novel THz-Frequency Spectrometers by Integrating Widely-Tunable Monochromatic THz Sources and Detectors, or Arrays of Emitters and Detectors (CBD 2004 SBIR Phase 1)
Dr. Yuliya B. Zotova (PI) 610-762-0170, yzotova@hotmail.com
Arklight, Inc., Center Valley, PA
Contract Number: W911NF-04-C-1235
Award Amount: $70,000
17MAY04 - 16NOV04

This SBIR Phase I project focuses on the comprehensive analyses and designs of the three novel prototype THz-frequency spectrometers. Such a goal is built upon the recent success of the implementations of widely-tunable monochromatic THz sources and the accomplishments of chemical sensing, characterization of bio tissues, studies of photonic bandgap crystals, and quantum detectors. During the Phase-I period, we will perform comprehensive analysis and design of nonlinear parametric sources in terms of their capabilities including appropriate crystals, tuning ranges, peak powers, and linewidths. We plan to investigate performances of various conventional and novel quantum-based detectors in terms of operational temperatures, sensitivities, and frequency ranges. We propose to study effects of photonic bandgap crystals on THz sources and detectors. We will then design the three prototype systems by integrating sources and detectors, or arrays of emitters and detectors, with photonic bandgap crystals, that can be used to perform chemical and biological spectroscopic detections. We will analyze potentials of the prototype systems for point and remote sensing to make the systems compact, portable, and suitable for battlefield deployment.

Onboard PCB Detection using a Portable Raman Analyzer (Navy 2004 SBIR Phase 1)
Dr. Kevin M. Spencer (PI) 781-769-9450, spencer@eiclabs.com
EIC Laboratories, Inc., Norwood, MA, http://www.eiclabs.com
Contract Number: N65538-04-M-0129
Award Amount: $70,000
13MAY04 - 13NOV04

Contractors dismantling ships are unlikely to have preexisting knowledge of toxins; therefore continuous materials analysis is part of the dismantling operation. For example, polychlorinated biphenyl (PCB) was used routinely in ship components ranging from gaskets to paints to power cords. There is no EPA-approved field method for PCB detection, and laboratory analysis is costly and slows down dismantling. We propose to develop a portable PCB analyzer based upon resonance Raman spectroscopy. Raman spectroscopy allows rapid and unique identification of the desired analyte; resonance enhancement allows low ppm detection. By overlapping the laser with a PCB absorption band, PCB can be selectively enhanced over any complex matrix. Using a compact portable UV echelle spectrograph, fiber-optic coupling, and a compact UV laser, we will develop a portable unit capable of rapid (<120 s) quantitative PCB identification. We will determine detection limits, reproducibility, calibration accuracy, and absence of potential matrix effects. The automated turnkey system will be useful in military and commercial applications.

Passive Sensor for the Detection of Hydrazine Leaks in Missile Canisters (DoD MDA 2004 SBIR Phase 2)
Dr. Howard C. Wikle III (PI) 334-887-3985, wiklehc@mindspring.com
Weld Star Technology, Inc., Auburn, AL
Contract Number: W9113M-04-C-0025
Award Amount: $750,000
18MAR04 - 17MAR06

The Air Force has set the maximum exposure limit to hydrazine at 10 ppb for an 8-hour period. A hydrazine sensor is needed to protect personnel from hydrazine leaks and insure the readiness of the THAAD missile. Seventy-five sensors were fabricated under the successful Phase I research effort. The sensor was demonstrated to be able to detect as little as 2 ppb to hundreds of ppm hydrazine with a rapid response time of less than a second. No degradation in the sensor response after 90 days of storage was measured. The objective of this Phase II project is to complete the research required to deliver to the THAAD program for military qualification testing a low-cost, easy-to-use, passive, nonreversible, MEMs-based chemiresistor sensor for the detection of hydrazine in missile canisters. The sensor delivered for qualification testing will be capable of operating in two modes: 1) a storage monitoring mode where the sensor will monitor long-term levels of hydrazine to insure the integrity of the THAAD missile system and 2) an alarm mode to provide an instantaneous warning that a leak has occurred.

Portable Cell Maintenance System (Army 2004 STTR Phase 1)
Dr. Theresa Curtis (PI) 607-272-0002, tcurtis@agavebio.com
Agave Biosystems, Inc., Austin, TX (www.agavebio.com) with Cornell University, Office of Sponsored Projects, Ithaca, NY
Contract Number: W81XWH-04-C-0140
Award Amount: $98,953
10AUG04 - 22MAR05

Cultured cell-based biosensors offer insight into the physiological action of the agent of interest, which is an advantage over other types of sensors. The development of field-portable cell-based biosensors would increase their utility in toxicology and environmental monitoring. One of the most significant issues hampering the development of field-portable cell-based biosensors is the maintenance of optimal cultured cell environment under field conditions. A key technology to overcoming this issue is the use of microfluidic systems. A microfluidic-based system would allow assaying small quantities of sample while optimizing storage and transport conditions by minimizing the overall system size and fluid monitoring requirements. In Phase I, Agave BioSystems and Cornell University propose to develop a cell maintenance system (CMS) with integrated pH, osmilarity, CO_2, and temperature sensors to support multiple vertebrate cells and cell types under field conditions. An inexpensive and disposable microfluidic cell cartridge suitable for use in hand-held devices and fabricated from biocompatible materials will be developed. The proposed CMS would maintain vertebrate cell viability and sterility through transport, storage, and testing and be compatible with interfaces for acquisition and analysis of cell signaling data relevant to toxicity identification.

Portable Microcapacitor Chemical Detector System (Navy 2004 SBIR Phase 2)
Todd Mlsna (PI) 760-473-8602, tmlsna@seacoastscience.com
Seacoast Science, Inc., Carlsbad, CA, www.seacoastscience.com
Contract Number: M67854-04-C-3038
Award Amount: $594,937
27FEB04 - 27AUG06

The purpose of this program is to develop MEMS chemicapacitive sensors and integrate with a MEMS preconcentrator. The initial focus will be on the development of chemoselective materials for the detection of chemical warfare agents (CWA), toxic industrial chemicals (TIC) and toxic industrial materials (TIM). This work will ultimately lead to the development of a low-cost, low-power chemical badge detector based on micromachined capacitors. Our MEMS sensor array utilizes micromachined chemicapacitors coated with chemoselective polymers optimized for the detection of target chemicals. Capable of detecting many chemical mixtures, each chip has ten sensors, with several different coatings for redundancy and interferent rejection. Exceptionally low power consumption, inexpensive production cost, and robustness make our detector ideal for field deployment. As part of this Phase II effort, we will fabricate a small battery-powered prototype to demonstrate the capabilities of this technology. The system will include a chemical sensor array selective and sensitive to CWA, TIC, or TIM and a small, rugged, lightweight, low-power system designed for use as a badge sensor.

Portable SERS Spectrometer for PCB Analysis (Navy 2004 SBIR Phase 1)
Dr. John Steinbeck (PI) 717-871-8971, john.steinbeck@illuminex.biz
Illuminex Corp., Lancaster, PA
Contract Number: N65538-04-M-0130
Award Amount: $70,000
13MAY04 - 13NOV04

A portable PCB detection and quantification system is proposed based on Surface Enhanced Raman Scattering (SERS). The system comprises a SERS sensor head and fiber optics interfaced to a commercially available PDA or handheld computer. Surface Enhanced Raman Scattering is capable of detecting molecules at the parts per trillion level and is well-suited to meet the 50 ppm threshold for PCB detection. Since every molecule and isomer has a unique Raman spectrum, it will be possible to determine the composition of PCB mixtures with high accuracy. The phase I program will construct a prototype system using off-the-shelf components and custom analysis software to evaluate the ability of a portable fiber optic system to meet the detection needs of Navy salvage operations. Phase II will refine the prototype system of phase I by upgrading the detection and analysis components and construct a field deployable test system.

Portable System for Sample Preparation and Differentiation of Pathogens at Strain Level (CBD 2004 SBIR Phase 1)
Dr. Adrian Denvir, 979-693-0017, adrian.denvir@lynntech.com
Lynntech, Inc., College Station, TX, http://www.lynntech.com/
Contract Number: W911SR-04-P-0049
Award Amount: $69,180
21APR04 - 21OCT04

During the anthrax attacks in 2001, investigators had difficulty in differentiating the strains apart because B. anthracis has a low level of genetic variability. This event demonstrated the need for rapid and precise molecular subtyping technologies. Lynntech proposes to develop an ultra-sensitive quantum dots-based molecular beacon fluorogenic reporter system to identify the presence of specific pathogen species at the strain level. The technology will be incorporated with the surface sampling device and the portable PCR-unit being developed by Lynntech. Molecular beacon (MB) is a hair-pin shaped oligonucleotide probe that has a fluorescent dye and a quencher located at each end of the strand. MBs become fluorescent upon hybridization and they have selectivity for single base-pair mismatch identification. MBs modified with fluorogenic quantum dots of characteristic emission colors will allow more sensitive multiplex detection of DNA sequences with much simpler and less expensive instrumentation. Lynntech will demonstrate the technology's ability to discriminate between different strains of E. Coli. Lynntech will also demonstrate the ability to differentiate different amplicons obtained from similar species such as Escherichia coli and Salmonella. These assays will be carried out entirely in sealed PCR tubes, enabling fast and direct detection of E. Coli. in an automated format.

Reactive Fluorescent Sensors for Detecting CW Agents at Sub-Chronic Levels (CBD 2004 SBIR Phase 1)
Dr. Greg Frye-Mason (PI) 405-372-9535, gfryemason@nomadics.com
Nomadics, Inc., Stillwater, OK, www.nomadics.com
Contract Number: W911NF-04-C-0043
Award Amount: $69,997
21APR04 - 20OCT04

None of the current chemical warfare (CW) agent sensors or field test kits has sufficient sensitivity to detect nerve and blister agents at allowable exposure level concentrations. Thanks to a remarkable chromophore developed by Professor Timothy Swager at MIT, Nomadics believes that we can achieve these detection levels in a small, low-cost sensor. Recently, Nomadics has demonstrated an exciting new fluorescence-based chemical warfare agent sensor that provides very high sensitivity with a unique selectivity to the toxicity of these agents. The platform is soon to be tested against live agents and has not responded to any potential interferent other than substances that are themselves hazardous materials. Because the chromophores are so sensitive, use a dark-field detection mechanism, require only simple optics and electronics, and because of Nomadics' extensive experience in developing low-cost, sensitive, rugged field instruments, we expect to be able to demonstrate a functional model in Phase I that will confirm the system's potential as a practical handheld CW agent detector.

Real-Time LIBS-Based Sensor for Measuring Arsenic Concentration in Water (Air Force 2004 SBIR Phase 1)
Robert F. Dillon (PI) 781-273-5995, bob.dillon@lumenlabs.com
Lumen Laboratories, Inc., Burlington, MA, www.lumenlabs.com
Contract Number: FA9300-04-M-1009
Award Amount: $99,612
13MAY04 - 13FEB05

Lumen Laboratories will demonstrate the feasibility of using an inexpensive form of laser-induced breakdown spectroscopy (LIBS) to detect arsenic (As) in water at concentrations of 1 part per billion (ppb). Phase I research will show the feasibility of 1 ppb detection using a novel concentrator scheme combined with a LIBS device constructed using a passively Q-switched microchip laser. A breadboard system will be constructed for this purpose. Phase I reported results will include analysis of measured data, a conceptual prototype design, a Phase II test plan, and a survey of potential commercial applications. The conceptual instrument design will be refined, prototyped, and tested with real-world samples in Phase II.

Real-Time Process Control Sensor for Measuring Arsenic Concentration in Water (Air Force 2004 SBIR Phase 1)
Dr. Badawi Dweik (PI) 781-529-0520, bdweik@ginerinc.com
Giner, Inc., Newton, MA, www.ginerinc.com
Contract Number: FA9300-04-M-1007
Award Amount: $99,883
11MAY04 - 11FEB05

U.S. EPA recently lowered its water standard for arsenic from 50 ppb to 10 ppb. To comply with the new standard, there is an urgent need to develop new, simple, and effective treatment and monitoring systems. Currently, accurate measurement of arsenic in drinking water requires laboratory analysis. The objective of this research is to develop and demonstrate an easy-to-use, reliable, field-deployable, and practical real-time sensor device for rapid on-site quantitative determination (at ppb levels) of dissolved arsenic in drinking water. The proposed monitor will employ fabricated thin-film, boron-doped diamond microelectrode arrays utilizing differential pulse anodic stripping voltammetry (DPASV) and select microarrays to detect both arsenate and arsenite in water. The combination of DPASV methods with microelectrode technology conveys advantages for the rapid on-line measurement of arsenic in water without addition of supporting electrolyte, while requiring little or no maintenance. Phase I will investigate the optimal design configuration, electrode material, and operating conditions that will enhance sensitivity and enable reproducible detection of arsenic at low ppb levels with negligible interference. A compact packaged prototype instrument, including the sensor hardware and the corresponding electronic circuitry, will be developed in Phase II.

Remote Infrared Nanostructured Adsorber-Based Chemical Agent Monitor (CBD 2004 SBIR Phase 1)
Dr. Ranjit D. Pradhan (PI) 310-320-3088, sutama@poc.com
Physical Optics Corp., Electro-Optics Holo Div., Torrance, CA, www.poc.com
Contract Number: FA8650-04-M-1693
Award Amount: $69,981
23APR04 - 23OCT04

To address the Chemical and Biological Defense Program request for an inexpensive, reusable, stand-alone, remote-signaling point detector for sensing chemical warfare agents (CWAs), Physical Optics Corporation (POC) proposes to develop a remote infrared nanostructured adsorber-based chemical agent monitor (RINACAM). In RINACAM, broadband infrared radiation from a solid-state emitter is coupled into an infrared optical waveguide with a specially patterned nanostructured surface, designed to efficiently and reversibly adsorb CWAs. These adsorbed species directly affect the waveguide optical output recorded by POC's scalable superhigh-resolution miniature spectral sensor. Through smart data processing of this high-resolution spectral data, RINACAM robustly identifies

CWA chemical signatures. At the end of each measurement cycle, the integrated heater element heats the nanostructured adsorption infrared waveguide to exhaust the adsorbed CWAs back into the air. This clears RINACAM for a new measurement, making the device continuously reusable. RINACAM is a rugged, compact, low-power-consuming package, with all solid-state components and no moving parts. In Phase I, POC will demonstrate the feasibility of RINACAM by assembling and testing a laboratory breadboard representing all component technologies. In Phase II, POC will develop an advanced RINACAM prototype. The proposed RINACAM will also meet USAF requirements for a remote signaling CWA point detector.

Respiratory Endothelial Cell Sensor for Real-Time Air Toxicity Monitoring (Army 2004 SBIR Phase 2)
Dr. Theresa Curtis (PI) 607-272-0002, tcurtis@agavebio.com
Agave Biosystems, Inc., Austin, TX, www.agavebio.com
Contract Number: W81XWH-04-C-0043
Award Amount: $730,000
03JAN05 - 02MAY07

Because many chemical and biological toxins selectively target respiratory endothelial cells, a biosensor using these cells in combination with Electric Cell-substrate Impedance Sensing (ECIS) technology has many useful applications for detection and early warning monitoring of a broad range of toxic agents. In the Phase I SBIR program, Agave BioSystems was highly successful in demonstrating that endothelial cells are a robust system that can be harnessed in a new class of extremely sensitive yet versatile biosensors to detect a wide variety of chemical toxins. Through simple monitoring of the integrity of respiratory endothelial monolayers using ECIS technology, we successfully detected paraquat, pentachlorophenol, and half-mustard contamination within minutes of addition to the biosensor. By combining the respiratory endothelial cells with state-of-the-art microfluidics, we were able to continuously deliver samples to the biosensor and demonstrate real-time toxicity monitoring over a 2-week period. The focus of the Phase II plan will be to test the system with a wide range of toxic chemicals, refine the microfluidic biochip for continuous flow conditions, develop a field portable ECIS biosensor, and integrate an air sampling system for continuous monitoring.

Sensitive GaN-based Chemical and Biological Detectors for Monitoring of Water Supplies (Army 2004 SBIR Phase 1)
Dr. Andrew Wowchak (PI) 952-934-2100, wowchak@svta.com
SVT Assoc., Inc., Eden Prairie, MN, www.svta.com
Contract Number: W9132T-04-C-0009
Award Amount: $69,994
09DEC03 - 08JUN04

Effective monitoring is critical in protecting populations against the dangers of accidental or intentional contamination of water supplies. For both civilian and military operations, fast-acting remote sensors are needed that can detect a range of possible biological and chemical substances, below toxicity levels in water supplies, and report the results to central computers. For troops in the field, these sensors should be portable, easy to install, and low-maintenance for long-time continuous operation. In this Phase I project, SVT Associates in collaboration with the University of Florida will demonstrate the feasibility of chemical and biological sensors based on III-nitride optical and electrical devices for fast, reliable, and automated monitoring of hazardous materials in water supplies.

Small Unmanned Aerial Vehicles (UAVs) for Detection of Agents of Mass Destruction (SUDAMaD) (Air Force 2003 SBIR Phase 1)
Dominick DiNovo (PI) 614-798-8215, ndinovo@guildassociates.com
Guild Assoc., Inc., Dublin, OH
Contract Number: F33615-03-M-3334
Award Amount: $99,399
23JUL03 - 23MAY04

Current chemical and biological warfare (CBW) detection programs have advanced the state of chemical and biological detection, yet issues remain. Fielded technologies and those under development address CBW attacks in conventional battle space. For stand-off detection in particular, the units are large, complicated, and expensive; limited in range, sensitivity, and specificity; and subject to environmental interference and obstruction (hills, mountains, buildings, etc.) Pervasive detection over a broad area, at reasonable cost, and with high confidence embodies an unmet need. Advances in UAV/MAV systems and sensor technology make feasible an inexpensive, flying CBW sensor array. Such a system could be deployed by forward units, or dispatched by other air vehicles in order to scout and report back data of interest. The autonomous aerial detection arrays resulting from this project will mitigate issues in current stand-off detection. Other applications include monitoring releases of hazardous chemicals or gases arising from conflagrations, industrial operations, vehicular accidents, nuclear power plants, or environmental hazards, such as volcanoes.

STEALTH: A New Chem/Bio Sensor Based on Differential Fluorescence from Molecularly Imprinted Polymers (Army 2004 STTR Phase 2)
Dr. Royal Kessick (PI) 804-270-1411, rkessick@msn.com
Sentor Technologies, Inc., Glen Allen, VA (www.sentortechnologiesinc.com) with Virginia Commonwealth University, Richmond, VA
Contract Number: W9132V-04-C-0023
Award Amount: $749,964
30SEP04 - 01OCT05

Sentor Technologies Inc. proposes to develop and demonstrate a new STEALTH chem/bio sensor technology based on differential fluorescence from molecularly imprinted polymers. In Phase I, the feasibility of both the STEALTH sensor as well as an integrated vapor sampler/concentrator based on the charged nanodroplets produced from an electrospray source was successfully demonstrated. The vapor sampler/concentrator was invented by Nobel prize winning chemist Dr. John Fenn, the Virginia Commonwealth University PI on this proposal. The proposed STEALTH sensor utilizes a patent-pending sensing strategy that eliminates the need for spectroscopic analysis, thereby greatly reducing the sensor hardware and power requirements. The Phase II project will culminate in the development and demonstration of a fully integrated sensor prototype with a combination of performance parameters surpassing any existing technology.

Streamlined Site Investigation Procedures (Air Force 2004 SBIR Phase 1)
Jeffrey M. Brammer (PI) 405-364-9726, jbrammer@surbec-art.com
Surbec-Art Environmental, LLC, Norman, OK
Contract Number: FA8103-04-C-0135
Award Amount: $93,942
03AUG04 - 03MAY05

Typically, the path to site closure is a very long and indirect one. The currently accepted "trial and error" method of drilling and sampling monitor wells, and based on the sample results, drilling and sampling additional wells, is neither efficient nor cost effective. Site delineation can often require several years, and often does not acquire the necessary information for optimal and innovative remediation technologies. Site remediation has also yielded similar frustrations with slow remediation times and the inability to achieve the cleanup contaminant levels. The purpose of this project is to develop a document entitled "Decision Tree Streamlined Methodology" for site investigation/remediation that responsible parties can use to select the optimal methodology (technology) for an effective site investigation and cleanup. This document will guide the user, step by step, to achieve an efficient and cost-effective site closure. Ultimately, this will result in significantly reduced investigation and remediation time and costs for DoD. In Phase I and continued in Phase II, traditional and innovative investigation and remediation technologies will be evaluated and tested. Results of recent innovative remediation efforts, at Tinker AFB and elsewhere, will also be presented.

SuMo SERS: A Novel, High-Reliability CBW Agent Detection System Using Surface-Modified Gold Nanoparticles as a SERS Substrate (Air Force 2003 STTR Phase 1)
Dr. Robert Shelton (PI) 405-372-9535, rshelton@nomadics.com
Nomadics, Inc., Stillwater, OK (www.nomadics.com) with Michigan State Univ., East Lansing
Contract Number: F49620-03-C-0061
Award Amount: $100,000
02SEP03 - 02SEP04

Surface Enhanced Raman Spectroscopy (SERS) is a powerful technique for detecting and identifying target analytes, such as CBW agents, even at very small concentrations. Traditional SERS techniques often suffer from poor reliability and reproducibility, whereas nanoparticle-based SERS has a tremendous advantage over bulk-surface SERS due to a very high amount of surface area for interaction in a small volume. The nanoparticles must be carefully stabilized to remain in solution, which limits their ability to interact with analyte as is required for SERS. Nomadics proposes to develop an improved SERS technology by determining the optimum shape and size of nanoparticles to maximize the SERS response. We will chemically modify the surface of nanoparticles to maintain the nanoparticles suspended in solution and preferentially bind the target analyte to the nanoparticles, optimizing the SERS response. With this improved SERS platform, we will develop a robust, reliable SERS-based sensor technology suitable for detecting even trace amounts of CBW agents that will be useful to both the military and various civilian law enforcement and emergency-response agencies. Trace detection of nearly any chemical or molecular species should be possible with this technology, with a large range of potential sensor applications: pesticides, water purity, drug discovery, and so on.

Use of Pattern Recognition to Optimize Site Investigation (Air Force 2003 SBIR Phase 1)
Dr. G. Gina Ling (PI) 808-441-3600, gina.ling@nova-sol.com
Contract Number: F34601-03-C-0467
Award Amount: $99,931
20AUG03 - 20MAY04

NOVASOL proposes to develop pattern-recognition technology in the analysis of data related to remedial investigations at sites affected by dense nonaqueous phase liquid (DNAPL) contamination. The proposed Pattern Recognition Optimization Technology for Investigation of Contaminated Sites (PROTICS) system will consist of geostatistical modeling, spatial visualization modeling, pattern recognition modeling, and geographic data integration to analyze diverse data types, identify data gaps or insignificant data types, and provide a useful tool to identify potential DNAPL sources in the subsurface. Though these modeling approaches have previously been used individually in many environmental applications, combining them into one systematic analysis tool will overcome the limitations of each individual model to establish spatial relationships among the different data types. This data integration and digestion system will optimize the enormous amounts of information that have been collected for many DoD sites. The spatial data analysis and statistical modeling results produced from the proposed research will enable more precise delineation of DNAPL contaminant plumes. The proposed PROTICS system embodies features that will yield a unique competitive advantage in the marketplace. A great need exists for a systematic approach to intelligently digest the large quantities of data that remedial investigation produces at DNAPL sites. The advanced pattern recognition and modeling capability of PROTICS will allow improved site characterization, thereby aiding the development of effective remedies and reducing remediation costs.

Wearable Electrophysiologic Sensor Suite for Detection of Neurotoxic Effects (Army 2003 STTR Phase 1)
Dr. Robert Mtthews (PI) 858-373-0832, robm@quasarusa.com
Quantum Applied Science & Research, Inc., San Diego, CA, with Scripps Research Institute, La Jolla, CA
Contract Number: DAAD1903C0101
Award Amount: $99,946
11AUG03 - 09FEB04

This program combines a breakthrough in electrophysiologic sensors with state-of-the-art (SoA) research into the determination of cognitive state and autonomic arousal. The sensor breakthrough enables accurate measurement of bioelectric signals without contact to the skin, even operating through clothing if desired. The target configuration for the prototype system to be built in Phase II is a small array of the new bioelectrodes mounted on the outer surface of a lightweight cap or on the inside of a helmet. In Phase I, measurements will be performed at the Cognitive Electrophysiology Laboratory (CEL) at the Scripps Research Institute to define a set of measurement channels that can be used as the inputs to a cognitive gauge. This gauge will combine the physiologic inputs using SoA algorithms and insights, to produce a single reading indicative of impending cognitive dysfunction. The measurements will use low levels of alcohol intake to affect cognitive performance under protocols developed at CEL over the last five years. In Phase II, a functional prototype including the sensor array and all algorithms will be demonstrated. The prototype will be tested for extended periods and under different conditions on a statistically significant number of subjects at CEL. The proposed system will provide a dramatic improvement in capability to monitor the cognitive state. By measuring brain function directly, the system will be able to detect effects due to neurotoxins, uncompensated stress, sleep loss, and information overload. Other military applications could include alertness monitoring, and as a component of future man machine interfaces. Significant commercial opportunities exist in the research market transitioning to medical applications such as neuropharmacology, and civilian security applications such as fire departments and hazardous waste treatment.

Yeast Based Biosensor for Oganophosphate Detection (CBD 2003 SBIR Phase 2)
Thomas Wavering (PI) 434-972-9951, waveringt@lunainnovations.com
Luna Innovations, Inc., Blacksburg, VA, www.lunainnovations.com
Contract Number: DAMD17-02-C-0098
Award Amount: $673,443
16MAY03 - 16MAY05

A need exists for rapid, accurate, and sensitive methods for the detection of organophosphates (nerve agents and pesticides) in cluttered environments. The in vitro modification and selection (IVMS) process under development by the Luna team overcomes the limitations of current biosensor technologies by converting a known biomolecular sensor -- the receptor for a steroid hormone -- into a new sensor that specifically recognizes the target organic compound of choice. Luna and UVa are utilizing the IVMS process to develop a flexible biosensor platform for the detection of VX. During the Phase I program, the Luna team has focused on developing the receptor technology and demonstrating its feasibility for the detection of organophosphates in a yeast-based biosensor. Specific Phase I program achievements include the optimization of the screening process, selection of a receptor library enriched for receptors that bind Demeton-S, and demonstration of a yeast-based FRET biosensor technology with ppb sensitivity. During the Phase II program, Luna will leverage the experience with Demeton-S to develop a rapid, reliable, and sensitive detection system for VX, easily expandable to incorporate additional organic chemical targets of interest. Research concerning biosensors will yield immediate applications in 1) chemical/ biological agent detection, 2) mine and explosives detection, 3) drinking and wastewater monitoring, 4) therapeutic drug monitoring, and 5) chemical analysis.

U.S. DEPARTMENT OF ENERGY

A High Intensity Neutron Source for the Detection of Unexploded Ordnance (DOE 2004 STTR Phase 1)
Dr. Charles Mansfield, PI, 505-661-3651, coyote2@swcp.com
Alme and Associates, Los Alamos, NM; with Los Alamos National Laboratory, Los Alamos, NM
DOE Grant No. DE-FG02-04ER86209
$99,995

This project addresses the identification of unexploded ordnance, using a nuclear assay with neutrons produced by fusion reactions. In particular, a portable neutron source will be developed that is capable of detecting high explosives, particularly unexploded ordnance (UXO) and landmines buried underground, using the nuclear assay. The high intensity neutron source will be based on an inertial electrostatic confinement (IEC) plasma device developed under the sponsorship of the DOE Office of Fusion Energy Sciences. Phase I will experimentally verify calculation for scaling the IEC source and complete an engineering design for a portable IEC source. The neutron source should be large enough for use in a real-time assay for the detection of high explosives. The removal of unexploded ordnance is a key task in the decommissioning of military bases and their conversion to civilian uses. Other applications include the identification of landmines in former combat areas, the identification of special nuclear materials, and the field detection of chemical weapons.

Ultra-Trace Molecular Detection Instrumentation Based on Aerosol Nucleation with Rapid Preconcentration and Separation (DOE 2004 STTR Phase 1)
Dr. Vladimir B. Mikheev, PI, 509-375-1093, vladimir@tekkie.com
InnovaTek, Inc., Richland, WA, www.tekkie.com; with Pacific Northwest National Laboratory, Richland, WA
DOE Grant No. DE-FG02-04ER86188
$100,000

Detection networks and systems are needed to support the wide-area monitoring, detection, location, and characterization of non-declared nuclear activities by monitoring of chemical signatures of nuclear material production (effluents from uranium conversion and enrichment facilities). A novel sensor, based on the nucleation principle (gas-to-particle phase transition), will be developed in order to detect low concentrations (parts per trillion and less) of various chemicals in air that are signatures for nuclear material production. In particular, both methods and prototypical hardware will be developed for using aerosol nucleation in combination with high speed chromatographic separation for the selective detection of traces of semi-volatile and volatile chemical signatures of nuclear material production. Phase I will determine the feasibility of developing a sensor that is sensitive, selective, and fast. A sensor based on ultra-sensitive analytical techniques should be widely used for nuclear non-proliferation purposes. Other applications include explosives detection, monitoring for chemical weapons and toxic industrial materials, leakage testing, and clean room control.

Development of Soft-Ionization for Particulate Organic Detection with the Aerodyne Aerosol Mass Spectrometer (DOE 2004 SBIR Phase 1)
Dr. Douglas R. Worsnop, PI, 978-663-9500, worsnop@aerodyne.com
Aerodyne Research, Inc., Billerica, MA
DOE Grant No. DE-FG02-04ER83890
$100,000

Small, organic, airborne particles, generated from energy-related activities, contribute to the formation of acid rain and adversely impact visibility, global climate and human health. This project will develop an instrument with unique capabilities for particle measurement, including real-time measurement of particle size and chemical composition. It will replace standard electron impact ionization with two less energetic (softer) ionization approaches: Lithium Ion Attachment and UV Photo-ionization. These methods will extend the chemical selectivity of the aerosol mass spectrometer and improve the identification of organic species. In Phase I, the low energy ionization sources will be developed, constructed, and fitted to the AMS for laboratory testing. The analytical sensitivity and selectivity of the instrument towards different classes of organic compounds will be assessed and compared with results obtained using the conventional "hard" electron impact ionization source. The instrument should have application in ambient pollution monitoring, chemical and biological warfare agent identification, and the characterization and control of aerosol emissions from a variety of industrial and energy production processes that produce aerosol-laden gaseous exhaust or waste streams.

A Compact, In-Situ Instrument for Organic Acids (DOE 2004 STTR Phase 1)
Dr. Susanne Hering, PI, 510-649-9360, susanne@aerosol.us
Aerosol Dynamics, Inc., Berkeley, CA; with Colorado State University, Fort Collins
DOE Grant No. DE-FG02-04ER86179
$100,000

Among the contributors to atmospheric pollution, carboxylic acids (including mono- and dicarboxylic acids, aliphatic ketoacids, and aromatic acids) are an important class of oxygenated, organic compounds in atmospheric aerosols. To better understand their sources and atmospheric transformation processes, an automated method for measuring their concentration is required. This project will develop a new, in situ instrument for the routine identification and quantification of organic acids in the particulate phase. The system will combine an innovative method for particle concentration and collection with emerging "laboratory-on-a-chip" capillary electrophoresis analytical methods. The analytical microchip, measuring a few centimeters across, will contain all of the critical components for chemical quantification, including the collection reservoir, capillary electrophoresis separation column, and conductivity detector. Phase I will: (1) adapt a water condensation technology for the direct deposition of submicrometer and nanometer diameter particles onto the analysis chip, (2) evaluate the capillary electrophoresis microchip analysis of directly deposited standards at the sub-nanogram level, and (3) interface these technologies to demonstrate the potential of the method using laboratory-generated aerosols. The instrument should find use in the routine, hourly monitoring of carboxcylic acids in atmospheric aerosols, substantially lowering the cost per sample and providing higher time resolution than possible with current methods.

Ultra-Sensitive, Compact Mid-Infrared Spectrometer for Airborne and Ground-Based Atmospheric Monitoring (DOE 2004 SBIR Phase 1)
Dr. Joshua Paul, PI, 650-610-0956, jbpaul@novawavetech.com
NovaWave Technologies, Inc., Redwood Shores, CA
DOE Grant No. DE-FG02-04ER84027
$100,000

This project will develop an instrument to make highly sensitive atmospheric concentration measurements of a variety of important chemical species--including formaldehyde, carbon monoxide, ethylene, and acetylene--by combining a novel tunable single-frequency, mid-infrared laser source with cavity ringdown spectroscopy. The combination will allow many important atmospheric constituents (including formaldehyde, CO, ethylene, acetylene, and N2O) to be monitored with unprecedented sensitivity (less than 25 pptv mixing ratio) in real time (less than 30 seconds). In Phase I, a single-frequency infrared laser source, operating in the 2.65 um spectral region, will be constructed and fully characterized. This source will be used in conjunction with cavity ringdown spectroscopy, and the ability to achieve the aforementioned sensitivity level to be assessed. The instrument should have a wide ranging impact on our understanding of atmospheric chemistry and dynamics. Commercial applications for the technology include trace gas monitoring, pollution monitoring, and industrial process monitoring.

A Rugged, Quantum Cascade Laser-Based Cavity Enhanced Spectrometer for Highly Sensitive Trace Gas Measurements in Troposphere (DOE 2004 SBIR Phase 1)
Dr. Michelle L. Silva, PI, 978-689-0003, silva@psicorp.com
Physical Sciences, Inc., Andover, MA, www.psicorp.com
DOE Grant No. DE-FG02-04ER84044
$99,946

This project will develop a high sensitivity, optical absorption spectrometer to monitor trace species such as carbon monoxide, nitric oxide, formaldehyde, and ethylene. The spectrometer will combine advances in Quantum Cascade laser technology with cavity enhanced absorption methods, resulting in detection sensitivities on the order of 100 pptv. It will be deployable on small research aircraft. During Phase I, a quantum cascade laser will be coupled to a high finesse optical cavity, and the required measurement precision for the ambient monitoring of each target species will be demonstrated. A complete conceptual design for a compact, lightweight sensor that is particularly well suited for airborne monitoring will be developed. A highly sensitive monitor for trace gases would fulfill a long-standing need in environmental and air quality monitoring. Other applications include combustion emissions analysis, fugitive emissions control, industrial process control, and contraband detection.

Optical "Nose" for Rapid, Part-Per-Trillion Trace Gas Detection (DOE 2004 STTR Phase 1)
Dr. Scott Davis, PI, 303-296-6766, davis@vescentphotonics.com
Vescent Photonics, Denver, CO; with JILA (Joint Research Inst. of NIST and Univ. of Colorado), Boulder, CO
DOE Grant No. DE-FG02-04ER86199
$99,997

This project will construct an optically based, chemical detection system with extraordinary sensitivity (sub-ppt), specificity, and versatility (with detection capabilities for essentially any gas-phase molecule). The system will utilize novel optical detection schemes that provide sub ppt absorption sensitivities; a unique atmospheric sampling technique that greatly minimizes intake losses and maximizes detection sensitivity; and fiberdized optical components that are robust, miniature, and have low power consumption. In Phase I: (1) the sophisticated electronics required for this approach will be designed and built; (2) the atmospheric sampling technique will be modeled and the Phase II device will be designed; (3) the requisite spectral information will be assembled and utilized to determine chemical detection efficacy; and (4) the basic components of the novel, ultra-sensitive optical detection system will be designed, assembled on a benchtop, and tested. In addition to atmospheric monitoring, the ultra-sensitive chemical detectors should have application to the detection of chemical weapons, unearthing of land-mines and unexploded ordnance (it is estimated that 110 million unexploded land mines are still buried around the world), medical breath analysis (providing surgery-free indications of disease, or a means of quantifying anesthesia intake in the operating room), and industrial monitoring of leaks in subterranean pipes or storage tanks (only trace quantities of leaked chemicals migrate to the surface for detection).

Long-Term, Autonomous Measurement of Atmospheric Carbon Dioxide Using an Ormosil Nanocomposite-Based Optical Sensor (DOE 2004 SBIR Phase 1)
Dr. Kisholoy Goswami, PI, 310-530-4974, kisholoy.goswami@innosense.us
InnoSense, LLC, Lomita, CA; www.innosense.us
DOE Grant No. DE-FG02-04ER83980
$100,000

Because of cost and performance constraints, in situ and continuous measurements of atmospheric CO2 are not possible with current instrumentation. This project will develop a simple, inexpensive, and longer lasting CO2 sensor suitable for autonomous measurements in the field. The sensor's performance will match that of larger and more expensive instruments. Phase I will establish feasibility of the technical approach by fabricating a working model of the device. High signal-to-noise ratio will be obtained by utilizing a triple correlation-based signal processing algorithm to achieve a resolution of 1 part in 3,000 or better. The sensor will be characterized with respect to long-term drift, sensitivity, accuracy, resolution, and lack of interference from humidity. In addition to its use in atmospheric CO2 measurements, the technology could be used to construct portable sensors for the autonomous monitoring of other gaseous pollutants, pipelines, storage facilities, and process control sensors for the energy and chemical production industries.

Compact, Low Cost CO2 Isotope Ratiometer (DOE 2004 SBIR Phase 1)
Dr. Joshua Paul, PI, 650-610-0956, jbpaul@novawavetech.com
NovaWave Technologies, Inc., Redwood Shores, CA; www.novawavetech.com
DOE Grant No. DE-FG02-04ER84026
$100,000

Carbon isotope ratio measurements are used to distinguish between natural sources of carbon in the atmosphere and those resulting from human activity, but currently available instruments are too large and costly. This project will combine a novel single frequency mid-infrared laser source with a flowing gas sample cell arrangement to determine this ratio. The resulting instrument will be low cost, compact, rugged, and energy efficient, and enable CO2 isotope ratios to be determined with a precision exceeding 0.01% min-1. The mid-infrared laser source will be demonstrated during Phase I and integrated into a bench-scale laboratory instrument to perform CO2 isotope ratio measurements. The results of these tests will demonstrate the precision and accuracy of the approach, and will be used to determine specifications for the Phase II instrument. The worldwide market for low-cost, high-precision CO2 isotope ratiometers should be quite large due to the need to monitor greenhouse gas emissions and enforce world-wide emission standards. Other commercial applications include trace gas monitoring, pollution monitoring, and industrial process monitoring.

A Soil Probe for In-Situ Near Infrared Spectroscopic Measurement of Soil Carbon (DOE 2004 SBIR Phase 1)
Mr. Colin D. Christy, PI, 785-825-1978, christyc@veristech.com
Veris Technologies, Inc., Salina, KS
DOE Grant No. DE-FG02-04ER84115
$72,929

This project will use near infrared reflectance spectroscopy via a soil probe to make carbon measurements. The probe will measure carbon and bulk density, allowing a rapid carbon inventory to be made on a field or project scale. In Phase I, a prototype probe will be designed, built, and briefly tested in a laboratory. Then the probe will be tested in fields in at least two different states to determine how accurately it can measure soil carbon. Finally, the uncertainty of the measurements made with the probe will be compared to standard methods. In addition to its use in auditing carbon stocks sequestered in the soil, the probe should find application in production agriculture for investigating soil quality and soil compaction.

Nanocrystal Labels for Multiplex Assays (DOE 2004 SBIR Phase 1)
Dr. Savvas C. Makrides, PI, 781-769-9450, savvas@eiclabs.com
EIC Laboratories, Inc., Norwood, MA
DOE Grant No. DE-FG02-04ER83933
$99,990

DOE's Genomes to Life program has identified a need to develop new reporting labels for the multiplex detection of biomolecules. The existing organic dyes that are used to label affinity agents have several limitations: narrow absorption bands, which makes it difficult to excite several colors with a single light source; broad spectral overlaps; poor photostability; and fast decay times. This project will develop novel probes for multiplex assays, based on quantum dots (QDs). The desirable properties of QDs include a narrow, tunable, symmetric emission spectrum, enabling a larger number of probes within a spectral region; excitation of different-size QDs with a single light source; and excellent photostability. The QDs will be functionalized with antibody-binding moieties for the simultaneous detection of multiple types of protein using a single light source. In Phase I, a bacterial expression vector will be constructed for the production of a biotinylated antibody-binding moiety, which will be used to functionalize streptavidin-coated QDs. Two different size QD probes will be prepared to enable simultaneous detection of two types of protein using a single light source. QDs should find use as probes for the multiplex detection of biomolecules, immunoassays, medical imaging, analysis of clinical samples, detection of antigens in flow cytometry, staining of biomolecules in electrophoretic separations, and screening of ligands using microarray platforms.

SARD: A Novel Surveying Method to Develop Genomic Reagents (DOE 2004 SBIR Phase 1)
Dr. Dago Dimster-Denk, PI, 415-254-3554, dimster@earthlink.net
Taxon Biosciences, Inc., Mill Valley, CA
DOE Grant No. DE-FG02-04ER84089
$99,757

Current microbial survey methods capture only the most abundant organisms in complex populations, organisms that may represent less than 1% of the species present. This project involves the further development of a new genomics tool, known as SARD (Serial Analysis of Ribosomal DNA), which enables deep surveys of complex microbial populations by creating an inventory of short DNA sequence tags representing members of the population. A particular application of the technology is the identification of bacterial species that can be used to locate hydrocarbon plumes that originate from sub-surface petroleum reservoirs. In Phase I, the SARD diversity profiling technology will undergo further development and a set of SARD tag sequence inventories will be created from a transect of samples collected from a producing oilfield in Texas. These profiles will be compared to concurrent geophysical data in order to determine whether specific sequence tags can be identified that show strong correlation to the producing areas of the oilfield. By creating inventories of any microbial population, the SARD profiling technology should have commercial application to petroleum and mineral exploration, pollutant detection, and clinical diagnostics. In addition, the SARD DNA sequence tags themselves represent a genomic resource that should find use as (1) a PCR (polymerase chain reaction) primer to recover the corresponding full-length 16S rRNA gene, (2) a primer in a quantitative PCR assay to query the presence of the tag sequence in a large sample collection, (3) a fluorescently labeled probe in fluorescent in situ hybridization (FISH) experiments, and 4) a probe on a DNA microarray for hybridization-based surveys.

Scintillating Fiber Optic Groundwater Monitors with Radionuclide-Selective Hydrophilic Cladding (DOE 2004 STTR Phase 1)
Dr. Andrea E. Hoyt, PI, 505-346-1685, aehoyt@adherent-tech.com
Adherent Technologies, Inc., Albuquerque, NM 87111-1522; with Battelle, Pacific Northwest Division, Richland, WA
DOE Grant No. DE-FG02-04ER86178
$100,000

Many DOE sites require the monitoring of radionuclide contamination in surface water, groundwater, soils, and the vadose zone--often in real-time and with remote monitoring capability; however, existing site characterization procedures typically involve the collection and shipment of samples to an off-site laboratory, leading to costly delays in site remediation as well as to increased risk to personnel. This project will develop a scintillating fiber-optic-based sensor system with a hydrophilic, radionuclide-selective cladding material for the detection of technetium-99 and/or strontium-90 in groundwater. The configuration can be easily adapted to real-time and remote monitoring scenarios. Phase I will prepare and evaluate dual-purpose (radionuclide-enriching and optically functional) cladding materials for use with plastic scintillating optical fibers. The selectivity and detection limits of these sensors will be evaluated. A simple sensor will be demonstrated, using actual Hanford groundwater samples spiked with the radionuclide of interest. Expansion of the technology to other radionuclides will occur in Phase II. The fiber optic sensor configuration should find primary application in DOE site remediation activities and in the long-term environmental monitoring of these sites.

Hand-Held Phytoremediation Monitor (DOE 2004 SBIR Phase 1)
Dr. Andrew Freedman, PI, 978-663-9500, af@aerodyne.com
Aerodyne Research, Inc., Billerica, MA; www.aerodyne.com
DOE Grant No. DE-FG02-04ER83893
$100,000

There is a need to monitor the efficiency of phytoremediation, in which green plants are used to extract and remove metals, radionuclides, and other contaminants from soil, subsurface sediments, or ground water. In particular, the concentration and partitioning of the contaminants in plant roots, shoots, stems, and leaves must be determined. This project will develop a hand-held Laser Induced Breakdown Spectroscopy (LIBS) device, utilizing a microchip laser, to provide in situ analysis of phytoremediation sites. The handheld LIBS device will be designed and constructed in Phase I. Plants with known uptake of toxic metals will be analyzed in collaboration with researchers at the University of Florida. In addition to phytoremediation analysis, a handheld metals analysis tool should have application in alloy analysis, toxic industrial chemical monitoring, toxic waste monitoring, and the federal monitoring of transuranic elements.

Monitoring Volatile Organic Tank Waste Using Cermet Microsensors (DOE 2004 SBIR Phase 1)
Dr. Edward G. Gatliff, PI, 513-895-6061, ans@fuse.net
Applied Natural Sciences, Inc., Hamilton, OH; www.treemediation.com
DOE Grant No. DEFG02-04ER83901
$100,000

Storage tanks of contaminated mixtures exist at many DOE sites; however, very few inexpensive technologies are available for determining the contents of the tank waste or for monitoring the chemistry of tank constituents in near-real time. This project addresses this problem by developing and assessing ceramic-metallic-based microsensors that can determine the constituents of a liquid organic storage tank by examining gases in the headspace of the tank. Specifically, inexpensive (less than $1.00 each), rugged electrochemical microsensors will be chemically designed and tailored for specific compound detection and then tested in a laboratory environment to verify that they can detect these compounds at given concentrations. Further testing will be conducted to ensure that the sensors can discern compounds of interest from others that may be housed in the same tank. A library of chemical signatures of interest will be established. Results of this research should indicate whether the microsensors are capable of accurately measuring both the concentration and type of organic compound housed within a tank. The new sensors should be inexpensive and rugged, provide results in near-real time, and be left in situ for future sampling efforts. Also, their use should reduce the human health risks associated with sampling unknown or unstable tank waste. Due to the widespread storage and use of organics in process industries, defense applications, and cleanup efforts, other applications for the product appear likely.

Microscale Voltammetric Mercury Monitor (DOE 2004 SBIR Phase 1)
Dr. Michael T. Carter, (PI), 303-530-0263, eltron@eltronresearch.com
Eltron Research, Inc., Boulder, CO; www.eltronresearch.com
DOE Grant No. DE-FG02-04ER83937
$99,999

Heavy metal contamination in ground and surface water is a widespread problem within the DOE complex. Advanced methods and instrumentation will be required to provide reliable, long-term monitoring for evaluation and remediation of this contamination. This project will develop a low-cost, portable monitor for mercury, achieving superior stability, reproducibility, and sensitivity. The active element of the device will be a microfabricated electrochemical chip that exploits the unique advantages of microband electrode geometry to promote the sensitive detection of metals. Phase I will encompass efforts to demonstrate the proposed concept, including (1) design and fabrication of the device, and (2) evaluation of detector performance. Electrochemical detection of heavy metals would provide a low-cost, portable avenue to on-site testing for industrial and personal environmental evaluations, such as in drinking water and waste water analysis, process effluent analysis, and environmental remediation.

A Robust Remote Automated Monitoring Device for Mercury in Liquid Wastes (DOE 2004 SBIR Phase 1)
Dr. Carl E. Hensman, (PI), 206-622-6960, carlh@frontiergeosciences.com
Frontier Geosciences, Inc., Seattle, WA; www.frontiergeosciences.com
DOE Grant No. DE-FG02-04ER83960
$100,000

Most natural water systems, industrial processes, wastewater streams, and storage facilities are monitored by analyzing periodic grab samples, a process that results in a low-resolution understanding of the aqueous stream's chemistry. With limited data points, transient events may positively bias an analyte's temporally averaged concentration; even worse, brief high- or low-concentration events may not be detected, exposing workers to possibly hazardous conditions. This project will develop a robust, self-calibrating-and-validating, regulatory-compliant, continuous mercury-monitoring system for natural and industrial wastewater streams, as well as for hazardous storage facilities at DOE sites. The system will be based on well-established mercury measurement methods and laboratory instrumentation, modified to accomplish the difficult demands of on-line, regulatory compliance analysis. Phase I will combine a sample pre-treatment module and an atomic fluorescence detector in a flow-based system. The system will be optimized to handle difficult matrices and negate interferences while producing compliant data. The software to control each module will be prepared. Finally, the instrument will be validated in the laboratory for short- and long-term unattended operation. Phase II will convert the final design into a market-ready product and validate it at demonstration sites. The device should be able to obtain real-time concentrations of mercury in any liquid stream or waste storage tank. Due to its robust nature, the instrument should be useful for monitoring difficult matrices such as industrial wastewater, mining wastewater, and nuclear waste. In addition, local municipalities could continuously monitor their drinking water or effluent discharge wastewater, ensuring compliance with water quality criteria.

Automated Impedance Tomography for Monitoring Permeable Reactive Barrier Health (DOE 2004 SBIR Phase 1)
Douglas LaBrecque, (PI), 775-425-9606, dlabrecque@mpt3d.com
Multi-Phase Technologies, LLC, Sparks, NV; www.mpt3d.com
DOE Grant No. DE-FG02-04ER84013
$99,857

Permeable reactive barriers are an important new treatment option for groundwater remediation, but reliable methods are not available to monitor or predict their long-term behavior. The large-scale implementation of reactive barriers will require a means of monitoring their long-term degradation. For example, gaps can occur in the placement of the reactive material, particularly when construction methods such as jetting or deep soil mixing are used. This project will develop a reliable method to verify placement and monitor effectiveness of permeable reactive barriers. The approach will use arrays of inexpensive electrodes, coupled to autonomously operating hardware and software, to characterize the barrier and determine its effectiveness. Phase I will conduct column tests for monitoring the specific geochemical conditions and aging of the chosen sites. The requirements for data accuracy, sensor spacing, and borehole locations will be determined using numerical modeling. A fully autonomous system will be developed and a site will be chosen for a Phase II field implementation. By the time this project is completed, the automated monitoring system should find use in more than 100 permeable reactive barriers that will have been installed in North America.

Surface Plasmon Resonance Sensor for Radionuclides (DOE 2004 SBIR Phase 1)
Dr. Shaopeng Wang, (PI), 405-372-9535, swang@nomadics.com
Nomadics, Inc., 1024 S. Innovation Way, Stillwater, OK 74074-3415; www.nomadics.com
DOE Grant No. DE-FG02-04ER84022
$100,000

It is important to determine the fate and transport of contaminants generated from past weapons production and from current energy production activities. In support of this goal, this project will develop technology for the highly sensitive real-time detection of radionuclides in the subsurface under field conditions. The approach relies on surface plasmon resonance for detection, and incorporates an innovative multi-cell approach for enhanced selectivity and sensitivity. Phase I will demonstrate the viability of the detection method and characterize the performance of a prototype system. Surface plasmon resonance is a highly versatile sensor platform that can be tailored for specific analytes. Therefore, the system should be able to be adapted for numerous applications, including the identification of environmental contaminants, monitoring industrial release, and chemical sensing related to defense and security applications.

High Resolution Sensor for Nuclear Waste Characterization (DOE 2004 SBIR Phase 1)
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Radiation Monitoring Devices, Inc., Watertown, MA; www.rmdinc.com
DOE Grant No. DE-FG02-04ER84056
$100,000

Gamma ray spectrometers are an important tool in the characterization of radioactive waste, such as found at many DOE sites. These gamma ray spectrometers require good energy resolution, high detection efficiency, compact size, light weight, portability, and low power requirements. No available spectrometer satisfies all these requirements. This project will investigate a new scintillator that appears to be very promising for gamma ray studies, in view of its excellent energy resolution. Phase I will demonstrate the feasibility of applying the new scintillation material towards nuclear waste studies. New dopants and compositions will be examined to optimize the scintillator. Large crystals of the proposed scintillator will be grown, and their scintillation properties and energy resolution will be evaluated. A compact detection system will be built and analyzed in Phase II. In addition to its use in nuclear waster studies, the new scintillator should have applicability to non-proliferation monitoring; nuclear, high energy, and space physics experiments; medical imaging; NDE; geological exploration; industrial CT imaging; X-ray instrumentation; and materials analysis.

Remote In-Situ Monitoring of Metal Contaminants in Groundwater with a Compact Grazing-Incident Monochromatic Microbeam X-Ray Fluorescence Analyzer (DOE 2004 SBIR Phase 1)
Brian Gallagher, (PI), 518-880-1500, bgallagher@xos.com
X-Ray Optical Systems, Inc., East Greenbush, NY
DOE Grant No. DE-FG02-04ER84122
$99,940

The evaluation of radionuclide and metal contaminants in the groundwater at DOE sites is typically done off-site using plasma mass spectroscopy or optical emission spectrometry. These analysis techniques are not suitable for automated field use because they require control gas or vacuum to function. A simple, robust, non-destructive analysis technique is required for in situ remote monitoring applications. This project will develop a grazing-incident-monochromatic micro x-ray fluorescence (GI-MMXRF) analysis system, which, when combined with an innovative dried spot sample preparation system, will offer high sensitivity and automated sample preparation. The combination of low power GI-MMXRF and ink jet printing technology makes this an approach that can be readily adapted for remote monitoring or in situ applications. In Phase I, a doubly-curved crystal optic will be designed for use with an existing x-ray fluorescence analysis setup. A laboratory setup of the sample deposition system will be used to evaluate spot size and GI-MMXRF detection limits with various film substrates. The feasibility of a field-deployable system will be evaluated. In addition to the remote monitoring of radionuclides and metals in groundwater at hundreds of DOE sites, the technology also should draw interest from industries and government agencies concerned with the monitoring of groundwater and groundwater remediation.

Using Downhole Probes to Locate and Characterize Buried Transuranic and Mixed Low Level Waste (DOE 2004 SBIR Phase 1)
Dr. Donald K. Steinman, (PI), 281-835-6364. dksteinman@aol.com
Applied Physics and Measurements, Inc., Missouri City, TX
DOE Grant No. DE-FG02-04ER83902
$100,000

There is a substantial amount of buried transuranic waste (TRU) and mixed low-level waste (MLLW) stored at DOE sites around the nation. Recent efforts to remediate this waste have been hindered by lack of exact knowledge of the details of where and which materials were buried in several of the locations. Because these materials are hazardous to humans, it would be desirable to locate them more precisely, so as to reduce the threat to workers in remediation programs. This project will demonstrate the applicability of using oilfield-type instruments, operating in steel probe holes placed in subsurface disposal areas, for locating and characterizing certain radioactive materials and mixed wastes. During Phase I, the performance of the instruments will be modeled mathematically to assess their ability to locate and characterize wastes in highly heterogeneous media. The modeling effort will be used to build algorithms that will indicate the intensity and location of waste in the subsurface disposal areas. In Phase II, the concept will be proved using actual instruments in waste holes. The technology should be applicable to cleanup efforts at several sites, allowing more waste to be assessed at lower cost compared to the currently-used sampling and laboratory assaying methods. It also will require significantly less time and be safer to use in the field.

Fast, Portable Characterization System, Integrating Time-Domain Electromagnetic with Induced and Natural Field Magnetic Measurements (DOE 2004 SBIR Phase 1)
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Multi-Phase Technologies, LLC, Sparks, NV; www.mpt3d.com
DOE Grant No. DE-FG02-04ER84012
$99,902

DOE has estimated that from the 1940s through the 1970s, 126,000 cubic meters of transuranic wastes were disposed of by shallow burial and other techniques at sites owned and operated by the federal government. The excavation and retrieval of the transuranic and mixed waste are time-consuming and expensive. Improved imaging technologies are needed to provide better resolution and improved characterization of buried wastes and buried waste containers. This project will combine state-of-the-art magnetic field sensors with fast, high-resolution data acquisition technology to create a flexible, portable system for container characterization. Time-domain electromagnetic measurements, natural field magnetic gradient measurements, and induced-magnetic field measurements will be combined into a single portable instrument. Phase I will build a prototype instrument that uses the magnetometers both as natural field sensors and as receivers for the time-domain electromagnetic instrument. The ability to detect and characterize subsurface targets under practical field conditions will be determined. The instrument will then be optimized for field use. The improved characterization of transuranic waste sites should see extensive use at DOE, DoD, and commercial sites. The technology should improve the imaging and identification of subsurface containers and associated hazards, thus improving safety and reducing remediation costs.

Low-Cost Autonomous Wireless Sensors with Integrated Vibration Power Harvesting (DOE 2004 STTR Phase 1)
Dr. Jeremy E. Frank, (PI), 814-867-4097, jfrank@kcftech.com
KCF Technologies, Inc., State College, PA; www.kcftech.com; with Pennsylvania State Univ., University Park
DOE Grant No. DE-FG02-04ER86189
$99,397

Low cost, self-powered wireless sensors that never require battery changing or other maintenance are needed for pollution-producing systems. Systems of these sensors will enable a revolution in industrial efficiency, safety, and reduced maintenance costs. This project will develop a wireless sensor with an integrated vibration-power-harvesting piezoelectric unit. The key features of the proposed technology are a structurally isolated vibration-based piezoelectric element and an integrated energy-scavenging circuit. The piezoelectric device converts mechanical vibration energy from the structure to electrical energy. The integrated scavenging circuit rectifies and stores the converted electrical energy. Optimal design of both features will maximize power harvesting in the smallest possible package. The device will be fully self-contained, low cost, simple to install, and maintenance free for its usable life. Phase I will develop and demonstrate the power-harvesting module and scavenging circuit. A turnkey system of wireless sensors that never needs battery replacement should provide (1) reduction of total life cycle costs for pollution sensing by permanently eliminating wires and batteries, (2) increased safety and security via greatly expanded sensing of pollutants, (3) expanded sensing and communication functions for many radio-frequency applications with the integrated power-harvesting unit, and (4) pollution reduction via continuous wireless sensing in harsh environments where wired sensors are not feasible.

Badge-Sized Sensor System with Integrated Chemicapacitive Technology and Pattern Recognition Algorithm for Chemical Identification (DOE 2004 SBIR Phase 1)
Dr. Sanjay Patel, (PI), 858-449-2151, sanjay@seacoastscience.com
Seacoast Science, Inc., Carlsbad, CA; www.seacoastscience.com
DOE Grant No. DE-FG02-04ER84069
$99,950

The chemical industries require low cost chemical sensors for monitoring and detecting mixtures of chemicals and measuring changes in their composition. The sensors must be small and inexpensive to be compatible with use in a range of environments, and they must be robust and require little power for long-term unattended operation. This project will develop prototype sensor systems that will combine state-of-the-art pattern recognition with a novel MEMS (microelectromechanical system) microcapacitor sensor array, and also will be low cost. The sensor arrays will be filled with several chemoselective polymers whose electric permittivity changes upon exposure to different vapors, thereby compensating for changes in humidity, temperature, and composition. Phase I will demonstrate the feasibility of using the novel MEMS sensor arrays with a pattern recognition algorithm to detect fuels. The sensors will be characterized in the laboratory for sensitivity, selectivity, and ruggedness to humidity and temperature variations. The sensor arrays should fill a need for low-cost, low-power, smart leak detectors required for many applications, including chemical process monitoring and control, toxic vapor leak detection, industrial process control, and industrial health and safety. The sensors could monitor and identify leaks of fuels, distinguish stored fuels, and control processes.

Wireless Vibration Energy Harvesting System (DOE 2004 SBIR Phase 1)
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Wilcoxon Research, Inc., Gaithersburg, MD; www.wilcoxon.com
DOE Grant No. DE-FG02-04ER84119
$99,982

The advent of a truly wireless world in the future has created an opportunity and the need to develop a sensor that not only communicates in a wireless fashion but also obtains its power in a wireless fashion. While a conventional battery fits this description of a power source, it severely limits the long-term autonomy of the sensor due to the life span of the battery. To make the sensor truly wireless, a source of energy that exists in the sensor's operational environment and a method of harnessing that energy is needed. This project will develop a completely self-sustained, truly wireless sensor system powered solely from harvested environmental vibration energy. A unique transducer that utilizes a new piezoelectric material and an electrical storage circuit will be designed to harvest ubiquitous vibrational energy. The new piezoelectric material will be 7-10 times more powerful than existing materials and, in concert with the new transducer design, will result in a highly efficient energy conversion system. Phase I will investigate the combination of three technologies for the truly wireless sensor: super capacitors and rechargeable batteries for the power storage device, an electrical charging circuit, and the use of existing low power radio communication devices as the means of wireless transmission. A truly wireless sensor system, which could harvest its own electrical energy from the readily available vibration energy that exists in most manufacturing and production facilities, should find predictive uses in almost every industry segment and lead to greatly improved efficiencies.

Demonstration of Heat Rate Increase for a Coal-Fired Boiler Utilizing Novel In-Situ Combustion Sensor Technology in Combination with Neural Net Optimization (DOE 2004 STTR Phase 1)
Dr. Andrew D. Sappey, (PI), 303-604-5849, asappey@zolotech.com
Zolo Technologies, Inc., Boulder, CO; www.zolotech.com; with Stanford University, Stanford, CA
DOE Grant No. DE-FG02-04ER86203
$99,979

Currently, coal-fired utility boilers are poorly-controlled devices that could benefit greatly from closed-loop feedback control for combustion optimization. Newly developed neural net software addresses part of the systems' need for closed-loop control; however, the sensors that currently supply the neural network with data are located well downstream of the boiler and are often extractive. This project will develop new, in situ sensor technology that utilizes recent advances in diode laser and fiber-optic technology to provide more effective operation of the neural net. The new sensors will be based upon wavelength-multiplexed, tunable diode laser spectroscopy and will be able to measure O2, CO, and H2O species concentrations and temperature directly in the fireball in multiple locations. In

Phase I, quantitative spectroscopy will be performed in order to enable the quantification of species concentration and temperature. Optical and mechanical engineering tasks will be conducted to optimize the wavelength multiplexer design. During Phase II, the new sensor technology will be combined with neural net optimization to enable efficiency closed-loop control.

An Innovative Laser-Based Sensor for Monitoring Mercury in Gasifier Syngas (DOE 2004 SBIR Phase 1)
Dr. Josef Blair Simeonsson, (PI), 919-806-8250, joesimeonsson@earthlink.net
Advanced Monitoring, Inc., Durham, NC
DOE Grant No. DE-FG02-04ER83888
$100,000

The major sources of mercury (Hg) emissions include fossil fuel combustion, waste incineration, and chloralkali production. With the increased development of coal gasification technologies, the monitoring of Hg in gasifier synthesis gas is needed to protect both the environment and the equipment used to generate hydrogen and other refined chemical products from the processed synthesis gas. This project will develop an innovative laser-based sensor for measuring Hg in gasifier synthesis gas. The sensor will use fiber-optic coupled, laser-induced fluorescence detection for real-time measurements directly in the synthesis gas. Phase I will demonstrate the feasibility of the laser-based monitoring system at the laboratory scale and evaluate the sensor's key measurement capabilities (sensitivity, limits of detection, response time, and selectivity) in simulated syngas mixtures. A prototype system will be developed in Phase II. Commercial applications for the Hg sensor should include coal gasifiers, fossil fuel-based power plants, metal smelters, cement kilns, and waste incinerators. The sensor could be modified to monitor other trace metal pollutants, such as arsenic, selenium, cadmium, and nickel.

Novel MEMS Chemical Sensors for Gasification (DOE 2004 SBIR Phase 1)
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Transducer Technology, Inc., Glen Ellyn, IL
DOE Grant No. DE-FG02-04ER84109
$99,995

Chemical sensors will make a significant contribution to the development of gasifiers, a key technology for many energy-related needs of the future. Specific sensors are needed for process components like methane, hydrogen, and toxic and corrosive contaminant gases like hydrogen sulfide and carbon monoxide. This project will develop low cost, high performance sensors by incorporating new sensor technology and MEMS (micro-electro-mechanical systems) fabrication. Phase I will fabricate a prototype MEMS sensor platform and functionalize it for two different applications: one thermal/catalytic and one electrochemical. The feasibility of a single MEMS platform will be demonstrated for multiple sensor applications. Ultimately, the sensors will be tested for sensitivity, selectivity, response time and stability for gases such as methane and hydrogen sulfide. In addition to the gasifier application, additional benefits from the sensors developed include safety, homeland security, and medical markets. The total market for MEMS sensor is $2 billion, and the chemical sensor market is one of the most rapidly growing segments.

Novel Ultra Sensitive Instrumentation for Trace Gas Measurements in the Field (DOE 2004 SBIR Phase 2)

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DOE Grant No. DE-FG02-03ER83695
$623,844

The understanding of atmospheric chemistry and pollution transport in the troposphere, on large and small spatial scales, is limited by the availability of reliable, sensitive, and accurate instrumentation that is easy to use and yields rapid, real-time results. This project will develop a novel, compact, and rugged instrument that sensitively and accurately measures the concentrations of important atmospheric trace gases (NO, NO2, NO3, N2O, CO) and the fluxes of N2O and CO. The instrument, based on a novel technology called Off-Axis Integrated Cavity Output Spectroscopy (ICOS) and on state-of-the-art diode lasers and quantum-cascade lasers, will be easy to use and will provide real-time measurements in the field and on board aircraft. Phase I designed, built, and tested an Off-Axis ICOS instrument using three diode lasers and a quantum cascade laser, to conduct measurements of the target species (NO2, NO3, N2O5, CO, N2O), based on absorption in the visible and infrared regions. By performing measurements on calibrated gas mixtures, the accuracy, precision and sensitivity of the instrument was established. A Phase II instrument, capable of operation in the field and on-board aircraft, was designed, and a detailed estimate of the cost of building and selling the instruments, was determined. Phase II will develop and test advanced prototype multi-gas analyzers capable of simultaneous measurements of NO2, NO3, N2O5, CO and N2O in the laboratory, in the field, and on an airplane. In addition, the instrument will be deployed in the Arctic for autonomous field measurements. The instrumentation should find application in atmospheric studies, homeland security, and the monitoring and control of several industrial processes.

Mid-Infrared Optical Cavity-Based Spectrometer for Multispecies Airborne and Ground-Based Atmospheric Monitoring (DOE 2004 SBIR Phase 2)

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NovaWave Technologies, Redwood City, CA; www.novawavetech.com

DOE Grant No. DE-FG02-03ER83732
$749,986

Recent advances in both mid-infrared laser sources and ultrasensitive optical detection technologies promise to allow trace atmospheric species such as formaldehyde to be studied with unprecedented detail and accuracy. The availability of such instrumentation for both airborne and ground-based monitoring applications would have a wide ranging impact on our understanding of atmospheric chemistry and dynamics. The proposed solution combines a novel tunable high-power, single-frequency, mid-infrared laser source with an ultrasensitive optical cavity-based absorption method known as off-axis integrated cavity output spectroscopy. The combination of these two innovative technologies will allow many important atmospheric constituents to be monitored with unprecedented sensitivity (<25 pptv mixing ratio) in real time (<30 s), including formaldehyde, CO, ethylene, acetylene, and N2O. During Phase I, a widely tunable mid-infrared laser producing over 2 milliwatts of power in the 2.7 micron spectral region was constructed from all room-temperature solid-state components. This source was used in conjunction with off-axis integrated cavity output spectroscopy to achieve ultrasensitive detection of gas phase isotopic water. In Phase II, the basic laser design will be refined to produce in excess of 15 milliwatts in the 3.3 micron spectral region. The laser again will be used in conjunction with off-axis integrated cavity absorption spectroscopy to detect hydrocarbons and other species at the parts-per-trillion level. The instrument should have a wide ranging impact on our understanding of atmospheric chemistry and dynamics. Commercial applications include trace gas monitoring, pollution monitoring, and industrial process monitoring.

A Remote and Affordable Detection System for Cr(VI) in Groundwater (DOE 2004 SBIR Phase 2)
Dr. Michael T. Carter, (PI), 303-530-0263, eltron@eltronresearch.com
Eltron Research, Inc., Boulder, CO; www.eltronresearch.com
DOE Grant No. DE-FG02-03ER83646
$749,835

Chromium contamination is a widespread problem within the DOE complex. This project will develop a compact, portable, low-cost detection system for the electrochemical monitoring of hexavalent chromium in groundwater. The novel electrocatalytic approach employs robust, screen-printed electrodes that can specifically detect Cr(VI) in the presence of Cr(III) using a simple flow injection analysis system. The monitoring system will provide a reliable and affordable detection scenario for the evaluation and remediation of groundwater. Phase I fabricated miniaturized sensors on chips, proved the technical feasibility of the detection method, and characterized the sensor under a variety of conditions including electrolyte concentration, electrolyte pH, applied electrode potential, and flow rate. Sensitivity, linear dynamic range, detection limits, and response times for this amperometric method were determined and potential interferences present in DOE groundwater were also investigated. During Phase II, the methods and apparatus will be refined and optimized to produce a robust, sensitive system for the reliable detection of hexavalent chromium in groundwater. Electrochemical detection of chromium(VI) in water should provide a low-cost, portable solution for on-site, in situ testing in industrial and personal environmental evaluations. The technology should find applications in drinking water and wastewater analysis, process effluent analysis, electroplating, metal finishing, and environmental remediation.

Nanoscale Inorganic Ion-Exchange Films for Enhanced Electrochemical Heavy Metal Detection (DOE 2004 SBIR Phase 2)
Dr. Michael T. Carter, (PI), 303-530-0263, eltron@eltronresearch.com
Eltron Research, Inc., Boulder, CO; www.eltronresearch.com
DOE Grant No. DE-FG02-03ER83645
$749,995

Heavy metal contamination represents a major problem for DOE sites and several private sector operations, such as mining and metal finishing. This project will develop a compact, portable, low-cost electrochemical monitoring system for heavy metals in water. The system provides a significantly improved sensitivity and detection limit, along with improved reliability and durability of the electrodes, by using a clay-mineral modified surface to enhance signal-to-noise for the analyte. In Phase I, miniaturized monitoring devices on a chip were fabricated and the technical feasibility of the proposed method was proven. Sensitivity and detection limit were improved five-fold (i.e., 500% improvement) compared to a standard anodic stripping electrochemical detection approach. The response of the proposed methods was characterized under a variety of conditions including analyte concentration, pH, and ionic strength. During Phase II, the methods and approaches will be refined and optimized to produce a robust, sensitive system for reliable monitoring of heavy metals. The system will exploit microelectrode technology and an innovative, nanostructured clay mineral preconcentration layer to enable high sensitivity, cost efficient monitoring solutions for toxic heavy metals. The sampling and monitoring system should be applicable to surface and subsurface water contamination problems relevant to DOE needs. In addition, potential private sector applications include monitoring emissions at metal plating facilities, on-site analysis of ground water quality, and on-line and point-of-use monitoring of municipal drinking water.

System for Imaging Leaks from the Primary Water Loop (DOE 2004 SBIR Phase 2)
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Southwest Sciences, Inc., Santa Fe, NM; www.swsciences.com
DOE Grant No. DE-FG02-03ER83781
$750,000

The primary water loop in a nuclear reactor includes numerous welds that can develop leaks over time. Existing methods for leak detection are slow, resulting in costly down-time. A system that could rapidly identify the location of leaks would improve the safety and economics of plant operation. This project will develop technology for illuminating the leaking area with a hand held camera. The camera will include a laser beam that detects the presence of water escaping from the leak. The image of the water will be superimposed on a video image of the weld, so that an operator can instantly identify the leak location. The system also will indicate areas of the weld that have been sufficiently illuminated but do not leak. Phase I determined the best wavelengths for detecting water vapor and heavy water vapor, demonstrated a simple signal recovery method, and showed the proposed approach is accurate and sensitive. In Phase II, a prototype camera will be designed, built, and tested, both in the laboratory and at a research reactor. The effects of radiation on key components will be studied, and the best method for continuous monitoring inside the containment area will be identified. By suitably adjusting the laser wavelength, additional products could be developed for monitoring natural gas lines and detecting toxic gas leaks at oil refineries and other facilities.

A Down-Hole Probe for Real-Time Ore Grade Assessment in 'Look Ahead' Mining (DOE 2004 SBIR Phase 2)
Dr. Rand Swanson, (PI), 406-586-3356, swanson@resonon.com
Resonon, Inc., Bozeman, MT; www.resonon.com
DOE Grant No. DE-FG02-03ER83766
$750,000

The removal, sorting, disposal, and treatment of waste rock in mining operations are expensive processes, wasteful of energy, hazardous, and environmentally damaging. The best possible remedy is to avoid creating the waste rock in the first place. This could be accomplished with existing mining techniques if 'look-ahead' ore grading were used to evaluate unmined rock in real time. This project will develop a down-hole sensor that will use recently developed optical techniques with induced polarization and resistivity sensors, to provide look-ahead ore grade assessment. The probe will allow miners to assess the local ore grade before blasting, thereby enabling selective mining. In Phase I, proof-of-principle demonstrations showed that a down-hole probe for hyperspectral imaging will provide good spatial resolution. An improved design eliminated the need for moving parts. Measurements taken on ore samples indicate induced polarization measurements will indicate ore grade. In Phase II, a prototype down-hole sensor system will be built, calibrated, and tested. The system will be evaluated in an underground platinum/palladium mine to grade ore in real-time. Finally, benefits provided by the down-hole system will be documented, refinements in the system will be made, and the range of applications will be expanded to include gold mining. The down-hole probe, initially targeted for look-ahead mining applications, should enable selective mining and local morphology mapping. The system should decrease the amount of waste rock generated, improve mine safety, decrease energy usage, improve productivity; and decrease the environmental impacts of mining. The technology should become increasingly important as near-surface ore bodies are depleted and smaller, deeper ore bodies must be found.

U.S. ENVIRONMENTAL PROTECTION AGENCY

Biosensor for Field Monitoring of Pesticides in Water (EPA 2005 SBIR Phase 1)
Michael T. Carter (PI), 303-530-0263, eltron@eltronresearch.com
Eltron Research Inc., Boulder, CO
EPA Contract Number: EPD05025
March 1, 2005 - August 31, 2005
$69,999

This research project involves the development of a portable, low-powered amperometric biosensor for the detection of organophosphorus and carbamate insecticides in water. Eltron will design a renewable, robust biosensor to specifically detect insecticides based on an immobilized enzyme on a sensor electrode. This method will allow for the analysis of insecticides in water without significant dilution or reduction in the sensitivity of the detected species. The miniaturized biosensor will use modified, screen-printed microelectrodes, which will enhance the sensitivity and the limit of detection of the device. The sensor will be applicable to real-time, on-site monitoring of insecticide concentrations in fresh water, and will offer a cost-effective solution to screening potentially contaminated water sites. Biosensors will facilitate environmental monitoring of water supplies. Potential agricultural pollution output includes runoff and leaching of unused or misapplied pesticides and chemical air emissions from spray drift.

Compact, Low-Cost, Long Optical Path, Multiple Gas NDIR Sensor (EPA 2004 SBIR Phase 1)
Mark P. McNeal (PI), 781-788-8777
Ion Optics Inc., Waltham, MA
EPA Contract Number: EPD04016
March 1, 2004 - August 31, 2004
$ NA

Affordable atmospheric and industrial monitoring and controlling systems are needed that can reliably detect and quantify volatile organic compound (VOC) pollution sources within the U.S. EPA range of regulating standards. These sensors must measure VOC concentration in the range of 1 to 50 ppm to a high degree of accuracy and with a very short response time. Though there are several sensor architectures available that may meet some of these demands, Ion Optics submits that only a nondispersive infrared (NDIR) based detection scheme will meet all of them. The Phase I goal is to develop an innovative NDIR system based on a highly compact, folded-path optical design. The specially designed optics will enable the use of incoherent broadband sources and sustain high throughput efficiencies over sufficiently long optical path lengths, thus enabling detection limits approaching 1 ppm of hydrocarbon (HC) based VOCs. The proposed system is compact, robust, and readily deployable in the most demanding atmospheric and industrial environments. A prototype system has demonstrated low ppm CO sensitivity in high-pressure, high-humidity, and percent-level background CO_2 diesel exhaust streams. Ion Optics proposes further innovative design modifications of the sensor for accurate detection of any VOC as well as determination of the total VOC mass flow. This will be accomplished by strategic selection of band pass filters selected to coincide with the strongest HC absorption peak (common to all VOCs) and one or two satellite peaks unique to the selected constituents. By calibrating the sensor response to known concentrations of high purity gas, the signal processing algorithms then may be adapted for identification and mass analyses of the selected constituents. The estimated cost for this instrument when manufactured in quantity would be less than $100.

Demonstration of a Continuous, Real-Time PM2.5 Chemical Speciation Monitor Based on an Aerosol Mass Spectrometer (EPA 2004 SBIR Phase 1)
Douglas R. Worsnop (PI),
Aerodyne Research Inc., Billerica, MA
EPA Contract Number: EPD04008
March 1, 2004 - August 31, 2004
$ NA

This Phase I project addresses the need for improved monitoring technologies for continuous particulate mass and chemical speciation of ambient aerosols. Aerodyne Research has developed an aerosol mass spectrometer (AMS) that measures ambient aerosol mass, chemical composition, and chemically speciated size distributions of nonrefractory submicron aerosol particles in real time. The AMS has been deployed successfully in more than 20 national and international field campaigns and has participated in several intercomparisons with a variety of independent instruments that highlight the capability of the AMS to quantitatively measure and classify particulate inorganics (ammonium, nitrate, sulfate, chloride) and organics (primary combustion, oxidized secondary compounds) in real time. The value of the AMS as a state-of-the-art aerosol research tool is underscored by its commercial success (20 instruments have been delivered to date). The Phase I goals are to develop a simpler, smaller, and cheaper autonomous prototype Aerosol Chemical Speciation Monitor (ACSM) based on the AMS and evaluate the performance of the ACSM for continuous monitoring applications by conducting side-by-side comparisons with filter measurement techniques. These goals will be accomplished through three tasks: (1) quantify the capability of the AMS to measure known composition laboratory PM2.5 aerosol, including supermicron and nonspherical particles, (2) modify an existing AMS to test the concept of a simple, inexpensive ACSM that has the same quantitative capabilities of the original AMS, and (3) directly compare the prototype ACSM with filter-based PM2.5 particulate mass and chemical speciation methods (Federal Reference Method and Particle Composition Method) for quantifying well-characterized laboratory-generated aerosol and ambient aerosol.

Demonstration of a Continuous, Real-Time PM2.5 Chemical Speciation Monitor Based on an Aerosol Mass Spectrometer (EPA 2005 SBIR Phase 2)
Douglas R. Worsnop (PI),
Aerodyne Research Inc., Billerica, MA
EPA Contract Number: EPD05057
April 1, 2005 - June 30, 2006
$225,000

This Phase II project addresses the need for improved monitoring technologies for continuous particulate mass and chemical speciation of ambient aerosols. Aerodyne Research will develop a prototype aerosol chemical speciation monitor (ACSM) that measures ambient aerosol mass and chemical composition of nonrefractory submicron aerosol particles in real time, which will provide quantitative measurements of particulate ammonium, nitrate, sulfate, chloride, and organics. The ACSM will be designed to run autonomously for extended periods of time and will need no expensive post-processing analysis. The ACSM will be based on technology developed for Aerodyne Research's aerosol mass spectrometer (AMS), including the inlet for efficient particle sampling and the mass spectrometric detection for quantitative mass measurements. The value of the AMS as a state-of-the-art aerosol research tool is underscored by its commercial success (34 have been delivered to date). In Phase II, Aerodyne will construct a prototype ACSM and evaluate its performance for continuous monitoring applications. Specific tasks include (1) further improvement to particle collection efficiency; (2) laboratory evaluation of the prototype ACSM; (3) development of data acquisition software; and (4) intercomparison of the ACSM with the AMS and with filter-based PM2.5 particulate mass and chemical speciation methods. A Phase II option will develop a dual chopper scheme for measuring particle size distributions. The ACSM will be a simple, robust, modestly priced aerosol chemical speciation instrument ideal for monitoring local and regional air quality; continuous emissions at hazardous waste incinerators, power plants, and manufacturing facilities; and process control.

Detecting Metals in Ambient Particulate Matter: X-Ray Fluorescence Analysis of High-Volume Impaction Deposits (EPA 2004 SBIR Phase 1)
Thomas J. Hope (PI), 518-452-0065
Rupprecht & Patashnick Co, Inc., Albany, NY
EPA Contract Number: EPD04019
March 1, 2004 - August 31, 2004
$ NA

The Phase I goal is to develop a prototype instrument capable of performing specialized elemental speciation of ambient particulate matter (PM) in near-real time (1-hour batch collection/analyses). The prototype monitor will incorporate high-volume impaction and x-ray fluorescence technology to accomplish the stated task. Through previous research, Rupprecht & Patashnick Co., Inc. (R&P), has determined that both x-ray fluorescence speciation and high-volume PM impaction are feasible. This project will be a marriage of the two proven technologies. Preliminary research has proven the ability to successfully perform speciation analyses of ambient PM on the selected impaction substrate. To keep costs reasonable, development work must be conducted to determine both the optimal x-ray analyses head geometric configuration and the most efficient sample concentration technique. Once optimization studies are complete, an Alpha prototype will be constructed. The Alpha will be capable of performing all functions necessary to prove the viability of concept and function. The Alpha prototype will be laboratory/field tested and knowledge gained during the Alpha testing will be used to determine Beta prototype specifications. The monitor's features likely will include Ethernet capability and a USB port for other communication links. Additional options could include compact flash memory, a global positioning module, and wireless communication. The final design will minimize the need for user training. The unit will be designed to be easily portable and consume as little power as possible. The low power demand should allow flexibility to operate the unit using an automobile cigarette lighter or car battery for rapid response to emergency situations.

Detecting Metals in Ambient Particulate Matter: X-Ray Fluorescence Analysis of High-Volume Impaction Deposits (EPA 2005 SBIR Phase 2)
Thomas J. Hope (PI), 518-452-0065
Rupprecht & Patashnick Co, Inc., Albany, NY
EPA Contract Number: EPD05061
April 1, 2005 - June 30, 2006
$224,934

The design, construction, and feasibility testing of X-ray fluorescence (XRF) based instrumentation capable of detecting the presence of atomic species within ambient particulate matter (PM) on a near real-time basis was completed successfully in Phase I. The XRF analysis is feasible for hourly ambient PM samples through the implementation of novel high-volume flow impaction and post-impaction concentration techniques. Rupprecht & Patashnick conducted a preliminary study of the first-generation base system's level of detection (LOD) for various elemental species (i.e., Cr, Mn, Ni, Zn, Cd, Ba, Hg, and Pb). It proved capable of measuring ambient PM trace element composition at or near the level expected in urban air samples for 1-hour duration samples. Only 10% of possible X-ray exposure time was utilized in the measurement process. The measurement system will benefit from further reduction of element-specific LODs through increased exposure time, increased collection time, improved collection techniques, primary X-ray filtering, and/or employing the use of variable excitation energy to the X-ray generation tube when required. A study of ambient PM collected in the Albany, NY, area during summer 2004 showed that the first-generation system was capable of detecting Fe, Ca, and S in 1-hour duration samples collected during very low ambient PM2.5 conditions (< 100 ug/m3). Additionally, several signal-to-noise improvement techniques were investigated in Phase I. The Phase II goal is to produce a Beta instrument capable of providing reliable, quantitative measurements of ambient PM elemental composition on an hourly basis. The system is integrated in a package whose size, weight, and power consumption compare favorably with continuous gaseous and particle instrumentation currently deployed in air quality monitoring networks.

Engineered Magnetic Nanoparticles for Advanced Biosensor Signal Processing and Detection of Waterborne Pathogens (EPA 2005 SBIR Phase 1)
Nile Hartman (PI), 678-287-2408, nhartman@ngimat.com
nGimat Co., Chamblee, GA
EPA Contract Number: EPD05032
March 1, 2005 - August 31, 2005
$70,000

nGimat Co. proposes to advance the versatile integrated optic chip sensor for the detection and identification of waterborne bacterial and viral pathogens and toxins. nGimat will utilize magnetic nanoparticles to enable an advanced signal-processing scheme that promises enhanced optical biosensor detection sensitivity (sub-ppb). Fabrication of the necessary magnetic nanoparticles will be facilitated by nGimat's proprietary Nanospray(SM) process. The state-of-the-art nanopowders will be tailored in size (ultrafine and monodisperse), composition (complex if necessary), and architecture (coated, shape) for sensor performance. The incorporation of magnetic nanoparticles is projected to enable a 102 to 104 increase in detection sensitivity. Specifically, a magnetic field will be utilized to induce nanoscale displacements of tethered magnetic particles immobilized on the waveguide surface. These displacements will induce a phase shift in the output of a waveguide interferometer that will be used to discriminate noise from the collected signal. nGimat expects the proposed technology to build on the base optical sensor and be capable of real-time, direct detection (no labeling, additional chemistry steps, or reagents) of multiple biomolecules (proteins, toxins, nucleic acids) in the femtomolar concentration range and pathogens (bacteria, viruses) at concentrations of less than 100 organisms/mL. Performance at this level would place the technology well ahead of existing and emerging sensing methodologies and position it to be competitive with sophisticated laboratory analytical tools.

Fiber Optic Diisocyanate Personal Monitoring Device (EPA 2005 SBIR Phase 1)
Steven A. Lis (PI), 781-449-5297, stevenlis@comcast.net
LightLine Technologies, Inc., Needham, MA
EPA Contract Number: EPD05018
March 1, 2005 - August 31, 2005
$70,000

LightLine Technologies plans to develop a highly sensitive fiber optic personal monitoring device, similar to a sampling badge, targeted for the simple and convenient measurement of total isocyanate and diisocyanate (I&DCY) airborne exposure. With very modest sampling processing (controlled heating), sensing of all types of I&DCYs will be possible and is the primary goal of this research project. The same derivatization reagent can be used to provide simultaneous fiber pad adsorbent sampling for further conventional analysis so that identification and individual quantification of specific I&DCYs and exposure levels is enabled. Current measurement methods fail to provide adequate sensing of all I&DCY species simultaneously. It is anticipated that this project will result in (1) the determination of an optical fiber-based sensor fabrication process, use procedure, and readout process that provides high sensitivity and high confidence evaluation of all isocycanate and diisocyanate vapor species in air; and (2) the design, building, and testing of a prototype personal exposure sensor and readout package that accurately provides sensing capabilities for human exposure determination in industrial environments. The commercial application of this technology is primarily as a personal sensor directed at assuring the safe use of these chemicals during the production and use of a wide range of polyurethane products. The largest potential user group is associated with automotive painting and auto repair (auto body shops).

Field-Portable Fluorescence Sensor for Polycyclic Aromatic Hydrocarbons (EPA 2005 SBIR Phase 1)
Kristen Peterson (PI), 505-984-1322, peterson@swsciences.com
Southwest Sciences Inc., Santa Fe, NM
EPA Contract Number: EPD05041
March 1, 2005 - August 31, 2005
$70,000

Southwest Sciences proposes to design, build, and test a real-time, field-portable instrument for the detection of polycyclic aromatic hydrocarbons (PAHs). The technology uses time- and wavelength-resolved fluorescence spectroscopy (T&WFS) to identify PAHs at sub-parts-per-billion concentrations in water. The instrument incorporates an innovative approach to fluorescence lifetime detection that is based on radio frequency electronics and is considerably less expensive than other approaches to T&WFS. The Phase II prototype will be compact, cost effective, and reliable. It will use an ultraviolet diode laser for excitation of fluorescence and fiber optics to deliver and collect light at the sampling site. The entire instrument, including the diode laser optics, detector, electronics, and computer, will fit into a space the size of a briefcase and will be capable of running on batteries. Potential customers include hazardous waste sites and industrial treatment facilities, DOE (for waste monitoring and remediation), and municipal waste disposal sites. Southwest Science's portable onsite assessment instrument offers the advantages of providing PAH contamination profiles and distributions and real-time monitoring during remediation efforts.

Fine and Course Particulate Continuous Emissions Monitoring System (EPA 2005 SBIR Phase 1)
Tom Baldwin (PI), 775-850-1800, tbaldwin@baldwinusa.com
Baldwin Environmental, Inc., Reno, NV
EPA Contract Number: EPD05021
March 1, 2005 - August 31, 2005
$70,000

Baldwin Environmental, Inc., will demonstrate the feasibility and practicality of applying beta attenuation monitors (BAMs) to quantify hourly concentrations of fine particulate matter (PM2.5; particles with aerodynamic diameters less than 2.5 um) and coarse PM (PM10-2.5; particles with aerodynamic diameters between 2.5 um and 10 um) in diluted extracts from stacks at hazardous waste combustors. BAMs quantify mass by measuring the reduction in flux of electrons generated by a radioactive source through a filter tape that collects particles. The U.S. EPA and other regulatory agencies need PM2.5 and coarse continuous emissions monitors (CEMs) to better estimate and control emissions that affect public health, visibility, and climate. Though BAMs are widely used for ambient PM10 monitoring, they exhibit differences with respect to filter samples depending on the composition of the particles collected. These differences are exacerbated in source samples owing to the large fraction of semi-volatile material and hygroscopic components, like sulfates. This project will combine a newly developed BAM that simultaneously measures PM2.5, PM10-2.5, and BC with an extraction-dilution system. Through testing of simulated stack samples, it will quantify the extent to which such a configuration can accurately portray mass concentrations as they appear in the atmosphere immediately after cooling. This testing will determine the optimum dilution ratios and aging times needed to obtain relative humidities that create a stable mass concentration and size distribution. This feasibility testing will be translated into a practical design, applicable to a wide number of incinerator waste inputs, operating conditions, and stack configurations in anticipation of a Phase II project to develop a commercial prototype. The design intends to meet PS-11. EPA Conditional Test Method 039 will be used as a guideline for the prototype design. Phase III will carry the prototype to a commercial product.

Fluorescent Nanoparticle-Aptamer-Magnetic Bead Sensor for Bioterrorism Detection in Water (EPA 2004 SBIR Phase 1)
John G. Bruno (PI), 210-731-0015
Operational Technologies Corporation, San Antonio, TX
EPA Contract Number: EPD04027
March 1, 2004 - August 31, 2004
$69,918

Some bioterrorism agents cause disease at very low infective doses and their presence can be masked by the environment. Ultrasensitive detection is required for homeland defense applications. In this Phase I research project, Operational Technologies Corporation (OpTech) proposes to couple DNA aptamers made by the systematic evolution of ligands by exponential enrichment (SELEX) process to commercially available fluorescent nanoparticles (NPs) composed of chelated europium in polystyrene. OpTech will demonstrate aptamer-NP-mediated detection of a bacterial, viral, and toxin simulant at low levels. Fluorescent NPs are plastic and metallic "beads" that endow superior sensitivity in clinical assays (up to zeptomolar [10-21] detection limits). OpTech also will couple the DNA aptamers to magnetic microbeads and demonstrate magnetic separation and purification of the bioterrorism agent simulants from natural water samples in conjunction with aptamer-fluorescent NP detection (i.e., sandwich bead assay). In Phase II, OpTech will design and build a prototype compact or handheld fluorescence reader. The reader will be equipped with a special magnetically assisted cartridge and employ simple magnetic microbead aptamer-fluorescent NP sandwich assays to probe, capture, and concentrate bioterrorism agents from environmental samples prior to analysis, thereby pushing the limits of sensitivity to unprecedented low levels, even in "dirty" water samples.

A Low-Cost UV Raman Instrument Measuring Nitrate and Nitrite for Improved Operation and Control of Nitrification/Denitrification Treatment Processes (EPA 2005 SBIR Phase 1)
William F. Hug (PI), 626-967-6431, w.hug@photonsystems.com
Photon Systems, Inc., Covina, CA
EPA Contract Number: EPD05033
March 1, 2005 - August 31, 2005
$70,000

Photon Systems, Inc., will develop a unique, on-line, in situ autonomous monitoring and process control system that will improve the reliability and performance of wastewater treatment systems designed to remove nitrogen through simultaneous nitrification and denitrification. A key technology component of this innovative process control system will be an analytical instrument based on deep ultraviolet resonance Raman (UVRR) spectroscopy, which will measure nitrate and nitrite concentrations in biological nutrient removal system reactors without the need for sample handling, reagent additions, or complex calibration procedures. Detection limits for the proposed instrument are expected to be below about 2 ppb for nitrates and nitrites. The proposed instrument uses a unique deep UV laser technology with a 224 nm emission wavelength and subminiature Raman analysis detection methods to make a very inexpensive, miniature (less than 4 L), lightweight (less than 5 lbs), low power consumption (less than 5 W) instrument that can be used in situ for autonomous measurements in harsh environments. The size, weight, and power consumption specifications are for the complete instrument, including lasers, detectors, and all power supplies and controllers. Potential commercial applications of this new technology include in situ monitoring and control of a variety of wastewater treatment systems; in situ, autonomous monitoring of air, water, and soil; and a wide range of other commercial, industrial, and medical applications.

MEMS-Based Volatile Organic Compound Monitor (EPA 2004 SBIR Phase 1)
Dharanipal Doppalapudi (PI), 781-933-5100
Boston MicroSystems Inc., Woburn, MA
EPA Contract Number: EPD04014
March 1, 2004 - August 31, 2004
$ NA

Boston MicroSystems, Inc. (BMS), proposes to develop a microelectromechanical system (MEMS)-based volatile organic compound (VOC) monitor by integrating analyte-specific polymer films with SiC-AlN microresonators. BMS and the Naval Research Laboratory will integrate microresonators and polymer films with functional groups sensitive to aromatic compounds (e.g., benzene and toluene); halogenated hydrocarbons (e.g., methylene chloride); and aromatic alcohols (e.g., phenols and catechols). When exposed to hazardous air pollutants, the polymer films absorb the vapors, increasing their mass and resulting in a shift in the resonant frequency that is proportional to the pollutant concentration. The proposed MEMS-based sensor system is compact and robust, and has low cost and power requirements and high sensitivity. By using an array with multiple sensors, each with high sensitivity to a particular pollutant, a high selectivity is achieved. The fully functional multichannel monitor is expected to be a battery-powered instrument consisting of a microresonator array, drive/sense electronics, rechargeable power supply, visual display, self-test, data storage, and an interface for data downloading. The proposed VOC monitor will provide a compact handheld or remotely operated instrument that enables rapid, real-time, low-cost measurement of multiple pollutant gases for industrial applications as well as for U.S. EPA field agents. Primary applications include emissions monitoring in smokestacks and exhaust streams of chemical, pharmaceutical, and power-generating plants and refineries; leak detection and process control near industrial machinery and processes with potential hazardous emissions; monitoring a wide range of source locations in and around industrial facilities (fenceline monitoring); and monitoring toxic dump sites.

Microchip Capillary Electrophoresis for Online Measurement of Inorganic Aerosols (EPA 2004 SBIR Phase 1)
Susanne Hering (PI), 510-649-9360
Aerosol Dynamics Inc., Berkeley, CA
EPA Contract Number: EPD04012
March 1, 2004 - August 31, 2004
$ NA

The U.S. EPA has identified the need for continuous monitors that can operate unattended and provide real-time data on the concentration of the major chemical components of PM2.5, defined as particles with diameters of less than 2.5 um. The chemical composition of fine airborne particles is needed to identify sources, understand formation mechanisms, and further elucidate exposures and health effects. Aerosol Dynamics proposes a compact, inexpensive, and sensitive instrument using capillary electrophoresis (CE) mounted on a microchip. Ambient particles are deposited directly on the CE chip by means of humidification, growth, and impaction. Ambient particles are extracted directly in a small aqueous volume for the in situ CE analyses of particle-bound inorganic ions. Both cations and anions will be determined. This "laboratory on a chip" technique will provide online, time-resolved quantification of a suite of PM2.5 inorganic ions found in ambient aerosol. This approach will provide a 5-minute time resolution for ions with detection limits of 10 ng/m3 or better. Commercial applications include monitoring in homes, schools, and offices in addition to central monitoring sites. The CE technique is inherently far more cost-effective than current approaches.

Microchip Capillary Electrophoresis for Online Measurement of Inorganic Aerosols (EPA 2005 SBIR Phase 2)
Susanne Hering (PI), 510-649-9360
Aerosol Dynamics Inc., Berkeley, CA
EPA Contract Number: EPD05058
April 1, 2005 - June 30, 2006
$219,136

A compact and affordable microchip-based system for the automated, in situ analysis of inorganic ions in atmospheric aerosols will be develop and verified against traditional, filter-based methods. Aerosol Dynamics will combine two new technologies: (1) a growth tube impactor for particle collection, and

(2) lab-on-a-chip (LOC) analysis of sulfates and nitrates. The growth tube impactor enlarges individual airborne particles by water condensation in a laminar, thermally diffusive flow. Once encapsulated within a water droplet, particles with a diameter of 0.015 uM or larger are deposited directly onto a small reservoir on the LOC. The LOC utilizes capillary electrophoresis with embedded conductivity detection. Separation of sulfates and nitrates is achieved in less than 2 minutes, with detection limits of 1 uM. The instrument will provide 5-minute time resolution for fine particulate matter (PM2.5) sulfate and nitrate, with detection limits of 100 ng/m3 or better. The analyzer will be both quiet and compact. The pressure drop required for sampling is just 0.5 kPa, and thus pumping requirements are small. As such, it will be suitable for microenvironmental sampling in offices, homes, schools, and air monitoring stations. By providing a low-cost alternative to other continuous analyzers, widespread deployment will be encouraged.

Microdischarge-Based Multimetal Emission Monitoring System (EPA 2004 SBIR Phase 1)
Cy Herring (PI), 217-265-6070
Caviton Inc., Champaign, IL
EPA Contract Number: EPD04015
March 1, 2004 - August 31, 2004
$ NA

Caviton, Inc., has developed an ideal microsensor for the continuous monitoring of multiple metals. These detection systems rely on microdischarge technology (patent pending), utilizing the power of emission spectroscopy for parts per billion (ppb)-level sensitivity and laboratory instrument-level selectivity. Microdischarge sensors provide real-time continuous monitoring of metals (and other chemical species) simultaneously using a single detector. The instrument consists of a detector tip, where the discharge is located and sensing takes place; an optical fiber that couples the light from the discharge to a small commercial spectrometer that analyzes the light; and a computer for data processing. The stable plasma discharge operates in air, and the color of the light from the discharge is altered by any chemicals in the surrounding environment. The spectrometer separates the light into wavelengths, indicating the specific identification of any chemicals present, and is particularly powerful for the detection of metals, e.g., mercury, nickel, lead, cadmium, and selenium. All components of the surrounding environment are broken down by the high-energy discharge to their atomic (and diatomic) constituents, such that metal organics, oxides, and salts are stripped, providing data on the total content of a specific metal. This detection system is compact, rugged, and can be made easy to use, requiring minimal training of technicians and engineers. Nickel and nickel compounds have been preliminarily characterized in the discharge, as have mercury, silver, copper, aluminum, and chromium, providing estimates of detection limits in the tens of ppb. These sensors are capable of operating in harsh environments because of the materials used in construction, and have been operated at more than 1,000 degrees C in previous experiments, with no observable breakdown of detector components. The detector contains no moving parts.

Micro-Discharge Based Multi-Metal Emissions Monitoring System (EPA 2005 SBIR Phase 2)
Cy Herring (PI), 217-265-6070
Caviton Inc., Champaign, IL
EPA Contract Number: EPD05059
April 1, 2005 through June 30, 2006
$225,000

Caviton, Inc., has developed a novel technique for the continuous monitoring of trace metals emissions that is based on a microdischarge light, which is collected by a spectrometer and analyzed. All metals tested to date can be detected, and the focus of this Phase II research project is to develop a sampling system, carry out laboratory tests, and perform field tests of sampling and analysis. An instrument design will be completed that will detail the final form of the instrument. This system will consist of a collection tube, a filter, a sample collection surface that can be heated to release the sample, and a microdischarge device with related analysis equipment. The entire instrument will have no moving parts and will be made from corrosion-resistant materials. To date, detectors have been operated at temperatures higher than 1,000 degrees C with no signs of degradation. Caviton will consult with an experienced stack tester to provide side-by-side comparisons to current equipment. This consultant also will aid in the final instrument design to ensure ease of use and real-world functionality. Caviton intends to produce a rugged, sensitive, and cost-effective solution to multiple metals monitoring that will be useful for surveys and for continuous emissions monitoring in harsh environments, such as smoke stacks, burners, boilers, and incinerators. The company also will consult with a business development and marketing expert with whom it has had a long-standing relationship to identify the proper partners for licensing and producing the resulting instrument.

Monitoring Groundwater Contaminants (EPA 2004 SBIR Phase 1)
Anuncia Gonzalez-Martin (PI), 979-693-0017
Lynntech Inc., College Station, TX
EPA Contract Number: EPD04039
March 1, 2004 - August 31, 2004
$70,000

The Phase I goal is to develop a low-cost, compact, reliable, automated, unattended, and long-term monitoring system for hydrocarbons in groundwater. Lynntech also will use an innovative sampling system in the field test. The monitoring system consists of an array-based sensor composed of incrementally different electrically conducting polymer elements. It will allow the identification and quantification of organic pollutants present in groundwater. A pre-concentrator with a microfluidic design will be incorporated into the sensing system. This will allow a resolution into the ppb and ppt levels. The effectiveness of the proposed system will be evaluated based on its ability to detect hydrocarbons in model and real groundwater samples. The proposed system will reduce the cost associated with sampling and contaminant monitoring and provide timely, continuous information. Also, it will provide the possibility for unattended monitoring of the migration of contaminant plumes, as well as for monitoring contaminants that breach containment operations. The primary end-users will be agencies of the federal government (e.g., DOE, DoD, and EPA) and private industries that are involved in the monitoring of chemical analytes in groundwater and the subsurface. Similar sensors will find wide application to gauge the effectiveness of remediation efforts, to effect waste minimization, and to detect the presence of toxic, hazardous, or otherwise regulated chemicals in water, as well as in other areas.

Monitoring Multiple Volatile Organic Compounds With Cost-Effective Optical Remote Sensing Instrumentation (EPA 2004 SBIR Phase 1)
Loren D. Nelson (PI), 303-933-2200
OPHIR Corporation, Littleton, CO
EPA Contract Number: EPD04017
March 1, 2004 - August 31, 2004
$ NA

One method to dramatically reduce the cost associated with air quality sensors is to develop a sensor technology whereby all sensors share a large degree of commonality in hardware, software, manufacturing, and calibration. The economy of scale provided by largely equivalent sensors will enable these devices to be economically mass produced. The success of the U.S. EPA's Residual Risk Program (which addresses the serious impacts of hazardous air pollutants) will be based largely on achieving widely distributed (and inexpensive) monitoring technologies. Ophir Corporation proposes to develop a correlation spectrometer based on synthetic spectra gratings to addresses this critical need. Ophir's method utilizes broadband infrared sources, eliminating specific lasers or light-emitting diodes for every different trace gas of interest. The goal of this Phase I research project is to prove the concept of combining Ophir's proven long-path (fenceline), active correlation spectrometer method with synthetic spectra gratings. Synthetic spectra gratings are an important, enabling technology. They enable many gases to be monitored in real time using a single sensor, and they can be economically mass produced. This research will provide the first demonstration of long-path, open atmosphere measurements of trace gas pollutants based on active, synthetic spectra correlation radiometry. This project includes a lab demonstration of the detection of toluene using a synthetic spectrum grating. Phase I will focus on the design and performance assessment of a prototype sensor for Phase II construction and testing.

Multi-Analyte Nanoelectronic Air Pollutant Sensors (EPA 2004 SBIR Phase 1)
Alexander Star (PI), 510-428-5300
Nanomix, Inc., Emeryville, CA
EPA Contract Number: EPD04045
March 1, 2004 - August 31, 2004
$70,000

Nanomix, Inc., proposes to develop and commercialize nanoelectronic chemical sensors for the detection and measurement of air pollution. The end product of the work, a tiny, low-cost nanosensor chip, will measure concentrations of three different analytes down to the single molecule level. The proposed work is an extension of the gas sensing technology developed at Nanomix using carbon nanotube sensing arrays. Nanosensors can be used to catalog and monitor fugitive emissions; detect leaks from manufacturing operations, storage tanks, and pipelines; and measure worker exposure in real time. The Phase I goal is to build and demonstrate a nanosensor prototype to detect and measure real-time concentrations of three types of analytes: (1) aromatic hydrocarbons; (2) acidic gases (e.g., HCl, HF, SOx, NOx); and (3) basic gases (e.g., NH3). The sensor itself consists of two major components: a transducer array made of single-wall carbon nanotubes on a complementary metal oxide semiconductor silicon substrate and chemical recognition layers or coatings that increase the transducer's sensitivity and selectivity to the target analytes. The major focus of Phase I will be the selection of a recognition chemistry for each analyte and sensor array fabrication and testing in a laboratory environment. Nanomix already has developed the underlying transducer architecture. Successful commercialization of the technology will allow designers to place air pollution sensors anywhere and everywhere they are useful for leak detection and air quality monitoring, significantly improving the detection and monitoring of hazardous air pollutants.

Multimetals Emission Monitoring System Based on Spark-Induced Breakdown Spectroscopy (EPA 2004 SBIR Phase 1)
Amy J.R. Hunter, 978-689-0003
Physical Sciences Inc., Andover, MA
EPA Contract Number: EPD04018
March 1, 2004 - August 31, 2004
$ NA

Physical Sciences, Inc., proposes to develop a multimetals emissions monitor to support Title V permitting of large air pollution sources based on its patented spark-induced breakdown spectroscopy (SIBS) technology. Previous work has shown that this technique is capable of sensitively monitoring metals in airborne particles that emit in the visible range (e.g., Pb, Cr, and Cd). To be useful for measuring all metallic hazardous air pollutants (HAPs), use of SIBS in the deep ultraviolet range must be developed. The goal of this Phase I research project is to develop a SIBS capability to monitor As and Se, which have strong emissions at 193.7 nm and 196.0 nm, respectively. This ability then will be married to existing SIBS technology to create the basis for a monitor able to identify and quantify all metals on the HAPs list. This monitor will be useful in enabling large air pollution sources, such as incinerators and power plants, to meet their Title V obligations of monitoring and reporting their emissions. The SIBS monitor will operate in real time, an improvement over the currently used U.S. EPA Reference Method 29, an extractive technique that is labor-intensive, slow, and not amenable to automation.

Multimetals Monitoring System Based Upon Spark-Induced Breakdown Spectroscopy (EPA 2005 SBIR Phase 2)
Amy J.R. Hunter, 978-689-0003
Physical Sciences Inc., Andover, MA
EPA Contract Number: EPD05060
April 1, 2005 - June 30, 2006
$224,877

Physical Sciences, Inc. (PSI) proposes to develop a multimetals emissions monitor to support Title V permitting of large air pollution sources based on its patented spark-induced breakdown spectroscopy (SIBS) technology. Work prior to Phase I has shown that this technique is capable of sensitively monitoring metals in airborne particles that emit in the visible range (e.g., Pb, Cr, and Cd). To be useful for measuring all metallic hazardous air pollutants (HAPs), however, use of SIBS in the deep ultraviolet must be developed. In Phase I, PSI began the development of SIBS capability to monitor As and Se, which have strong emissions at 193.7 and 196.0 nm, respectively. This ability will be optimized in Phase II and then it will be married to the existing SIBS technology to create the basis of a monitor that is able to identify and quantify all HAP metals. This monitor will be very useful in enabling large air pollution sources, such as incinerators and power plants, to meet the Title V obligations of emissions monitoring and reporting. The SIBS monitor will operate in real time, an improvement over the currently used U.S. EPA Reference Method 29, an extractive technique that is labor-intensive, slow, and not amenable to automation.

Multiplexed Chemical Sensor for Water Security (EPA 2005 SBIR Phase 1)
Stuart Farquharson (PI), 860-528-9806, stu@rta.biz
Real-Time Analyzers, Inc., East Hartford, CT
EPA Contract Number: EPD05034
March 1, 2005 - August 31, 2005
$69,994

The goal of this research project (through Phase III) is to develop a chemical sensor that can be multiplexed into water distribution systems to provide early warning of poisoned water supplies. This will be accomplished by developing surface-enhanced Raman (SER) sensors that can be integrated into water supply systems and coupled to a central Raman analyzer via fiber optics. In Phase I, Real-Time Analyzers, Inc., will develop the sensors to selectively detect several chemical agent hydrolysis products, toxic industrial chemicals, and pesticides at concentrations below 1 mg/L in flowing streams in 10 minutes. In Phase II, Real-Time Analyzers will interface the SER sensors into optical probes that tie into selected water distribution points, improve sensitivity to 10 ug/L in 10 minutes for 30 analytes, and develop multiplexing software compatible with supervisory control and data acquisition systems. Sensitivity, selectivity, and process capabilities will be evaluated using actual chemical warfare agents at Aberdeen Proving Ground under a subcontract.

A Nanocrystal Biosensor Array for Simultaneous Detection of Multiple Waterborne Pathogens (EPA 2005 SBIR Phase 1)
Yongcheng Liu,
Nanomaterials & Nanofabrication Laboratories,
EPA Contract Number: EPD05028
March 1, 2005 - August 31, 2005
$70,000

The goal of this research project is to develop a new generation of sensitive, rapid, portable, robust, and inexpensive biosensors for the simultaneous detection of multiple waterborne pathogens in water products and the environment. Nanomaterials & Nanofabrication Laboratories will develop new biomarkers by conjugating the various color nanocrystals onto the monoclonal antibodies and a new flow cell to specifically capture and concentrate the waterborne pathogens by immobilizing the monoclonal antibodies onto the porous membrane surface. The feasibility of this technology will be demonstrated by detecting protein A with the biosensor setup and using a photoluminescence detector to measure the photoluminescence emitted from the nanocrystals on the immunocomplexes. The nanocrystals as biomarkers make the biosensors capable of simultaneously detecting multiple waterborne pathogens in the same setup with a laser source because of their broad excitation spectra, narrow and symmetric emission spectra, and high resistance to photobleaching. The high density of the immobilized antibodies on the porous membrane surface will quantitatively capture the waterborne pathogens so that the sensitivity of the biosensor will be greatly enhanced and the detection limit will be lowered to one cell per one of the pathogens. The monoclonal antibodies used will diminish the nonspecific binding and the positive false signal.

Pneumatic Focusing Gas Chromatography: A Continuous, Automated, Ambient, Fenceline and Fugitive Emissions Monitoring Instrument (EPA 2004 SBIR Phase 1)
Thomas M. Hard (PI), 503-725-3881, hardt@pdx.edu
VOC Technologies Inc., Portland, OR
EPA Contract Number: EPD04020
March 1, 2004 - August 31, 2004
$ NA

VOC Technologies, Inc., will use the new technique of pneumatic focusing gas chromatography (PFGC, patent pending) in the development and testing of a commercial, continuous, speciated monitor for volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). This instrument is capable of continuous, remote operation for periods of weeks at a time, transmitting data over a network connection or cellular telephone and achieving sensitivity of 50 pptV for benzene with a 250 cc air sample injected directly into the portable instrument. The Phase I goal is to produce a PFGC instrument that costs less than $15,000. Prototypes will be configured with series photoionization detectors (PIDs) and flame ionization detectors (FIDs) that will enable dual response for some types of analytes, including aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylenes). Detector comparison will determine whether a single PID, a single FID, or a dual detector instrument would be most useful. The FID has the advantages of (1) requiring no maintenance, (2) universal sensitivity to VOCs and HAPs, and (3) potential for internal calibration on every sample using ambient methane concentrations while requiring compressed flame gases hydrogen and air or oxygen. The PID detector does not require compressed gases, but has limited response for some types of analytes and suffers from aging of the lamp. The PFGC instruments will be laboratory calibrated and field compared in a cooperative effort between VOC Technologies, Inc., and the Oregon Department of Environmental Quality using standard U.S. EPA protocols for canister sampling, including Method TO-14.

Pneumatic Focusing Gas Chromatography: A 3-in-1 Continuous, Automated, Ambient-Fenceline-Fugative Emissions Instrument (EPA 2005 SBIR Phase 2)
Robert J. O'Brien (PI), 503-725-4264, obrienr@pdx.edu
VOC Technologies Inc., Portland, OR
EPA Contract Number: EPD05062
April 1, 2005 - June 30, 2006
$224,934

VOC Technologies, Inc. (VOCTEC) developed a patent-pending new technology for analysis of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) by compressing an air sample to high pressure before injecting it into a specially designed gas chromatograph (GC). This GC is constructed entirely within a personal computer that operates unattended and indefinitely in the field with network communication. Compression both concentrates the sample and removes water vapor by condensation. This procedure is called pneumatic focusing gas chromatography (PFGC). This highly automated new technology has the potential to lower the cost of a VOC/HAP analysis by a factor of 100, requiring no special operator skills. With PFGC, a 300 cc sample can be injected directly on the column and achieve a 50 ppb level of detection (LOD) for benzene, with 500,000 theoretical plates using either flame or photoionization detection. Samples as small as 0.1 cc allow for direct stack monitoring. Because the entire air sample passes the column and detector, ambient methane serves as an internal standard on every analysis. Two PFGC instruments were constructed in Phase I. These instruments were equipped with commercial dual flame and photoionization detectors (FID/PID), and demonstrated ruggedness, sensitivity, and precision in monitoring outdoor air at an urban monitoring station run by the Oregon Department of Environmental Quality. In Phase II, VOCTEC will carry out a year-long ambient TO-14 inter-comparison under contract to the DEQ at no cost to the SBIR Program. This will involve EPA-approved sixth-day TO-14 canister analysis and VOCTEC's 24/7 in situ ambient air analysis. The TO-14 canisters will be analyzed using PFGC for comparison with the in situ data. Major improvements will be made in chromatographic resolution to better separate HAPs from less toxic VOCs, involving novel and proprietary software and hardware modifications of the existing PFGC instrument.

Remote, Real-Time Monitor for Elemental Speciation of Air Particulates (EPA 2005 SBIR Phase 1)
Ning Gao (PI), 518-880-1500, ngao@xos.com
X-Ray Optical Systems, Inc., East Greenbush, NY
EPA Contract Number: EPD05045
March 1, 2005 - August 31, 2005
$69,922

This research project is designed to provide near real-time, remotely accessed monitoring of toxic metal and other elemental contamination of air particulates to support monitoring for health advisories, research into medical and weather effects, and source attribution for the particulates. This approach is made possible by a novel technology that uses proprietary doubly curved crystal x-ray optics developed by X-Ray Optical Systems, Inc. The general analytical technique, x-ray fluorescence (XRF), is the laboratory technique most widely used by U.S. EPA monitoring stations. Advanced x-ray optics for collecting, concentrating, and improving the spectrum of the beam will enable the technique to be used for continuous monitoring in the field. This improved technique, microfocus monochromatic-excitation energy-dispersive XRF, will improve the performance sufficiently that the field units may exceed the sensitivity of the current laboratory units for detecting toxic metal contaminants. The resulting analyzers will be compact, rugged, reliable, and low-cost enough to be widely distributed both in the United States and internationally (perhaps even allowing retrofit of existing air particulate monitors).

Toward Developing a Rapid Field-Testing Device: Regenerable Fujiwara Reagent as a Portable Technology for Measuring Drinking Water Pollution (EPA 2004 SBIR Phase 1)
Kisholoy Goswami (PI), 310-530-4974
InnoSense LLC, Lomita, CA
EPA Contract Number: EPD04037
March 1, 2004 - August 31, 2004
$69,997

The goal of Phase I is to establish the feasibility of a regenerable chemical sensor for in situ detection of halogenated hydrocarbons (HHCs) in water. The technology is expected to generate a device for rapid field tests related to spills and accidents involving HHCs, such as trichloroethene (TCE). HHCs are among the most frequent contaminants of water, air, and soil across the United States. The EPA-mandated maximum allowable concentration of TCE in drinking water is 5 parts per billion. Fujiwara reaction is the only known reaction for detecting HHCs spectrophotometrically in the visible region. This reaction is irreversible, nonspecific, and it requires a fresh supply of reagent for each measurement. The liquid pyridine used in the Fujiwara reaction is a toxic, offensive-smelling material. InnoSense will develop a chemical sensor for detecting HHCs using a modified Fujiwara reagent.

Innovative regenerable and user-friendly reagents will enhance performance and cost effectiveness and reduce risk potential to field personnel. The approach to be investigated in this project is designed to remove the difficulties encountered by previous researchers using liquid pyridine. The anticipated results at the end of Phase II are expected to have impacts on (1) handling difficulties, (2) reagent delivery, (3) operational life, and (4) sensitivity and selectivity. The initial product launching will be aimed at rapid field testing needed to respond to spills and accidents. At the end of Phase III, a fully engineered, regulator-approved HHC sensor is expected that can perform analyses for $10/sample.

Ultrasensitive Biosensor for Detecting Biotoxins in Drinking Water (EPA 2004 SBIR Phase 1)
Michael Miller (PI)
Bioscale, Inc., Boston, MA
EPA Contract Number: EPD04010
March 1, 2004 - August 31, 2004
$69,557

The goal of this Phase I research project is to develop a novel microelectromechanical systems (MEMS)-based sensor capable of detecting low levels of biotoxins in drinking water. An automated detection system based on this technology will fulfill a critical need in homeland security threat management. Central to the proposed sensing approach is a resonating microstructure optimized for sensitive system-level identification of the vibratory modes and, hence, detection of target analytes. Choosing the appropriate surface chemistry and capture agents as well as operating in a multiplexed format provides a means of achieving high selectivity. Because the binding of the analyte to the surface is detected directly by monitoring changes in the vibrational spectra, no labeling is required. The sensing elements are microfabricated using wafer-level processes so that low-cost arrays become feasible along with an extension of capabilities. For example, individual sensing elements can be functionalized or addressed to target multiple analytes, allowing a complete assay on a single chip. BioScale will test program prototype sensing elements to prove the feasibility of the proposed approach. The proposed sensor technology can be deployed to detect a wide range of biological targets; therefore, it can be used in a broad range of biodetection applications, including contaminant detection for environmental monitoring or homeland defense, medical diagnostics, and pharmaceutical development and production.

Ultrasensitive Toxic Chemical Detector (EPA 2004 SBIR Phase 1)
Stephen N. Bunker, 617-246-0700
Implant Sciences Corporation, Wakefield, MA
EPA Contract Number: EPD04024
March 1, 2004 - August 31, 2004
$70,000

The ability to detect and identify trace concentrations of a wide range of chemicals in the field using a man-portable instrument is severely limited. The ability to quickly and reliably identify toxic industrial chemicals in the presence of typical building interferents would give the U.S. EPA a substantially higher probability of avoiding injury or death during a chemical attack or accidental chemical release. The goal of this Phase I research project is to combine an array of new technologies, including laser-based ion mobility spectroscopy, a unique long-distance cyclone gas sampling method, induced long-distance vapor emission from the environment, solid-phase microextraction fiber preconcentration with fast desorption, and bipolar mode analyses to significantly increase the sensitivity to trace toxic chemicals. Many of these new technologies already have been demonstrated in a portable ultrasensitive explosives detection system that is capable of detecting, within a few seconds, very low volatility plastic explosives at room temperature by emitted vapor alone and with no particle collection required. Implant Sciences Corporation will produce a portable, ultrasensitive toxic chemical detector for field analyses of buildings. A related product will be an inexpensive multisensor version with similar sensitivity that is intended for fixed monitoring of the atmosphere in entire buildings, subways, and other enclosed areas. This product may be adapted to a wide variety of chemical sensing, including trace chemical monitoring of manufacturing processes, medically relevant trace vapors, security applications, and incipient equipment failure, such as overheated wiring within bundles.

Water Security Sensor for Automatic Measurement of Micrograms of Heavy Metals in Drinking and Waste Water (EPA 2005 SBIR Phase 1)
Ingrid Repins (PI), 303-420-1141, info@itnes.com
ITN Energy Systems, Inc., Littleton, CO
EPA Contract Number: EPD05026
March 1, 2005 - August 31, 2005
$69,983

ITN Energy Systems, Inc. (ITN) will adapt its advanced x-ray fluorescence (XRF) technology to create an automated smart sensor for trace amounts of toxic heavy metals in water. ITN's technology is proven in solar cell manufacturing, where the sensor continuously monitors very small amounts of metal in products and automatically provides feedback to process control. The technique is inexpensive, very sensitive, and nearly maintenance free, and it generates a continuous signal for automatic monitoring. The sensor detects multiple metals simultaneously, including mercury, arsenic, and lead. ITN's XRF technology succeeds in applications where XRF previously has been inappropriate. Unique geometry allows the sensor to view a large portion of the sample and therefore obtain a larger signal and higher sensitivity. ITN's novel sensor encapsulation allows component operation in close proximity to liquids. The goal of this research project is to adapt ITN's XRF technology to provide a smart, automatic, early warning sensor for trace levels of toxic metals in water on a ug/L scale. In Phase I, the feasibility of this approach will be proven by showing that the sensor can detect 20 ug/L Hg in water without interference from other metals, chemical state of the metals, or organic material. In Phase II, sensor capabilities will be expanded. These improvements may include higher sensitivity, calibration for more elements, portability, remote communication of data, participation in EPA's Environmental Technology Verification program, or cost reduction. In Phase III, the sensor will be sold as a smart, automatic, early warning sensor for trace metals in water on a ug/L scale. This will be useful for water security, plant discharge monitoring, and possibly drinking water.

Wireless Decontamination Gas Monitor (EPA 2005 SBIR Phase 1)
Todd Mlsna (PI) tmlsna@seacoastscience.com, and Louis Haerle (Co-PI) louis@seacoastscience.com
Seacoast Science, Inc., Carlsbad, CA, 858-449-2151
EPA Contract Number: EPD05038
March 1, 2005 - August 31, 2005
$66,204

Seacoast Science, Inc., proposes to fabricate a detector that will monitor the presence and concentration of two chemicals commonly used for building decontamination. Ultimately, this project will yield a small, rugged, lightweight, low-power system designed for continuous unattended operation or handheld battery operation. In unattended mode, the proposed detector will monitor chemical concentration and transmit levels and a detector location identification code wirelessly back to a central control unit. When used in handheld mode, the system will display chemical concentration on an LCD display. The system includes a chemical sensor array optimized for detection of two decontamination chemicals (chlorine dioxide and hydrogen peroxide); a gas sampling system; a radio for wireless communication; and a small, rugged lightweight, and low-power system. Seacoast Science's microelectrical mechanical systems (MEMS) chemicapacitor technology utilizes an array of surface micromachined capacitors, coated with chemoselective polymer coatings optimized for the volatile decontamination chemicals. Inexpensive production cost, robustness, and low power consumption will result in a compelling detector system able to operate during the early phases of the decontamination process when chemical concentration is high as well as late in the process to determine if the building can be safely re-occupied. In Phase I, Seacoast Science will develop chemoselective coatings on their existing MEMS capacitor sensors and test these sensors by exposing them to chlorine dioxide and hydrogen peroxide. This information will be used in Phase II to fine-tune the coatings and ultimately produce four prototype units.

Wireless Underwater Telemetry System for Surface Water Quality Monitoring (EPA 2004 SBIR Phase 1)
Philip Schaefer (PI), 828-645-1026
Vortant Technologies LLC, Weaverville, NC
EPA Contract Number: EPD04049
March 1, 2004 - August 31, 2004
$69,338

The goal of this Phase I research project is to create a product to revolutionize the planning, installation, damage resistance, and cost effectiveness of in situ, real-time water quality monitoring systems. The proposed project will develop a water quality telemetry system that eliminates the wires, cables, and above-water electronics currently needed for real-time monitoring. Using an innovative technology that overcomes the problems of transmitting radio waves through water, the new system will transmit real-time data from a compact, submerged sensor module over land, to a telemetry receiver located at a convenient location, perhaps miles from the measurement point. The new telemetry technology will substantially eliminate inadvertent and intentional damage to critical water quality monitoring installations and greatly reduce complications of aesthetics, site choice, and cabling currently associated with real-time monitoring.

NATIONAL SCIENCE FOUNDATION (NSF)

Automated-Minirhizotron and Arrayed Rhizosphere-Soil Sensors [A-MARSS] (NSF 2004 Continuing Grant)
Michael Allen (PI) michael.allen@ucr.edu; Edith Allen (Co-PI); Michael Hamilton (Co-PI); Thomas Harmon (Co-PI); James Borneman (Co-PI)
University of California-Riverside, Office of Research Affairs, Riverside, CA, 951-827-5535
Award Number 0410408
October 1, 2004 - September 30, 2006
$1,354,061

This award supports the development of a robotic mini-rhizotron system and its integration with existing technologies into a network of environmental monitoring probes (nitrate, carbon dioxide, water, temperature, microbial composition) that can both receive instructions and transmit data and images remotely using new wireless technologies. Soil ecology has generally consisted of individual static or harvest measurements that lack adequate small-scale, rapid replication. The new instrumentation and integration approaches should provide a quantum leap in the ability to monitor and describe small-scale phenomena and integrate a large number of measurements both spatially and temporally into integrated complex mechanics of soil ecology. The project team consists of ecologists, environmental scientists, engineers, and computer scientists all working to develop the new instruments and integrate the array of parameters measured. All measurements are being designed to measure remotely, allowing for the observation of events as they occur. This project integrates prior work from programs in soil biocomplexity, technique development, and wireless engineering technologies. The project will take place at three locations (1) the James Reserve, a University of California Natural Reserve System site with an existing website and remote-controlled data access system used by schools nationally, (2) an agricultural technology test-bed near Palmdale, CA, where pollution sensors are being tested, and (3) a Long-Term Ecological Research (LTER) site, near Albuquerque.

A Bioinformatics System for GCxGC-MS (Comprehensive Two-Dimensional Gas Chromography) (NSF 2004 SBIR Phase 2)
Stephen Reichenbach (PI) reich@inebraska.com
GC Imaging, Lincoln, NE, 402-310-4503
Award Number 0450540
February 1, 2005 - January 31, 2007
$493,692

This Small Business Innovation Research (SBIR) Phase II project proposes to use bioinformatics to transform complex data produced by comprehensive 2-D gas chromatography with mass spectrometry (GCxGC-MS) to usable chemical information. GCxGC-MS is an emerging technology for chemical separations that provides an order-of-magnitude increase in separation capacity over traditional GC. Results from Phase I demonstrated the feasibility of using bioinformatics to automatically identify chemical components in complex matrices analyzed by GCxGC-MS. Phase II will carry out further theoretical and experimental research to develop solutions that will enable broader use of GCxGC-MS system. The key project objectives include (a) developing a hybrid method that combines three approaches for chemical identification from GCxGC-MS data, (b) establishing the mathematical foundation and practical algorithms for co-elution analysis in GCxGC-MS, and (3) developing new

XML technologies for shared and distributed GCxGC-MS data, metadata, and information. The commercial impact of this project will be to develop information technologies for a new generation of analytical instruments. GCxGC-MS system is likely to capture a significant share of the existing gas chromatography market, currently in excess of $ 1 billion per year, and to open new markets in applications requiring superior separations, e.g., environmental monitoring of air, water, and soil; development and processing of foods, flavors, fragrances, and essential oils; processing of petroleum and industrial chemicals; health-care assays of blood, urine, milk, and breath samples; and analysis and discovery of drugs and medicinal herbs.

Chip-Scale Integrated Nanofluidics/Affinity Microcolumn Biosensors (NSF 2005 Standard Grant)
Steven Brueck (PI) brueck@chtm.unm.edu; Gabriel Lopez (Co-PI)
University of New Mexico, Albuquerque, 505-277-2256
Award Number 0515684
March 15, 2005 - February 28, 2006
$240,000

The amounts of chemical and biological warfare (CBW) agent sufficient to cause harm to humans are very small, requiring instruments of exceptional sensitivity for rapid identification. Widely dispersed, inexpensive sensors are required to monitor large areas for agents. The variety of possible agents is virtually unbounded. To meet the sensitivity and areal distribution requirements, a chip-scale technology is required that is sensitive to a variety of agent classes, requires only very small (picoliter) volumes, and implements integral preconcentration processes. The broad goal of this work is to establish the basic understanding and the technological methodologies necessary to implement high-density arrays of nanoscale channels as versatile, sensitive and selective components for chip-scale biodetection systems that will allow response to a wide variety of CBW agents. Nanofluidic separation and detection provide the picoliter sensitivity and smart, functionalized receptor bead microcolumns provide the preconcentration and selectivity. A key enabling technology that will emerge from this effort is the development of inexpensive, facile, and manufacturable means for creating integrated fluidic circuits that allow the transition from macroscopic fluid handling (e.g., pipettes) to nanoscale dimensions.

Continuously Operating Sensor for Detection of Nerve Agent Contamination in Aqueous Solutions (NSF 2004 SBIR Phase 2)
Markus Erbeldinger (PI) markus@agentase.com
Agentase LLC, Pittsburgh, PA, 412-209-7298
Award Number 0422090
August 1, 2004 - July 31, 2006
$487,768

This Small Business Innovation Research (SBIR) Phase II project is to develop a continuously operating water monitoring device for the detection of chemical warfare agents and hazardous chemicals. Prior Phase I work demonstrated the feasibility of this method and resulted in the construction of a bench-top model that could respond rapidly to contamination, was resistant to environmental and chemical interference, and could operate for extended periods of time without user intervention. In Phase II, this model will be modified into a small, self-contained, inexpensive prototype. Several optimized prototypes will be constructed for field trials under operational conditions. The commercial application of this project will be in the area of bioterrorism and homeland security.

Design of Advanced Sensing Materials (NSF 2004 Continuing Grant)
Jiri Janata (PI) jiri.janata@chemistry.gatech.edu; Miroslawa Josowicz (Co-PI)
Georgia Tech Research Corporation - GA Inst. of Technology, Atlanta, 404-385-0866
Award Number 0452045
March 1, 2005 - February 28, 2006
$145,629

Professors Jiri Janata and Miroslawa Josowicz of Georgia Tech University will work on chemically-sensitive field-effect transistors (CHEMFET). The idea is to tune organic semiconductors for optimization of their electron transfer properties for use as gas sensors and novel devices for information processing. The group has previously utilized chemical, electrochemical, and photochemical means to change the Fermi level of the solid, with most studies focusing on polyaniline. The group is now pursuing other properties needed in a sensor, e.g., long-term stability and fast response time of the selective layer. The use of additional secondary dopants is being explored, including ionic liquids. A magnetic quartz crystal microbalance (MQCM) is being developed to simultaneously monitor changes in magnetic spin density and the mass dopant uptake by the solid. Organic electronics is a new technological area that offers a wide range of applications not feasible with conventional silicon electronics; however, understanding and controlling the chemical environmental factors is critical for both solid-state sensors and organic electronics intended for signal and information processing. Additionally, new chemical sensors are required to detect ambient vapors. Inexpensive, long-lasting and easily manufactured gas sensors also are needed in the interest of national security.

Development of Multi-Functional Heat Pulse Probe for Ecological and Soil Hydrological Monitoring of Plant Root Zones (NSF 2004 Continuing Grant)
Jan Hopmans (PI) jwhopmans@ucdavis.edu; Benjamin Shaw (Co-PI); Gregory Pasternack (Co-PI)
University of California-Davis, OVCR/Sponsored Programs, Davis, CA, 530-752-2075
Award Number 0410055
September 15, 2004 - August 31, 2008
$797,403

The objective of this research is to further develop and test the multifunctional heat pulse probe (MF-HPP) method for simultaneous measurement of bulk soil thermal, water flow and solute transport properties, and to design, develop and test a robust MF-HPP with wireless data transmission capabilities for remote in situ field applications for application in plant root zones of both natural and agricultural ecosystems. The intellectual merit of the proposed MF-HPP lies in the combination of various innovative measurement techniques that combined will (1) resolve measurement uncertainty issues that result from soil heterogeneities, and (2) provide for an essential new field approach that will advance the basic understanding of the coupled flow and transport of flow, chemicals and nutrients, and heat in plant root zones. The broader impacts of the proposed HPP development are both educational as well as scientific. Through the already established infrastructure of REMOTE (Real-time Educational Monitoring Of The Environment) at UC Davis, application of telemetry for wireless data transmission will make in situ environmental data available in both numerical and graphical form. The proposed research will be interdisciplinary with national and international collaborations, already ongoing through collaborations of University of California scientists with the co-investigators in the U.S., Japan, and Australia.

Development of Nano-Based Passive Sensors for RF/Wireless Sensing Systems (NSF 2004 Standard Grant)
Anh-Vu Pham (PI) pham@ece.ucdavis.edu
University of California-Davis, OVCR/Sponsored Programs, 530-752-2075
Award Number 0401375
July 1, 2004 - June 30, 2007
$210,000

The PI is proposing to develop microwave vertically aligned carbon nanotube resonator sensor for remote and wireless detection of chemical agents. The sensor will consist of an electromagnetic resonator integrated with vertically aligned carbon nanotubes used as a chemical transducer. The carbon nanotube resonator sensor is a passive sensing device and requires no power consumption. Passive sensor and zero power consumption address the challenges in the development of wireless sensor networks that employ numerous sensor nodes. The contactless sensor is important in applications that prohibit the use of wiring. The microwave carbon nanotube resonator sensor exhibits changes in resonant frequency when exposed to gases. An antenna array will be designed and incorporated into the carbon nanotube resonator sensor to communicate with a remote wireless reading system. The PI will develop a remote wireless reading system to probe the sensor. The major tasks of this research are (1) development of microwave carbon nanotube resonator sensor to detect chemical agents, and (2) development of a wireless remote sensing system using microwave carbon nanotube resonator sensors up to 20 GHz. The sensor can be integrated on a printed circuit board for practical applications. The research will enhance the understanding of the interaction occurring between gas molecules, their environment, and microwave electromagnetic signals. The use of emerging carbon nanotube materials will open numerous possibilities for the development of sensors that can detect new toxic and biological agents.

Distributed Optical Fiber Sensor Using Computationally Designed Fluorescent Proteins (NSF 2004 SBIR Phase 1)
Shiou-Jyh Ja (PI) puck@nomadics.com
Nomadics Inc., Stillwater, OK, 405-372-9535
Award Number 0441765
January 1, 2005 - October 31, 2005
$100,000

This Small Business Innovation Research (SBIR) Phase I project proposes development of a distributed optical fiber sensor using computationally designed fluorescent proteins. Surface plasmon coupled emission (SPCE) has been shown to be an excellent means to enhance fluorescence sensing technology. With grating-assisted SPCE (GASPCE), the fluorescence emission can be coupled into optical fibers with great efficiency. The integration of the GASPCE and existing optical fiber networking technology, such as spectral/time domain multiplexing, provides a robust infrastructure to perform distributed real-time resource monitoring. The core sensing technology is based on computationally designed proteins (CDPs), proteins containing a ligand-specific engineered binding site and conjugated fluorophore. The proposed system will address urgent needs related to homeland security and national defense. Further, it will have numerous industrial and scientific applications. The proposed enhancements have applicability across a wide range of fluorescent detection methods. The low cost and adaptability of CDP approach promises the expansion of detection systems into areas that were previously impractical to address.

Exploratory Research: Evaluation of Porous-Silicon Sensors for Marine Science Applications (NSF 2005 Standard Grant)
Glenn Sasagawa (PI) sasagawa@spot.ucsd.edu; Miriam Kastner (Co-PI); Michael Sailor (Co-PI)
University of California-San Diego, Scripps Inst of Oceanography, La Jolla, CA, 858-534-1293
Award Number 0525080
May 1, 2005 - April 30, 2006
$60,315

The PIs propose to evaluate Porous Silicon (pSi) sensors for marine applications. pSi sensors will be fabricated and tested in a laboratory pressure cell to simulate ocean pressures and temperatures. Optical nanostructures can be precisely fabricated in pSi sensors; the presence of an analyte will produce readily detectable changes in the nanostructure's optical properties, such as the reflectivity spectrum. pSi sensors have been used on land to detect a number of chemical and biological signals, and have also been used in liquid solutions for biomedical applications. The PIs feel that pSi sensors could be developed for ocean science applications with the desirable qualities of inherent pressure tolerance, high sensitivity, small size, low power consumption, and low cost. For this test, the chemical target will be methane. There are significant unknowns concerning marine applications for pSi sensors, particularly biofouling and corrosion. The oceans will be a new and untested operating environment for pSi sensors. New ocean sensors would have immediate applications in environmental monitoring and industrial processes.

Functionalized Nanowire Chem/Bio SERS Optical Detectors (NSF 2003 SBIR Phase 1)
Youssef Habib (PI) joe.habib@illuminex.biz
Illuminex, Lancaster, PA, 603-585-9252
Award Number 0339668
January 1, 2004 - June 30, 2004
$100,000

This Small Business Innovation Research Phase I project seeks to develop a novel biological and chemical agent detection system that utilizes optical resonances in nanowires to probe pathogenic species on the molecular and submolecular levels. The project will study the detection of pesticides using functionalized gold nanowire substrates for surface enhanced Raman scattering (SERS) analysis. Arrays of high-aspect ratio nanowires will be engineered and functionalized to detect a target molecule. The project will combine the techniques of immunoassay, Raman spectroscopy, and nanoengineering, with the goal of developing a detector with unprecedented sensitivity. SERS is well a known and extremely accurate detection method that can be employed to identify single molecules, antigens, nucleic acid sequences and protein structure. The goal of the project is to develop enhanced nanowire

SERS substrates for integration into a multiple channel fiber-optic nanowire heterostructure optical detector with diode pumped lasers and a charge coupled device sensor to make a rugged, compact, portable, highly accurate, and field-ready biological or chemical agent sensor. The commercial application of this project will be in the detection of low-level quantities of pathogenic chemical or biological agents in the environment. It will be used for environmental monitoring, medical testing, and monitoring for release of biological weapons. The device is being designed to identify virtually any molecular or cellular species by its unique Raman signature.

A Green Fieldable Analyzer for Arsenic (NSF 2004 Standard Grant)
Purnendu Dasgupta (PI) sandyd@ttu.edu
Texas Tech University, Lubbock, 806-742-3884
Award Number 0456120
February 15, 2005 - January 31, 2008
$353,000

Professor Purnendu Dasgupta of Texas Tech University aims to develop a new environmentally friendly tool for the analysis of various arsenic species in groundwater samples and drinking water sources. Most fieldable arsenic detectors involve the use of the toxic chemicals lead and mercury. Further, most test kits are not suitable for analyzing arsenic below 10 microgram/L (the current acceptable level set by WHO), and the method developed in this work will improve this sensitivity. The instrument is based on sequential injection (for speciation), zone fluidics (for hydride generation), and gas phase chemiluminescence (for detection). The integrated arsenic analyzer includes concentration and separation of arsenic species with ion exchange cartridges, electrooxidation of As(III) to As(V), electroreduction of As(V) to arsine with an electrolytic arsine generator, membrane-based electrodialytic salt splitter, and enhanced ozone generation by electrical discharge and oxygen feed. It only requires the use of NaCl and electricity to enable analysis of arsenic at the sub-microgram/L levels. With a preliminary setup, the PI achieved detection limits of around 0.1 ppb using only a 2 mL sample. By adjusting acidity, he can distinguish between arsenic(III) and arsenic(V), and he can detect organic arsenic species. The method being developed here would be applicable to field work in the rural areas of India and Bangladesh.

A Hydro Optical Analysis System (HOPAS) for Environmental Monitoring of Water Quality (NSF 2003 SBIR Phase 2)
Francis O'Brien (PI) fjobrien@cox.net; Charles Atkinson (Former PI)
System Science Applications, Inc., Pacific Palisades, CA, 310-678-5081
Award Number 0349581
January 15, 2004 - December 31, 2005
$491,760

This Small Business Innovation Research (SBIR) Phase II research proposes to complete the development of an environmental information system, the Hydro-Optical Analysis System (HOPAS). HOPAS combines an advanced radiative transfer model with a powerful nonlinear programming algorithm to enable transforms of optical water measurements into information on the composition and concentration of materials that effect water quality. For the first time, measurements of the light field from satellites, aircraft, moorings, and ships can be rapidly inverted to obtain accurate estimates of phytoplankton, suspended mineral particles, and dissolved materials. HOPAS will enable scientists, environmental engineers, and aquatic resource managers to use easily obtained in situ or remotely sensed optical data to understand and manage aquatic ecosystems. HOPAS will alleviate the need for expensive, labor-intensive laboratory analysis of water samples for use in addressing water quality issues, including microbial growth in drinking water supplies, surface pollutants from farms, industries, vessels, and domestic sources, algal blooms, fisheries and mariculture, and protection of coral reefs and sea grass beds.

Integrated Transduction, Actuation, and Control for Cell-Based Sensing (NSF 2005 Standard Grant)
Pamela Abshire (PI) pabshire@isr.umd.edu; Elisabeth Smela (Co-PI); Benjamin Shapiro (Co-PI)
University of Maryland, College Park, 301-405-6269
Award Number 0515873
March 15, 2005 - February 28, 2006
$311,315

The goal is to develop and demonstrate enabling technology for cell-based sensing. Cell clinics are microenvironments that enable the capture and characterization of cells. Each "clinic" is a micro-electro-mechanical system fabricated on a CMOS chip. Biological systems have high specificity, sensitivity, and adaptability that can be part of a highly integrated sensor. The first goals are sample preparation, cell loading, and system miniaturization using the tools of feedback control, integrated circuits, and microfluidics. Results will leveraged into two ongoing efforts in olfactory sensing and low-false-positive pathogen detection. Three aspects of the system will be demonstrated. (1) Electroosmotic flow control will remove all optically visible (>5 micron) particles from the sample. This will remove dirt, dust, and bacteria and leave behind odorants for presentation to the olfactory cell sensors. This system shall be capable of sufficiently high throughput to be used in real time. (2) Dielectrophoretic actuation for steering cells in three-dimensions will be used to position cells in the plane and to direct them into the cell clinic vials. (3) To develop field utility cell-based sensors, a vision system with the same dimensions as cell clinics for cell steering will be developed. The proposed technological advances will allow cell-based sensing to move toward actual implementation and use with real samples. Cell-based sensing has the potential for selectivity, sensitivity, and speed that far exceed today's chemical and biological sensors. Problems of olfactory sensing and pathogen detection are of immediate relevance to national security. This technology has clear applications in other diverse fields such as health care, pharmaceutical development, and environmental monitoring.

Joint Stochastic Non-Linear Inversion of Hydrogeophysical Data for Improved Vadose Zone Characterization and Monitoring (NSF 2004 Continuing Grant)
Yoram Rubin (PI) rubin@ce.berkeley.edu
University of California-Berkeley, 510-642-6000
Award Number 0439649
January 15, 2005 - December 31, 2005
$90,000

Several promising techniques have been proposed recently for providing more detailed, high-resolution imaging capabilities in the vadose zone, and additional investigation is needed to better understand their strength and limitations. The objective of the proposed research is to develop a stochastic inversion procedure that will allow addressing these challenges. We shall focus on the combined use of crosshole radar (GPR) and hydrogeologic data such as soil moisture and pressure head, obtained from boreholes, to provide high-resolution imaging of soil moisture dynamics, and subsequently for inverse modeling. Our hypothesis is that an inversion framework that is based on simultaneous inversion of geophysical and hydrological measurements and on non-linear modeling of the flow processes and of the geophysical surveys, improves our ability to characterize the vadose zone. The inversion of the geophysical and hydrogeological data will be carried out simultaneously using non-linear mathematical models of the flow and geophysical processes to relate between target parameters (lithology, permeability, other soil's parameters needed for modeling of the relative conductivity and water retentivity), and input data. A stochastic approach will allow rational treatment of the uncertainty due to spatial variability, data scarcity, and measurement error. A Bayesian formulation will allow combining prior information with site-specific measurements. Entropy-based methods (MRE: minimum Relative entropy) will be employed for determining prior probability distributions of parameters from constraints based on prior/extraneous information, with minimum subjectivity. Fuzzy neural networks will be used to develop petrophysical models. The proposed approach will be tested using a digital analogue-based synthetic model, and data from a field experiment carried out at DOE's Hanford site. The synthetic study will test our ability to identify the soil's hydraulic parameters away from wells, and the Hanford study will assess our capability to improve predictive capabilities.

Low Cost Sensitive Magnetometer for Remote Sensing (NSF 2003 SBIR Phase 1)
Saeid Ghamaty (PI) saeid@technologist.com
MS Technology, LaJolla, CA, 619-558-6293
Award Number 0338398
January 1, 2004 - June 30, 2004
$100,000

This Small Business Innovation Research Phase I project proposes to develop a new type of low-cost, low-power, small, fast magnetometer that could attain a sensitivity of approximately 1 femto Tesla (10-15 T) per root hertz. Magnetometers with such sensitivity could easily be used for remote sensing by measuring and locating the source of magnetic fields. These fields are typically one billion times smaller than the earth's magnetic field. This new magnetometer could be in a small (SO8, about 5x4x2mm3), low-power instrument package operating at ambient temperature. Such sensitivity currently requires costly superconducting quantum interference device (SQUID) that needs expensive and cumbersome cryogenics to operate. In Phase I, MST hopes to quantify the performance gains possible from this new magnetometer and its measurement of magnetic field and noise in operational contexts for remote sensing. The development of low-cost, high-performance, modular, miniature magnetometer delivery systems will expand the commercial markets for home and industrial security systems, industrial process monitoring systems, and environmental monitoring systems. The magnetometer would also augment the capability to detect land and naval mines. Commercial uses include prospecting for mineral deposits.

Measuring and Modeling Metal Adsorption in Bacteria-Water-Rock Systems (NSF 2002 Standard Grant)
Jeremy B. Fein (PI), fein.1@nd.edu, 219-631-7432, Bruce A. Bunker (Co-PI), & Charles F. Kulpa (Co-PI)
Univ. of Notre Dame, Notre Dame, IN
NSF Award Number 0207169
September 1, 2002 - August 31, 2004
$130,000

The proposed research program will use x-ray absorption spectroscopy (XAS) of natural and laboratory-generated samples to determine the importance of metal-bacteria adsorption in affecting the distribution of metal in bacteria/water/rock systems. The overall objective of the research is to test whether surface complexation modeling can account for the observed metal distributions under a range of conditions and complexities. Quantifying the effects of bacteria on adsorption reactions in water/rock systems has direct applications not only to contaminant transport modeling, but also to bioremediation engineering and to the understanding of bacterial pathogen mobility. The proposed research will ultimately lead to more accurate predictions of the mobility of aqueous metals in contaminated groundwater systems. The proposed research will deliver three things: 1) an understanding, provided by both XAS and bulk adsorption measurements, of whether bacterial surface adsorption of aqueous metal cations plays an important role in metal speciation in bacteria-bearing water-rock systems; 2) a rigorous testing of whether surface complexation modeling can account for the metal distribution in those systems; and 3) a test of whether natural populations of bacteria exhibit identical metal adsorption properties. The experimental results from this research not only will further the understanding of metal-bacteria interactions, but also will significantly improve the ability to accurately model the effects of bacterial adsorption on the fate and mobility of heavy metals in realistic geologic systems.

Miniature Mass Spectrometer for Liquids Analysis (NSF 2004 SBIR Phase 2)
John Grossenbacher (PI) grossenbacher@griffinanalytical.com
Griffin Analytical Technologies, Inc., West Lafayette, IN, 765-775-1701
Award Number 0450512
February 15, 2005 - January 31, 2007
$458,475

This Small Business Innovation Research (SBIR) Phase II project aims to develop novel instrumentation based on electrospray ionization (ESI) coupled with mass spectrometry for identifying and quantifying chemical species in liquid-phase samples in the field. The goal of this project is to employ an existing Minotaur miniature mass spectrometer (MS) to develop a portable, easy-to-operate detector that will provide real-time and highly sensitive detection of a broad range of chemical compounds in liquid samples in the field. The objectives of the research are to construct, integrate, and optimize an innovative miniature ESI source into the instrument to receive liquid samples and introduce the target analytes to the detector, while minimizing interference from background matrix constituents, and to fully develop and qualify the analytical characteristics and ease-of-use of the instrument during field operations. This development of the first field portable, miniaturized ESI-mass spectrometer will have applications in several governmental and commercial sectors, and has the potential to impact society broadly by providing improved monitoring of water resources and protection of the public from chemical exposure resulting from hazardous material accidents or acts of terrorism. If successful, this research will lead directly to developments allowing for determination of compounds of biological origin, e.g. biomarkers, which will provide additional dimensions of information as to the content of analytical samples.

Miniaturized Chemical Sensors Featuring Electrical Breakdown near Carbon Nanotube Tips: NIRT (NSF 2004 Standard Grant)
Nikhil Koratkar (PI) koratn@rpi.edu; Steven Cramer (Co-PI); Pulickel Ajayan (Co-PI); Saroj Nayak (Co-PI); Theodorian Borca-Tasciuc (Co-PI)
Rensselaer Polytechnic Institute, Troy, NY, 518-276-6000
Award Number 0403789
September 1, 2004 - August 31, 2008
$1,300,000

This nanoscale interdisciplinary research proposal focuses on developing a novel carbon nanotube ionization chemical sensor for emergency rescue crews and first responders that will enable on-site monitoring. The proposed sensor is light-weight, compact, robust, affordable, consumes low power (battery operated), and can provide definitive identification of contaminants in real-time mode with fast response. The idea for sensing takes advantage of the extremely high electric fields that are generated near nanotube tips as a means of inducing ionization and electrical breakdown of the gas at low voltages. By monitoring the breakdown voltage, the gas can be identified (every gas has a characteristic breakdown behavior) and by monitoring the discharge current, the gas concentration can be determined. We will perform a series of experiments with individual nanotubes as well as ensembles of tubes (electrode arrays) to gain a fundamental understanding of the basic mechanisms for ionization and breakdown of gas species and mixtures near nanotube electrodes. The experiments will be supported by density functional theory predictions for gas ionization near sharp nanotube tips. Based on the understanding gained from this study, we will assemble integrated devices to detect trace amounts of analytes in mixtures and then quantify the sensitivity, selectivity, and sensor power consumption.
On-site chemical sensing is critical to environmental monitoring, control of chemical processes, space missions, and agricultural and medical applications.

Noninvasive Imaging of Near-Surface Preferential Flow Pathways and Dynamics in Carbonate Vadose Zone (NSF 2004 Continuing Grant)
Mark Grasmueck (PI), mgrasmueck@rsmas.miami.edu; Sarah Kruse (Co-PI); Dani Or (Co-PI); Frederick Day-Lewis (Co-PI)
University of Miami, Key Biscayne, FL; 305-361-4800
NSF Award Number 0440322
April 15, 2005 - March 31, 2006 (Estimated)
$131,714

Field methods are needed to accurately describe flow and transport in the vadose zone to bridge the observational gap in scales from centimeters to meters and provide a 3-D picture of flow processes. Objectives: (1) To characterize and quantify vadose zone flow and transport in the Miami carbonate environment at scales from centimeter to meters; and (2) to develop and disseminate 4-D Ground Penetrating Radar (GPR) methodology and workflow for application in other vadose zone environments. A hydrological framework will be assembled by combining repeated high resolution 3-D

GPR surveys with borehole logging and direct sampling. A three-stage approach will be implemented in each study site: The first stage focuses on identifying key factors, particularly the role of water, influencing GPR reflections, using both laboratory measurements and synthetic GPR modeling. The second stage entails repeated 3-D GPR surveys of field sites to quantify hydraulic parameters based on dynamic changes of water content caused by natural rainfall and controlled injection. The third stage involves inverse flow modeling with field data to estimate 3D hydraulic conductivity volumes. The proposed research advances knowledge of vadose zone flow pathways and dynamics in carbonates at the field scale. Availability of a uniquely efficient 3-D GPR system, combined with the proximity of field sites allows for rapid and efficient data collection and facilitates involvement of both undergraduate and graduate students in this research. The resulting 3-D hydrological data will be available in unprecedented detail and at unique bridging scales. Data sharing and technology transfer efforts will help the near-surface community examine other vadose zones for improved understanding of groundwater recharge, contaminant migration, carbonate diagenesis and chemical / microbiological processes.

Novel Sensor Platforms Based on the Structural Integration of an Organic Light-Emitting Device, a Luminescent Sensing Element, and a Thin Film Si-Based Photodetector: SST (NSF 2004 Standard Grant)
Joseph Shinar (PI) shinar@ameslab.gov; Vikram Dalal (Co-PI); Ruth Shinar (Co-PI); Louisa Tabatabai (Co-PI)
Iowa State University, Ames, 515-294-5225
Award Number 0428220
October 1, 2004 - September 30, 2007
$400,000

The objective of this proposal is to develop novel photoluminescence (PL)-based sensors that are fully structurally integrated, i.e., the light source, the sensing element, and the photodetector (PD) and associated filter are fabricated on transparent substrates and attached back-to-back. The resulting sensors could therefore be extremely compact, robust, selective, fast, autonomous, low-power, and inexpensive. The proposal focuses on sensing oxygen, a key tool in medical, environmental, biochemical, and food monitoring, and *Bacillus anthracis* toxin (anthrax). The sensors for these two agents will be ideal for a broad range of applications in areas such as homeland security, medical, environmental, biological, food/brewing, and health/safety. Beyond these impacts, the devices define a new sensor platform for chemical and biological agents, which could lead to extremely compact and inexpensive multianalyte sensor microarrays. The proposed work will serve as a basis for the development of this platform. It will also expand the basic knowledge in embedding and/or immobilizing recognition elements, sensor design, and sensor engineering.

Permeability Measurements from Routine On-the-Fly CPT Sounding: Validation Against High-Quality Vis-CPT and In Situ Permeability Measurements (NSF 2004 Standard Grant)
Derek Elsworth (PI) elsworth@psu.edu
Pennsylvania State Univ., University Park, 814-865-4700
Award Number 0409002
July 15, 2004 - June 30, 2006
$210,000

Cone penetrometer testing (CPT) is a valuable tool for the rapid and continuous profiling of strength, deformability, density, stress-state, and cyclic mobility of soils. This project will evaluate the potential to determine in situ permeability profiles directly from routinely measured cone sounding metrics recorded on the fly. Prospective correlations between in situ field-scale permeabilities and penetration-induced pore pressures, cone end-bearing, and sleeve-friction will be developed and verified against high-quality field data, to be gathered in this study. The researchers will fabricate in situ cone-deployable permeameters that examine the effects of penetrometer-induced disturbance on measured permeability magnitudes. Deploy these permeameters concurrently with the visual-CPT to gather unique ensemble data that link CPT sounding metrics with co-located measured permeabilities and visually observed fine-scale soil texture. Measure permeability magnitudes at unusually high spatial resolution and correlate these with direct visual observations of soil texture derived from the visual-CPT. Apply the ensemble data to establish correlations between on-the-fly CPT sounding metrics and permeabilities. Develop and refine models for mechanical and fluid transport behavior in the tip process zone that honor observed data in situ and explain observed correlations. CPT soundings co-located with independent in situ measurements of permeability are meager. This study will add to these data, apply unusual constraint to permeability measurements through incremental permeability testing and visual identification of soil texture via the visual-CPT, and develop and explore CPT-permeability correlations through the directed use of model development and dimensional analysis. These ensemble techniques will provide an important tool to determine rates of migration of free-phase and aqueous contaminants in unconsolidated porous media at spatial scales of relevance.

Photonic Crystal Fibers with Nanoscale Functionalized Air Holes as Robust Chemical and Biological Sensors: NIRT (NSF 2004 Standard Grant)
Henry Du (PI) hdu@stevens.edu; Hong-Liang Cui (Co-PI); Svetlana Sukhishvili (Co-PI); Christos Christodoulatos (Co-PI); Ryan Bise (Co-PI)
Stevens Institute of Technology, Office of Sponsored Research, Hoboken, NJ, 201-216-5000
Award Number 0404002
August 1, 2004 - July 31, 2008
$1,300,000

The array of axially aligned air holes and the resultant optical characteristics in silica photonic crystal fibers (PCFs) present an enormous opportunity to develop sensors with detection sensitivity not achievable by conventional optical fiber technology. This nanoscale interdisciplinary research (NIRT) project aims to explore the frontier of hollow- and solid-core PCFs with nanoscale-functionalized air holes for chemical and biological sensing. PCFs will be fabricated via a modified sol-gel method for optical fibers. Nanoscale surface functionalization will be conducted following two strategies: (1) surface attachment of Ag nanoparticles mediated by self-assembled monolayers for chemical sensing, where surface-enhanced Raman scattering can be exploited and (2) surface binding of biospecific recognition entities for biological sensing. Surface functionalization studies will employ various surface-sensitive analytical tools. Sensing measurements will make use of a range of state-of-the-art laser techniques. Experimental studies will be augmented by computer simulation, taking into account of the effects of surface functionalization, analyte medium, and biospecific interactions on the optical characteristics of PCFs. This project represents the first known endeavor to integrate PCFs with nanotechnology for potentially robust chemical and biological sensing. Success of the project will enhance the prospects of nanoscale-functionalized PCF sensors, sensor arrays, and sensor networks for diverse applications such as remote and dynamic environmental monitoring, manufacturing process safety, medical diagnosis, early warning of biological and chemical warfare, and homeland defense.

Photonic Microcantilever Arrays for Chemical and Biological Sensing: SIRG (NSF 2004 Standard Grant)

Gregory Nordin (PI) nordin@ece.uah.edu; Michael George (Co-PI); Joseph Ng (Co-PI)
University of Alabama, Huntsville, 256-824-6120
Award Number 0428289
January 1, 2005 - December 31, 2009
$1,575,000

Microcantilevers that are properly functionalized with chemo- or bioselective coatings have been shown to be extremely sensitive to chemical and biological analytes in both vapor and liquid media. Microcantilevers therefore exhibit great promise as molecular and atomic recognition sensors for an extremely diverse set of applications including environmental monitoring, industrial process control, biological research, and homeland defense. Microcantilever operation is characterized by chemical reaction or adsorption of molecular species at the microcantilever surface which results in a change in the microcantelever's deflection and in properties such as its resonance frequency. While these induced changes can be very small (sub-nanometer cantilever deflection, for example), they are readily measurable with a laser beam reflection technique developed for atomic force microscope (AFM) cantilever measurements. To realize the full promise of microcantilever sensor technology, arrays of individually functionalized microcantilevers are required to enable the simultaneous detection of multiple target molecules while rejecting interference from other chemical species in the environment as well as stochastic noise such as thermal fluctuations. A critical problem is that current cantilever measurement methods do not lend themselves to practical implementation for large numbers of cantilevers that are suitable for high sensitivity operation in both vapor and liquid ambients. This proposal focuses on a solution to this problem based on waveguide cantilevers combined with a receiver waveguide splitter structure that enables differential detection of cantilever deflection. Combining these elements with recently invented compact waveguide components and with grating couplers to enable fiber coupling to off-chip detectors and an off-chip optical source permits the realization of a small microcantilever-based sensor with interchangeable or disposable microcantilever array chips. Compatibility of the waveguide structures with batch microfabrication techniques suggests that such arrays can be produced very inexpensively.

Plant Bioreporters for Arsenic (NSF 2004 STTR Phase 1)
Mark Elless (PI) elless@edenspace.com
Edenspace Systems Corporation, Dulles, VA, 703-961-8700
Award Number 0419742
July 1, 2004 - June 30, 2005
$100,000

This Small Business Technology Transfer Research Phase I project is to develop genetically-modified tobacco and fern plants to sense bioavailable arsenic, a human carcinogen, that is widely dispersed in the environment. The commercial application of this project will be to assist in detection and cleanup of environmental contaminants.

Plasmonic Nanostructured Devices for Chemical and Biological Sensing: NIRT (NSF 2004 Standard Grant)
Hong Koo Kim (PI) kim@ee.pitt.edu; Hrvoje Petek (Co-PI); Rob Coalson (Co-PI); David Waldeck (Co-PI); Gilbert Walker (Co-PI)
University of Pittsburgh, Pittsburgh, PA, 412-624-7400
Award Number 0403865
August 1, 2004 - July 31, 2008
$1,374,999

This nanoscale interdisciplinary research (NIRT) proposal focuses on investigating the fundamentals of plasmon phenomena in nanoscale metallic structures and exploring the use of plasmonic chip technologies in biochemical sensing. Metallic nanoaperture arrays will be investigated as a base structure to provide wavelength-dependent transmission of light with strong confinement (with lateral dimension much smaller than wavelength of light). We will chemically modify the nanoaperture surface with receptors for chemical and biological analytes. Analyte adsorption is expected to alter the local dielectric properties at metal surface and thus the optical transmission via a change in the near-field coupling in the aperture region. We propose mechanisms for analyte detection that exploit both the dispersive part of the analytes optical response and its absorptive (loss) part. This program is expected to lead to the development of an unprecedented (high-throughput and ultracompact) sensor technology, and will make major contributions to various areas that involve detecting and monitoring biochemical agents, such as health care, environment, and homeland security.

Portable SI-HPLC Analyzer (NSF 2003 SBIR Phase 1)
Louis Scampavia (PI) louis@flowinjection.com
FIAsolutions, Bellevue, WA, 425-376-0450
Award Number 0340181
January 1, 2004 - June 30, 2004
$100,000

This Small Business Innovation Research (SBIR) Phase I project proposes the development of a portable and fully automated chromatographic based analyzer. This analyzer will integrate several proven technologies to produce an automated instrument that is compact, robust and easily implemented for on-line, at-site, or field-ready use, especially where complex HPLC (high performance liquid chromatography) analyses are needed. Based on sequential injection (SI) protocol and HPLC instrumentation, this instrument will be full automated and provide an integrated approach with respect to sample collection, pretreatment, chemical modification, separation, and detection of target analytes. This chemical analyzer will exploit several novel technologies including sequential injection, portable high-pressure syringe pumps, and sol-gel HPLC columns in its development of this hybrid analyzer, referred to as Sequential Injection for High performance Liquid Chromatography (SI-HPLC). Although HPLC is a fundamental fixture in many laboratories, it remains largely a bench-top instrument due to its overall large size, high power consumption and need for manual sample retreatment/preparation prior to analysis. By integrating several evolving technologies, HPLC analysis can be fully automated and conducted at much lower pressures, which will also make this analyzer very compact and truly portable, as well as energy efficient. The proposed SI-HPLC instrument will find applications at on-line process control, environmental monitoring (e.g., field monitoring of pesticide or leachate contamination of water sources), or as a multipurpose field-ready analyzer for medical, law-enforcement, or military use. The SI-HPLC instrument will be a low cost, portable system that is highly adaptable to different applications since it will rely on an open architecture made possible by software programmability.

Sensor Technology Enabling Large Array Based Sensors (NSF 2004 SBIR Phase 2)
Rattaya Yalamanchili (PI) chow@lynntech.com
Lynntech, Inc., College Station, TX, 979-693-0017
Award Number 0450583
June 1, 2005 - May 31, 2007
$480,705

This research project involves an innovative gas sensor (DiskFET) based on a commercially available hard drive mechanism, proprietary polymers for sensing, and a modified field effect transistor (FET). The device as envisioned is small, handheld, lightweight, low power, and applicable to a diverse range of chemical sensing fields. The DiskFET operates by applying an electric field between a polymer coated rotating disk and stationary FET, which is "floating" a fixed distance above the disk surface. The field strength will be affected by the interactions of the analyte with the polymer coating on the disk. This change in field strength is measured by the FET. By combining the signal responses of all of these relatively non-specific sensors, a "fingerprint" for the analyte is constructed. Using Artificial Neural Network analysis, the concentration and identity of the analyte can be recognized based on a database of the sensor response characteristics for the detection of ammonia and VOCs with detection limits below current OSHA-accepted levels.

Sensors: High Selectivity Gas Sensing by Photostimulation of Semiconducting Metal Oxides (NSF 2004 Standard Grant)
Harry Tuller (PI) tuller@mit.edu
Massachusetts Institute of Technology, Cambridge, 617-253-1000
Award Number 0428696
September 1, 2004 - August 31, 2007
$250,000

The ability to sense an ever larger number of chemical species is essential for safeguarding the environment, protecting workers against toxic industrial chemicals, securing our nation against chemical weapons, and monitoring indoor air quality. Semiconducting metal oxide gas sensors (MOGSs), while exhibiting high sensitivity to different vapor species and simple construction suffer from relatively limited selectivity inhibiting wider use. Unlike polymers, MOGSs require heating to above 200 degrees C to insure sufficiently rapid kinetics, thereby increasing complexity and power demands. In this research program, we explore a novel approach for activating sensitivity and tuning selectivity of MOGSs by using monochromatic light to promote charge-transfer interactions between the sensor and adsorbed gas molecules thereby eliminating the need for thermal excitation. We will examine the sensitivity and selectivity of illuminated n-type SrTiO3 thin films, prepared by PLD with controlled orientation and microstructure, to a number of reducing and oxidizing gases. DC and AC impedance and photo-current spectroscopy measurements will be performed in situ in a unique microprobe system for achieving an improved understanding of the sensing mechanisms. Small arrays of MOGSs with integrated LEDs will be assembled to demonstrate the ability to monitor a number of gases with high selectivity at room temperature. Success along these lines would serve as a major breakthrough in the field of solid-state gas sensors and would create possibilities for the selective detection of numerous additional gases, improve device stability and lifetime, and contribute to an improved fundamental understanding of the gas sensing phenomenon.

Sensors: Narrow Band, Broad Band and Low Pass Metal Mesh Filters for Sensors in the IR to THz Region and Instant Multiple Wavelength Detection of Chemical Agents (NSF 2005 Standard Grant)
Haim Grebel (PI) grebel@njit.edu; Karl Moeller (Co-PI)
Foundation @ NJIT, New Jersey Inst. of Technology, University Heights, Newark, 973-596-5275
Award Number 0514361
June 1, 2005 - May 31, 2006
$133,397

This research program will develop new concepts for producing infrared filters for sensors based on integrated circuit microstructure technology. These components will be used in infrared through millimeter wave applications for remote sensing instruments in astrophysics, planetary, and space science. Infrared filters play an integral role on every infrared sensor, ground-based or portable, airborne and/or space mission, yet are currently a weak link in the U.S. infrared technology infrastructure. The group uses state-of-the-art modeling and fabrication to undertake the development. The plan is to develop and test filters for operation of all types of spectral sensors applied to a broad range of monitoring and detection systems from the visible to the THz region. This interdisciplinary proposal is combines fundamentals of wave propagation with applications to 3-D periodic hybrid structures to produce a robust technology that serves a wide rating of sensor needs. The study will enable novel 3-D design of spectral filters, splitters and combiners and novel imaging devices.

Sensors: Perfluorinated Matrixes as New Materials for Receptor-Doped Chemical Sensors with Extreme Robustness and Selectivity (NSF 2004 Standard Grant)
Philippe Buhlmann (PI) buhlmann@chem.umn.edu
University of Minnesota-Twin Cities, Minneapolis, 612-624-5599
Award Number 0428046
September 1, 2004 - August 31, 2007
$367,172

This project focuses on new materials for receptor-based ion-selective electrodes (ISEs) for analysis in clinical laboratories, process control, the food industry, and environmental applications. Commercial ISEs have shortcomings in terms of selectivity, detection limits, and robustness. The research program addresses these challenges by introducing new matrix materials based on fluoropolymers. These materials are hypothesized to improve biofouling resistance as well as selectivity of the electrodes. A key goal of the research is to prevent the extraction of electrically neutral lipophilic compounds into sensor membranes and to take advantage of the increased selectivity related to minimizing solvation of interfering ions in the sensor membrane. Synthesis of new perfluorocarbon sensor membranes and characterization of their properties will be performed. The perfluorinated materials are hypothesized to be promising for sensor applications because they are chemically inert, have been shown to resist cell growth, are highly insoluble in compounds that are lipophilic, and may exhibit higher selectivity than sensors based on other materials. In terms of the broader impacts, undergraduates will be actively recruited for the project. This work could lead to a new generation very highly selective sensors, which could be used to diagnose and treat disease, assess environmental problems, and, in general, monitor processes throughout the food processing chemical, petrochemical, pharmaceutical, and biotechnology industries.

SGER: Developing Metal-Tagged DNA Probes for High Resolution Imaging of Microbial Phylotype Distributions and Nanoscale Mineral/Microbe Associations in Environmental Samples (NSF 2004 Standard Grant)
Rachel Haymon (PI) haymon@geol.ucsb.edu; Patricia Holden (Co-PI)
University of California-Santa Barbara, 805-893-4188
Award Number 0406999
August 1, 2004 - July 31, 2005
$85,131

High-resolution electron microscope (EM) images greatly magnify microbes and their micro-habitats, and reveal minute features of microbial cells and their material surroundings. EM images potentially are of great use in studying how microbes interact with natural and man-made materials. The many types of microorganisms co-existing in natural samples typically cannot be distinguished from one another based on appearance alone. A means of visually distinguishing specific genetic types of microbes in EM images must be invented to fully exploit the potential of electron microscopy for learning about in situ microbial distribution and activity in the environment. A grant has been awarded to Profs. Rachel M. Haymon and Patricia Holden, University of California, Santa Barbara, and Dr. Stefan Sievert, Woods Hole Oceanographic Institution, for development of metallic "tags" that will attach to DNA sequences of selected microbes. When the metals are excited by electron beams used to generate EM images, the metals will emit X-rays and permit unambiguous visual identification of the targeted organisms at both high and low magnifications. This method will solve the existing problems in distinguishing spatial distributions and identities of microbes imaged with electron beams, and will make it possible to understand associations of microbes and minerals at small scales that are relevant to microbial life. The investigators hope to apply this new technique to studies of microbes in soils, where microbes are important to biodegradation of toxic anthropogenic compounds, and in hydrothermal systems, where microbes interact with geologic materials under extreme thermal and chemical conditions.

Toxic Mold Sniffer (NSF 2004 SBIR Phase 1)
Debra Mlsna (PI) tdhmlsna@adelphia.net
Seacoast Science, Inc., Carlsbad, CA, 760-268-0083
Award Number 0441499
January 1, 2005 - June 30, 2005
$99,040

This Small Business Innovation Research (SBIR) Phase I project will develop a MEMS sensor array for use in a small, battery-operated system to detect chemicals commonly produced by toxic molds. Most mold related health problems result from exposure to Stachybotrys, a fungus, which causes "sick building syndrome." The Stachybotrys mycotoxin is a trichothecene, a stable, multicyclic epoxide, which readily crosses cell membranes, attacking ribosomes and inhibiting protein synthesis. This sensor will utilize an array of surface micromachined capacitors coated with chemoselective polymeric materials that will be optimized for tricothecenes and similar analogs containing epoxides and multicyclic organics. The commercial application of this project will be to detect toxic molds that cause human health problems. Toxic mold is a $1 billion problem in this country. Growing awareness and concern about the health impact from fungal toxins has made the detection and isolation of suspect molds a major environmental concern. When combined with inexpensive wireless communications technology, these sensors will be ideal for monitoring a variety of chemical and physical targets in a distributed system where a premium is placed on early detection. Minor modifications to the detector would allow for development of products for other applications, such as monitoring of air pollution around factories, and of oil degradation in power transformers and fuel cells.

Ultra-Fast Broadband Imaging Spectroscopy for Geosciences Applications (NSF 2004 SBIR Phase 2)
Qiushui Chen (PI) qchen@bostonati.com
Boston Applied Technologies, Inc., Woburn, MA, 781-935-2800
Award Number 0422094
August 15, 2004 - July 31, 2006
$400,732

This Small Business Research (SBIR) Phase II project aims to capitalize on Phase I success of ultra-fast tunable optical filter technology for the applications of hyperspectral imaging, environmental monitoring, and optical communication. During Phase I, the feasibility of ultra-fast tunable filters based on electro-optical effect was demonstrated through prototyping. State-of-the-art filter characteristics have been achieved, including ultra-fast response (< 500 ns), wide tuning range (> 80nm at 1550nm), narrow line width (< 0.1nm), and broad working spectral band (from visible to middle infrared continuously). The major effort of Phase II will be to develop an advanced tunable filter platform. Several commercial products are expected to emerge, e.g., ultra-fast hyperspectral imaging systems suitable for geosciences and medical diagnostics, high frequency wavelength modulators for high-sensitivity spectroscopic detection of trace gas, and wide-range fast-tuning optical filters for spectroscopy and wavelength-division-multiplexing (WDM) optical communication. The proposed components and system, featuring light weight, fast action, broad wavelength band, and low cost, is needed for airborne hyperspectral imagery. The tunable add/drop promises to reduce network complexity and cost by eliminating expensive optical-electrical-optical conversion and reducing the inventory of fixed-wavelength devices. A fast wavelength modulation, combined with synchronized detection, can form a very sensitive spectroscopic analytic instrument for trace-gas sensing. These gases usually have characteristic absorption lines in infrared (IR) band, where no other fast tunable filter exists. There is a growing demand for chemical and environmental monitoring.

U.S.-Egypt Cooperative Research: Novel Highly Durable Sensors (NSF 2004 Standard Grant)
Eric Bakker (PI) eric.bakker@mail.auburn.edu
Auburn University, Auburn, AL, 334-844-4438
Award Number 0418004
September 1, 2004 - August 31, 2006
$30,000

This award is to support a cooperative research between Dr. Eric Bakker, Department of Chemistry, Auburn University, and Dr. Mohammed Abbas, Department of Applied Chemistry, National Research Center, Cairo. They plan to explore the covalent immobilization of active sensing reagents for the detection of anions, especially porphyrins, phthalocyanines, metallophthalocyanines, and their derivatives, onto a variety of polymeric materials used for the fabrication of electrochemical and optical sensors. Target polymers include acrylates and methacrylates as well as polypyrrole, polyaniline or polythiophene. The covalent attachment of active sensing ingredients will allow fabrication of ultraminiaturized, yet durable sensing systems where the leaching of active components is no longer limiting the lifetime of these devices. In recent years, ion-selective electrodes have experienced a paradigm shift by the discovery that they may reach extremely low detection limits, often in the low parts-per-trillion concentration range of total ion concentration measured. Research in improving the materials chemistry aspects is required for better chemical control of ion diffusion properties and the minimization of component leaching into the contacting aqueous solution. This research lays the groundwork for numerous current directions in the field of ion-selective electrodes and miniature optical sensors. The covalent attachment of active sensing ingredients will transform both fields from using traditionally doped systems to all-polymeric materials with unique properties. Ultraminiaturized sensing systems based on this technology will only be truly practically useful if this transition can be accomplished.

U.S.-India Cooperative Research: Development of Metal Oxide Silicon/ Porous Silicon MEMS Sensor and Signal Processing Unit for Atmospheric Monitoring in Underground Coalmines (NSF 2004 Standard Grant)
Prasanta Ghosh (PI) pkghosh@syr.edu
Syracuse University, Syracuse, NY, 315-443-2807
Award Number 0422782
August 15, 2004 - July 31, 2007
$10,905

This U.S.-India cooperative research is an exploratory study to address the limitations of existing mine gas sensors that will be conducted through a series of exchange visits between Professors Prasanta Ghosh of Syracuse University and Hiranmay Saha of Japavpur University, Kolkata, India. The PIs will collaborate in developing devices with the deposition of zinc oxide for sensing the desired toxic gases in underground coalmines. Additionally, they will detect the level of the gas and process the signal suitably for onward transmission to the control room located at the surface. The collaborators will employ the complementary strengths of Professor Ghosh in the area of thin film deposition and development of OTA based circuits with that of Professor Saha in the field of Porous Silicon and Silicon/Porous Silicon based MEMS Sensors. They expect their research to lead to the development of relatively cheap and reliable atmospheric monitoring systems suitable for underground coal mines. It will also enrich fundamental knowledge in the field of MEMS and will lead to the development of integrated silicon microsensors for gas and pressure sensing.

Ultrasensitive, Real-Time Explosives Sensor (NSF 2003 SBIR Phase 1)
James Scherer (PI) jjscherer@novawavetech.com
NovaWave Technologies, Redwood City, CA, 650-610-0956
Award Number 0339310
January 1, 2004 - September 30, 2004
$100,000

This Small Business Innovation Research Phase I project seeks to develop an ultrasensitive, real-time, laser-based explosives sensor. The novel, all solid state, laser-based system can be configured in numerous embodiments for use in walk-through, baggage, and cargo screening portals and can potentially be manufactured in man-portable versions for mine sweeping applications. The proposed sensor will combine a new laser technology with a new detection method to exceed the detection limits of presently employed ion mobility mass spectrometry based systems by orders of magnitude. The proposed sensor will be capable of rapidly detecting and discriminating among ultratrace levels of different explosives in real time with unparalleled sensitivity. The sensor will be capable of detecting common explosives such as TNT, RDX, and PETN at parts-per-trillion concentration level with high chemical specificity in less than 10 seconds. The commercial markets for such a sensor system are enormous and the need immediate. The proposed instrument will enable explosives to be detected in real-time with unparalleled sensitivity and selectivity. The same instrument can also be used for the trace detection of chemical warfare and potentially biological warfare agents. In addition to security applications, the same sensor can be used for applications in industrial process control, environmental monitoring, and natural gas sensing.