



# CONTENTS

Chapter 1: Introduction .....	3
SBIR and ORD's Strategic Plan .....	4
Chapter 2: Commercialization Assistance .....	5
Seventeen Companies That Successfully Commercialized Technologies Developed Under	
Chapter 3: Success Stories .....	8
EPA's SBIR Program .....	9
Profiles of Commercialized Technologies .....	10
Appendix: EPA's SBIR Program .....	45
EPA SBIR Program Proposal and Award Data .....	46
Geographic Distribution of EPA SBIR Awards .....	49
SBIR Program Contacts .....	51

# Environmental Solutions: Commercializing SBIR Technologies

*Success Stories*







## WHAT IS THE SBIR PROGRAM?

The Small Business Innovation Research (SBIR) Program was created by the Small Business Innovation Development Act of 1982 to assist small businesses in transforming innovative ideas into commercial products. EPA is one of 10 federal agencies that participates in the SBIR Program. EPA's SBIR Program has two phases—Phase I is the feasibility study to determine the validity of the proposed concept and Phase II is the development of the technology or product proven feasible in Phase I. EPA also offers a Phase II Option to accelerate the commercialization of SBIR technologies. Companies that leverage third-party financial support before completing Phase II can request additional funds from EPA under the Phase II Option. This additional support is intended to encourage companies to take the steps necessary to commercialize their technologies early in the development phase. EPA issues annual solicitations for Phase I and Phase II SBIR proposals and awards approximately 40-50 Phase I and 15-20 Phase II contracts each year.



## Chapter 1: Introduction

**T**he Small Business Innovation Research (SBIR) Program is an important part of the Environmental Protection Agency's (EPA) research and development efforts and helps the Agency in its mission to protect human health and safeguard the natural environment. Through the SBIR Program, EPA makes awards to small, high-tech firms to help develop and commercialize cutting-edge environmental technologies. The Program is intended to spawn commercial ventures that improve our environment and quality of life, create jobs, increase productivity and economic growth, and improve the international competitiveness of the U.S. technology industry.

**S**ince initiating its SBIR Program in the early 1970s, EPA has been supporting small business innovators in the development of technologies, products, and processes that are helping the Agency to achieve its strategic, long-term goals. These goals include clean air, clean water, safe drinking water, better waste management and restoration of contaminated waste sites, preventing pollution, and reducing the health and ecological risks associated with climate change and stratospheric ozone depletion. These SBIR technologies are helping to solve many of today's complex environmental problems and to equip our Nation to address the environmental challenges of tomorrow.





It is not by coincidence that the SBIR Program has yielded so many technologies that address EPA's priority environmental problems. Each year, EPA's Office of Research and Development (ORD) issues a solicitation for SBIR proposals. The topic areas included in the solicitation are linked directly to the research priorities identified in ORD's *Strategic Plan*, which in turn are designed to help the Agency achieve its strategic, long-term goals. The SBIR Program is one of the various mechanisms used by ORD for accomplishing the research objectives described in this plan which identifies priorities to be emphasized over the next few years. These include safe drinking water, high-priority air pollutants, emerging environmental issues (with a near-term focus on endocrine disruptors), improvement of ecosystem risk assessment and health risk assessment, and pollution prevention and new technologies for environmental protection. The Strategic Plan also highlights seven areas of high importance that will continue to be a major part of ORD's research program, including: tropospheric ozone, global change, environmental monitoring, contaminated sites, exposures to pesticides and toxic substances, ecosystem water quality, and air toxics. Each SBIR solicitation topic addresses one or more of these priority research areas. These topics are derived from the specific research plans that are developed by staff from ORD and the Program Offices to address the priorities identified in the *ORD Strategic Plan*. SBIR topics range from drinking water treatment to prevention and control of toxic air emissions to hazardous waste treatment. (The topic areas in the most recent SBIR solicitation are described in the Appendix.) The SBIR topics are updated as the strategic research focus of ORD shifts to address high-priority research needs.

## ORD's STRATEGIC PLAN

In May 1996, EPA's Office of Research and Development (ORD) completed work on the *Strategic Plan for the Office of Research and Development*, which provides a blueprint for ORD's research program in the years to come. With this Strategic Plan, ORD has instituted a new system for determining research priorities based on risk assessment and risk management principles. ORD uses this plan to direct its resources toward understanding and solving priority environmental problems, while supporting EPA in fulfilling its mandates. The Strategic Plan identifies ORD's vision, mission, long-term goals, the process for identifying specific research topics and setting priorities and criteria for measuring success. The Strategic Plan was updated in 1997 to reflect ORD's continuing evolution, to elaborate on the evaluation criteria for determining research priorities, and to provide a more detailed description of ORD's high-priority research areas.



## Chapter 2: Commercialization Assistance

Over the past decade, dozens of innovative technologies and products have emerged from EPA's SBIR Program. A number of these have moved quickly from "proof of concept" to commercialization. In other cases, companies are still seeking the start-up capital or other support needed to achieve commercialization of their technologies. EPA recognizes that there are a variety of barriers to commercialization of environmental technologies, including obtaining the necessary financing. New facilities, equipment, product development, and marketing often demand more funds than are available internally to a small company.

Companies are more successful at commercializing their technologies when they begin financial planning early. One of the keys to successful commercialization is a good business plan and technology commercialization strategy. Companies that have successfully commercialized environmental technologies stress the importance of early attention to identifying the competition and the company's competitive edge, developing a marketing strategy that focuses on entering realistic markets as quickly as practicable, and assembling a strong management team to solicit partners and/or investors.

EPA has implemented several initiatives to assist small companies in overcoming the barriers to commercialization. These initiatives include: (1) requiring companies to submit

commercialization plans with their SBIR proposals; (2) providing technical commercialization assistance to companies as they conduct their Phase I feasibility studies; (3) preparing and disseminating publications and resources designed to assist small businesses in commercializing their technologies; (4) organizing venture capitalist forums to help companies obtain financing; (5) sponsoring environmental forums to educate the investment and economic development communities about trends, challenges, and opportunities in the environmental industry; and (6) informing companies of the resources offered by the Small Business Administration (SBA) to small firms seeking to commercialize technologies.

### Requirements for Commercialization Plans

To encourage SBIR awardees to consider commercialization early in the development process, EPA now requires companies to submit an abbreviated commercialization plan as part of the Phase I technical proposal. EPA also provides commercialization technical assistance to companies during Phase I that is designed to help them prepare detailed commercialization plans, which must be submitted as part of their Phase II proposals. These detailed plans must address the following:

- a. **SBIR Project:** A brief description of the company, its principal field(s) of interest, size, and current products and sales is required. A concise description of the SBIR project and its key technical objectives also must be included in the commercialization plan.
- b. **Commercial Applications:** The plan should identify primary applications, markets, and uses of the technology specifying the potential customers and specific needs that will be satisfied. The contractor is not required to identify the capacity for secondary market opportunities or alternate uses associated with these markets. The contractor is expected to identify specific potential partners for the primary markets/uses identified for the technology.
- c. **Competitive Advantages:** The plan should describe what is particularly innovative about the anticipated technology or product. (Innovation may be expressed in terms of applications, performance, efficiencies, or reduced cost.) It also should identify the significant advantages of the proposed product over existing technologies.
- d. **Markets:** The anticipated market for the resulting technology, its estimated size, class of customers, and the company's estimated market share 5 years after the SBIR project is completed and/or first sales should be specified in the plan. It also should identify the current major competitors in the market as well as those anticipated in the future.
- e. **Commercialization:** The plan should briefly describe how the company expects to produce the product (e.g., manufacture it in-house, subcontract manufacturing, enter into a joint venture or manufacturing agreement, license the product). It also should describe the approach and steps (e.g., market the product itself, market it through dealers, contract sales, marketing agreements,

sales representatives, or foreign companies; enter into joint ventures) the company plans to take to commercialize the technology or product and to achieve significant sales. In addition, the company's strategy for raising money to support commercialization activities should be delineated in the commercialization plan.

#### Commercialization Technical Assistance

**T**he Small Business Act authorizes federal agencies with SBIR programs to enter into contracts to provide technical assistance to SBIR awardees on all facets of commercialization. For each Phase I award, EPA can provide up to \$4,000 of SBIR funds (above the Phase I SBIR contract award amount) for such technical assistance.

Each year, EPA engages a contractor experienced in business planning and commercialization to assist the Phase I awardees in preparing comprehensive commercialization plans. These plans typically include a description of the project, the potential commercial applications, and the competitive advantages envisioned by the company. The commercialization plans also include the results of market studies and a strategy for commercializing the technology. Over the past 2 years, this assistance has been shown to be invaluable in aiding small businesses to develop credible commercialization plans that will help them achieve their commercialization goals in a timely manner.

#### Commercialization Phase II Option

**E**PA also offers financial assistance to accelerate commercialization of SBIR technologies through a Phase II Option. Companies that receive Phase II contracts can request additional funds from EPA if they are able to leverage third-party financial support to accelerate Phase II. This Phase II Option is not intended to extend Phase II or delay market entry, only to accelerate technology commercialization by encouraging companies to attract third-party financing before completing Phase II. EPA's Phase II Option is aimed at helping small businesses explore commercialization at the same time they are conducting the research needed to develop the technology.

#### Commercialization Guides

**E**PA published the *Guide to Technology Commercialization Assistance for EPA SBIR Program Awardees* (EPA/600/F-97/014), which identifies federal, state, and private resources for commercialization assistance. This commercialization assistance guide presents information on various programs and organizations that offer technical and financial assistance as well as information and other resources, to small businesses and entrepreneurs. The guide also identifies resources available on the Internet that may provide useful information for companies interested in commercializing a technology. EPA also has disseminated to SBIR companies a pub-

lication entitled *Making Money With Your Technology: A Guide to Commercial Success*, which was prepared by the Research Triangle Institute under contract to the National Aeronautics and Space Administration (NASA). This guide offers insights from other companies that have successfully developed and marketed new technologies and identifies what these companies consider to be the key factors for commercialization success. EPA has plans to develop a guide that will assist small companies in obtaining financing for development and commercialization of environmental technologies and products.

#### Partnering Forums

**V**enture capitalist forums are organized by EPA to provide SBIR companies the opportunity to meet and discuss their technologies and financing needs with large companies, venture capitalists, and other small businesses. The Agency has found that such forums are an effective means of fostering partnerships as well as investments in new technologies. These forums offer SBIR awardees the opportunity to obtain the capital and resources needed to commercialize and market their technologies. EPA also sponsors environmental forums to educate the investment and economic development communities about trends, challenges, and opportunities in the environmental industry. These environmental forums promise to be an excellent vehicle to help investors and partner companies recognize the potential of small environmental technology firms.



# COMMERCIALIZATION GUIDES FOR SBIR Awardees



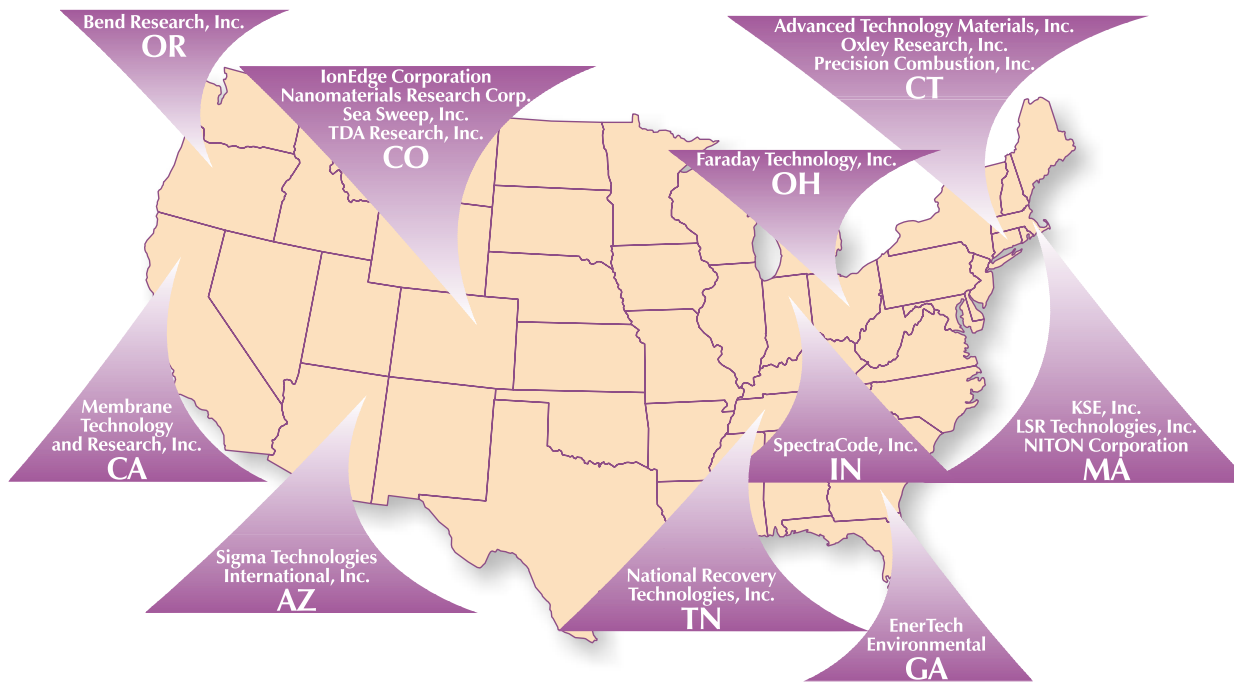
## SBA Resources For Small Businesses

The SBA has a number of resources, many of which can be accessed on the Internet at [www.sba.gov](http://www.sba.gov), to assist small businesses that are seeking commercialization assistance, including:

- a. **Commercialization Matching System (CMS):** The CMS links potential sources of capital with firms that are participating in the SBIR Program.
- b. **Small Business Development Centers (SBDCs):** The SBDC Program provides management and technical assistance to current and prospective small business owners.
- c. **Service Corps of Retired Executives (SCORE):** Executives and business owners donate their time to counsel, educate, and advise small businesses.
- d. **Business Information Centers (BICs):** The BICs offer counseling and training services to small businesses.
- e. **Small Business Investment Company (SBIC) Program:** SBICs use their own capital, plus funds borrowed at favorable rates with an SBA guarantee, to make venture capital investments in small businesses.
- f. **Financial Assistance Programs:** The SBA offers low interest loans to small businesses.
- g. **Angel Capital Electronic Network (ACE-Net):** The ACE-Net is an Internet-based service that provides information to angel investors on small companies seeking equity financing.

## Chapter 3: Success Stories

### WHERE ARE THESE 17 SUCCESSFUL COMPANIES LOCATED?



**D**ozens of small businesses have successfully commercialized technologies developed under EPA's SBIR Program. Seventeen of these companies are described in this chapter. These 17 success stories have been selected because these companies have successfully transitioned their ideas into commercially viable products which have generated revenues that exceed the funding provided by EPA's SBIR Program. Each profile includes a description of the technology, its environmental benefits, and the company's commercialization efforts.

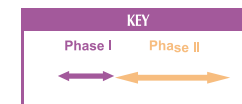
**T**his chapter highlights just a few of the innovative technologies that have resulted from EPA's investment in research at small companies across the country. These success stories testify to the important role that EPA's SBIR Program has played in enlisting the ingenuity and creativity of America's small high-tech firms to develop innovative technologies that improve and protect our environment.





# SEVENTEEN COMPANIES THAT SUCCESSFULLY COMMERCIALIZED TECHNOLOGIES DEVELOPED UNDER EPA'S SBIR PROGRAM

Company / Technology	Media	Page #	Year of Award										
			1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Advanced Technology Materials, Inc. Solid Scrubber for the Semiconductor Industry	Air	10	←	→									
Bend Research, Inc. Membrane-Based System for the Recovery and Reuse of Solvents	Air/Hazardous Waste	12								←	→		
EnerTech Environmental Slurry Carb™ Process for Clean Energy from Municipal Solid Waste	Pollution Prevention/ Solid Waste	14							←	→			
Faraday Technology, Inc. E-CHANGE In-process Recycling System for Electroplating Rinsewater	Pollution Prevention/ Hazardous Waste	16							←	→			
IonEdge Corporation Zero-Waste Dry Plating Process	Pollution Prevention/Air/ Hazardous Waste/Solid Waste	18			←	→							
KSE, Inc. Solvent-Free Polymerization Process	Pollution Prevention/ Air/Water	20				←	→						
LSR Technologies, Inc. Core Separator System for Controlling Particulate Emissions	Air	22			←	→							
Membrane Technology and Research, Inc. Membrane Process to Recover Monomer in Polyolefin Plants	Air	24		←	→								
Nanomaterials Research Corporation Hazardous Solvent-Free Manufacturing Process for Electroceramic Powders	Pollution Prevention	26								←	→		
National Recovery Technologies, Inc. Infrared Fingerprint Sorting of Postconsumer Plastics Resins	Pollution Prevention/ Solid Waste	28					←	→					
NITON Corporation NITON XL-309 Dual Detector Lead Paint Analyzer	Monitoring	30				←	→						
Oxley Research, Inc. Electrolytic Regeneration Process for Restoring Acid Cupric Chloride Printed Circuit Board Etchant	Pollution Prevention/ Hazardous Waste	32				←	→						
Precision Combustion, Inc. Microlith™ Fast Lightoff Catalytic Converters	Air	34	←	→									
Sea Sweep, Inc. Environmentally Benign Oil Absorbent	Water	36			←	→							
Sigma Technologies International, Inc. Surface Functionalization Process for Packaging Films to Promote Adhesion of Aqueous-Based Inks	Pollution Prevention/ Air/Hazardous Waste	38								←	→		
SpectaCode, Inc. RP-1 Polymer Identification System for Sorting Plastics	Pollution Prevention/ Solid Waste	40						←	→				
TDA Research, Inc. Selenium Removal Process for Petroleum Refinery Wastewaters	Water	42					←	→					



# SOLID SCRUBBER FOR SEMICONDUCTOR INDUSTRY

ADVANCED TECHNOLOGY MATERIALS, INC.  
DANBURY, CONNECTICUT

Advanced Technology Materials, Inc. (ATMI), was awarded an EPA SBIR contract to develop an innovative solid scrubbing material designed especially to reduce toxic air emissions from the semiconductor industry. With 30 times the capacity of activated carbon, the new material became the core of the Novapure dry scrubber system that was introduced into the market in 1991. The Novapure system has broad application in the electronics industry and in research and development institutions where small amounts of hazardous materials are routinely employed in chemical vapor deposition (CVD) processes.

The rapid growth of the American microelectronics industry has spawned new environmental challenges associated with the processes used to prepare semiconductor chips that are key components of sophisticated electronic devices. Silane, phosphine, and arsine are used in CVD steps in semiconductor fabrication. Although large companies have built expensive facilities for handling small amounts of these materials, small manufacturers have vented the gas to the atmosphere or used similar unacceptable techniques. As production increased, however, venting of these gases to the atmosphere was no longer an option. The Emergency Planning and Community Right-to-Know Act designates silane, phosphine, and ars-



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

ine as extremely hazardous chemicals used by the semiconductor industry; these chemicals also are regulated as toxic chemicals under the Clean Air Act. ATMI's scrubber system transforms these toxic gases into nonvolatile, benign solids through chemical absorption. By neutralizing, solidifying, and concentrating hazardous effluent up to 20,000 times, this technology helps to eliminate toxic air emissions and minimize solid toxic wastes from small semiconductor manufacturers.

Since the award of this SBIR contract, ATMI has developed a family of novel vent gas scrubbers that are cost effective in reducing toxic air emissions from small quantity CVD processes as well as toxic air emissions released by semiconductor manufacturers. ATMI has spun off this product line into its subsidiary, EcoSys, which is now the largest supplier of point-of-use emission control equipment for the semiconductor industry in the world. EcoSys process scrubbers are smaller than traditional air pollution control equipment. Instead of a single large installation outside a fabrication plant, EcoSys products are small enough to be located at each individual pollution source.

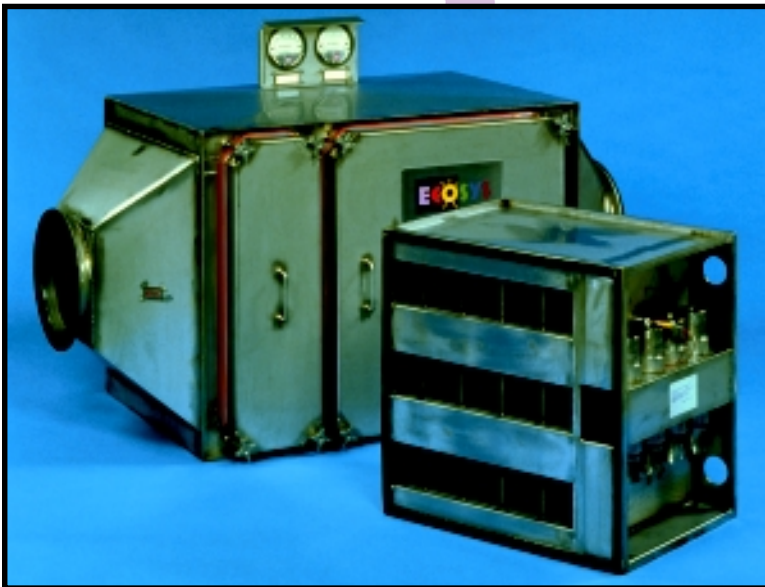
This SBIR project also led to the development of several new safety-related products for the semiconductor industry. One product, called the Safe Delivery Source or SDS that uses absorbent materials similar to those of the dry scrubber system, eliminates the use of high pressure toxic gases in the semiconductor industry.

ATMI was granted four U.S. patents on its dry scrubber technology, and in just 3 years, the company's business grew to nearly \$6 million in annual sales. To expand its environmental control equipment market, in 1994 and 1995 ATMI



acquired the rights to alternative technologies, including wet scrubbing and combustion scrubbing. These acquisitions increased ATMI's annual revenues to nearly \$30 million. Since 1987, when ATMI was awarded the EPA SBIR Phase I contract, the company has grown from four employees working in a small garage in New Milford, CT, to nearly 480 employees in numerous locations around the world with revenues of more than \$100 million. In recognition of its outstanding achievements in technology innovation, ATMI received the Tibbetts Award in 1996. This award is presented by the SBA to companies associated with the SBIR Program that are models of excellence in the area of high technology.

**Tibbetts  
Award  
1996**



ATMI's EcoSys Emergency Release Scrubber traps unexpected releases of toxic or hazardous gases before they can escape to the atmosphere.

## SBIR Impact

- **ATMI's dry scrubber system reduces toxic air emissions from the semiconductor industry.**
- **The innovative solid scrubbing material, the core of ATMI's Novapure dry scrubber, has 30 times the capacity of activated carbon.**
- **This SBIR contract led to the development of a family of novel vent gas scrubbers that are cost effective in reducing toxic air emissions from chemical vapor deposition processes as well as several new safety-related products that eliminate the use of toxic gases in the semiconductor industry.**
- **In 1996, ATMI received the Tibbetts Award in recognition of the company's excellence in the area of high technology.**
- **ATMI has grown from four employees in 1987 to nearly 480 employees in 1997 with annual revenue of more than \$100 million.**

# MEMBRANE-BASED SYSTEM FOR THE RECOVERY AND REUSE OF SOLVENTS

BEND RESEARCH, INC.

BEND, OREGON

Bend Research, Inc., through funding from EPA's SBIR Program and private clients, has developed a membrane-based system for the recovery and reuse of alcohol-based solvents. More than 2.3 billion pounds of solvents are used annually in the United States in manufacturing and industrial cleaning processes. Industry is steadily increasing its efforts to eliminate chemical emissions and to reduce the costs of hazardous waste disposal that result from solvent use. In this move toward reduction of hazardous wastes, industry has focused particularly on minimizing the use of hydrocarbon and chlorinated solvents, turning toward aqueous-, alcohol-, or glycol-based solvents. Hydrocarbon and chlorinated solvents are regulated as hazardous substances and many chlorinated solvents have been identified as ozone-depleting chemicals, which are being phased out by the Clean Air Act Amendments of 1990. Replacing hydrocarbon and chlorinated solvents with alcohol-based solvents eliminates the air emissions and hazardous waste disposal costs that were associated with their use. However, the switch to these "oxygenated" solvents has made recycling even more difficult, especially when water must be removed, because many oxygenated solvents form



Bend Research's membrane-based solvent recovery system can dehydrate solvents, such as isopropyl alcohol, effectively to make recycling of aqueous- or alcohol-based solvents practical and cost effective.

azeotropes with water. Conventional unit operations for "breaking" azeotropes are too expensive and/or too complex to make the recycle of alcohol-based solvents practical in many applications.

The membrane-based system developed by Bend Research overcomes these problems through two innovations: (1) solvent- and temperature-resistant hollow-fiber modules, and (2) a novel operating mode that maximizes system performance. In the process, the spent solvent is sent to an evaporator, and the vaporous overhead is sent to a membrane module containing permselective membranes. These highly selective "vapor-permeation" membranes allow water to pass through, while restricting the passage of the solvent. The membrane module produces a product stream of high-

purity solvent that is free from contaminants and suitable for recycle. This research has resulted in patents on the membrane module and the membrane system.

Through Bend Research's spin-off company, Cascade Separations, Inc., private clients have provided funding to commercialize this technology. The initial market focus is on the recycle of isopropyl alcohol (IPA) and the production of ultra-pure IPA for the electronics industry. Future market areas include the dehydration of other solvents (such as ethanol, tetrahydrofuran, and acetone) and the removal of contaminants other than water from solvents.

IPA is used as a drying agent by the electronics industry for drying parts (e.g., silicon wafers, hard disks, circuit boards). The parts are submerged into an IPA "vapor cloud," where hot IPA condenses on the cold parts and pulls off the water. The IPA/water mixture then is collected in a drip tray and removed from the dryer. The membrane-based system developed by Bend Research treats this "wet" IPA, producing dry IPA that can be reused in the dryer.

Tests have shown that the membrane-based system can take IPA contaminated with as much as 20 weight percent water and produce purified solvent containing less than 0.1 weight percent water (i.e., 99.9 weight percent IPA). This system allows reuse of the spent IPA, reducing the amount of IPA waste generated as well as the amount of new IPA that must be purchased for use in the dryer. The membrane-based system also removes particulates and metal ions from the IPA; therefore, the reprocessed IPA is often "cleaner" than newly purchased IPA.



Systems based on this technology have been in operation for more than 18 months, effectively reprocessing IPA for a hard-disk manufacturer. The systems have worked well in an industrial setting, resulting in increased yields in the disk-manufacturing process. Recently, this disk manufacturer brought another membrane-based system on line for an additional dryer.

Initial results have shown that this technology is both effective and economical. The results also have shown that improvements could be made to the hollow-fiber vapor-permeation modules to further decrease the costs of reprocessing the IPA. These improvements were the focus for the Phase II SBIR Program. The improved modules are being manufactured and will be installed soon.

By leveraging EPA funding with private-sector resources, Bend Research has successfully commercialized this membrane-based technology. The hollow-fiber vapor-permeation modules are being manufactured at Bend Research Manufacturing, a wholly owned subsidiary of Bend Research. These modules are sold to an exclusive licensee of this technology, Cascade Separations, Inc.—an engineering, systems manufacturing and marketing company that was created to provide membrane-separation systems to end users in target industries. Cascade has received funding from several private sources for commercialization of this technology. Cascade's initial market focus is providing systems for the electronics industry, with recent focus on the production of ultra-pure IPA using a modified flow scheme based on the hollow-fiber membrane technology developed by Bend Research under EPA's SBIR Program.

## SBIR Impact

- **Bend Research's membrane-based system makes the recycling of oxygenated solvents more cost effective, thus providing a desirable alternative to using hydrocarbon and chlorinated solvents that produce toxic air emissions and hazardous wastes.**
- **Bend Research has developed a membrane-based system that effectively dehydrates solvents. It can reduce the concentration of water in alcohols and other industrial solvents to as low as 10 ppm. The technology also can be used to break azeotropes.**
- **Several systems have been installed by a hard-disk manufacturer to reduce the amount of IPA required in vapor dryers used for drying parts. Results have shown that the use of this technology: decreases the amount of IPA waste generated, decreases the amount of new IPA needed, and increases manufacturing yields.**
- **The initial market focus is on IPA reprocessing and the production of ultra-pure IPA for the electronics industry. Future market areas include the dehydration of other solvents (e.g., ethanol, tetrahydrofuran, acetone) and removal of contaminants other than water from solvents.**

# CLEAN ENERGY FROM MUNICIPAL SOLID WASTE

ENERTECH ENVIRONMENTAL  
ATLANTA, GEORGIA

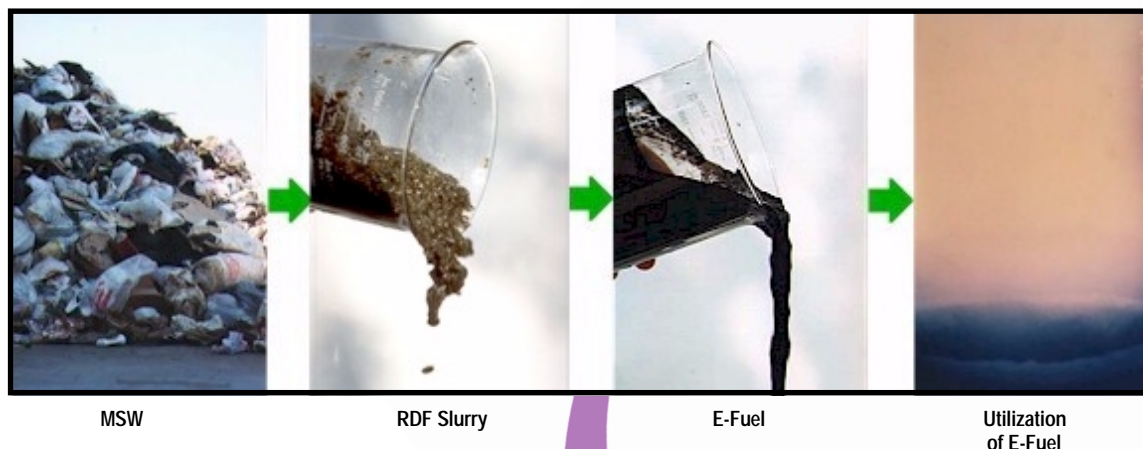
EnerTech Environmental, with the funding provided by EPA's SBIR Program, has successfully developed the SlurryCarb™ Process, an innovative process that chemically converts municipal sewage sludge (MSS), municipal solid waste (MSW), and other organic wastes into a high-energy, liquid fuel (or slurry) that is cleaner to combust than most coals. Because the SlurryCarb™ Process eliminates the need to burn or landfill organic wastes—such as MSS and MSW—its use can help address the problem of landfill overcrowding and air emissions (e.g., VOCs, hazardous air pollutants, methane) from landfills. In addition, this technology supports EPA's strategic goal of decreasing the quantity of waste requiring disposal.

SlurryCarb™ is a highly adaptive system that can stand alone or be used in combination with existing or planned waste disposal strategies. Simplicity of operation is key to the SlurryCarb™ procedure. MSS or MSW is brought to a central manufacturing facility where it is converted into a uniform, pumpable slurry. The slurry can be created from a single waste stream such as MSS or a combination of wastes such as MSS and MSW. The product fuel, known as “E-Fuel,” then can be transported through pipes or tankers to industrial and utility users where it is burned as a supplement or substitute for conventional fuels such as coal or oil.

E-Fuel™ can be produced up to 7,720 Btu/lb (wet or slurry basis) at 52.0 weight percent solids (the remainder is water) and easily fired into pulverized coal boilers via spray nozzles and combusted with less than 20 percent excess air. In addition, the SlurryCarb™ Process removes over 98 percent of the feed chlorine, greatly reducing HCl emissions and boiler corrosion from combustion of E-Fuel™. Without extensive air pollution control systems, the CO, NO<sub>x</sub>, trace metal, and dioxin emissions from the combustion of E-Fuel™ are well below EPA's New Source Performance Standards (NSPS) for Municipal Waste Combustion (MWC), and the SO<sub>2</sub> emissions are comparable to the NSPS for extensive air pollution control systems.

With the SlurryCarb™ process, collected waste is processed as a fluid in continuous equipment, which provides savings in capital and operating costs. The feed waste is chemically altered so

that it becomes a uniform, pumpable slurry fuel that can be used onsite or pumped, piped, or tankered to a customer. In addition, waste stream components, which typically must be cleaned from the flue gas after combustion (i.e., chlorine, ash, sulfur, etc.), instead are removed in the front-end of the process at a lower cost per ton of pollutant removed. The technical advantages of the SlurryCarb™ process all contribute to its excellent economics. A 100 ton per day sludge facility can operate profitably at a tipping fee of \$40 per as received ton (assuming the sludge enters the SlurryCarb™ system at 20 percent solids). Reduced-capacity units (i.e., 25-50 tons/day) have similarly strong economics. In the United States alone, 8 million dry tons of MSS and 210 tons of MSW are produced every year. EnerTech's cost of disposal is equal to or below the average cost of conventional disposal options for these wastes. Smaller communities now have available to them



The SlurryCarb™ Process can generate a quality fuel from several low-grade fuels and wastes, including municipal solid waste and municipal sewage sludge.



a clean and affordable method of MSS disposal that reduces landfill demands and eliminates the need for a combustion facility to burn wastes. Instead, the waste is converted to a valuable fuel and then exported to the marketplace.

Through an agreement with Mitsubishi Corporation, construction of a 20 ton/day (as received MSW) unit in Japan was completed in early 1997. EnerTech also has signed an agreement with TS Group, Ltd., to build a unit in Korea. Construction of this unit is expected to begin in 1999. Having successfully piloted this technology in the United States, EnerTech currently is working with Jacobs Engineering, the American Plastics Council, and the Westinghouse Savannah River Company to build its first commercial facility in this country by the end of 1999.



This 20 ton/day unit, which began operating in Japan in early March 1997, was designed as a fully integrated commercial-scale system for local MSW. The product fuel from the facility is cofired in a pressurized gasifier for hydrogen production or cofired in a cement kiln for heat production.

## SBIR Impact

- **EnerTech's SlurryCarb™ Process eliminates solid waste by converting municipal sewage sludge, municipal solid waste, and other organic wastes into a high-energy liquid fuel that burns cleaner than most coals.**
- **Because the SlurryCarb™ Process eliminates the need to burn or landfill organic wastes, its use can help address landfill overcrowding and reduce air emissions from municipal incinerators and landfills.**
- **The economic and operational viability of the SlurryCarb™ Process has been successfully demonstrated at the 20 ton/day level using municipal solid waste as a feedstock.**
- **EnerTech is negotiating with a consortium of companies to construct a 100 ton/day facility in the United States, which will springboard this technology into the U.S. commercial market.**

# IN-PROCESS RECYCLING OF CONTAMINATED ELECTROPLATING RINSE WATER UTILIZING A MODULATED ELECTRIC FIELD AND IN-SITU REGENERATION

FARADAY TECHNOLOGY, INC.  
DAYTON, OH

Faraday Technology, Inc. (FaraTech) has developed the patented E-CHANGE™ In-Process Recycling System with funding from EPA's SBIR Program. The E-CHANGE™ System can recycle approximately 90 percent of contaminated electroplating rinse water back into the plating process.

Contaminated rinsewaters from electroplating have been traditionally treated onsite by conventional hydroxide precipitation, resulting in solid-phase wastewater treatment sludges. In 1992, there were releases of 73,000 metric tons of copper/lead compounds and 227,000 metric tons of metals to the environment. Costs associated with the transport and disposal of copper/lead sludges and metal sludges were in excess of \$25 million and \$62 million, respectively, with additional costs associated with the liability of future landfill cleanup.

E-CHANGE™ offers the environmental benefit of nearly eliminating the generation of copper/lead sludges, which are regulated by EPA as hazardous substances. This system can save the average electroplater thousands of dollars by eliminating hazardous waste transport and disposal costs and reducing annual water and sewer expenses.

It also saves electroplaters money by recovering the metal content of the rinse water.

The E-CHANGE™ system is a unique, hybrid technology utilizing the benefits found in conven-

tional ion-exchange and electrowinning. The system utilizes a Modulated Electric Field (MEF) to enhance mass transport and to enable electric regeneration to occur *in situ*. Fara-Tech's objective in developing this technology was to provide the "average" job shop plater with "point-source" pollution prevention capabilities at a cost-effective price with a return on investment (ROI) of less than 12 months. Testing indicates that the E-CHANGE™ system can recycle approximately 90 percent of the contaminated rinse water (10 percent of the rinse water is lost due to evaporation). The dilute stream is adjusted for pH and used for rinsing plated parts. The concentrate is used to make up the plating solution, automatically readjusted for plating *in situ* without creating a secondary waste stream.



Faraday's E-Change™ In-Process Recycling System is capable of recycling approximately 90 percent of the contaminated electroplating rinse water back into the plating process, nearly eliminating metal sludges and significantly reducing water use.



FaraTech has validated this technology using two limited Beta tests for acid copper rinse water. FaraTech has delivered two systems, one for a limited production printed wiring board (PWB) manufacturing facility and another for a government research facility. Additional laboratory data have been compiled for lead-tin rinse water with a Beta test scheduled for late 1999.

FaraTech also has completed feasibility studies for the decontamination of hexavalent chromium and electroless nickel plating baths, and FaraTech plans to exploit this innovative technology for other rinse water constituents such as nickel and zinc.

FaraTech's commercialization efforts have included: (1) product promotion at professional society/industry conferences; (2) substantial corporate investment in both manufacturing issues and intellectual property; (3) a detailed economic analysis, including complete system cost and estimated system pricing scenarios; and (4) detailed discussions with several potential vendors for market distribution of the technology.

By implementing a unique business strategy that utilizes a "Technology Rich Platform" based on the scientific ways in which asymmetrical electric fields influence electrochemical processes, FaraTech is developing multiple products and processes for various markets. The platform represents a new way of applying electrochemical principles to the electroplating/metallization, fuel cell/power supply, machining, environmental, and corrosion market segments. FaraTech has three U.S. patents issued, seven U.S. patents pending, one foreign patent pending, and five additional U.S. patent applications to be filed in 1999.

## SBIR Impact

- **FaraTech's E-CHANGE™ can recycle approximately 90 percent of the contaminated electroplating rinse water back into the plating process. The system nearly eliminates the generation of metal sludges, and the liability associated with their transportation and disposal.**
- **FaraTech's innovative in-process recycling system is designed to provide the "average" job shop plater with a "point-source" pollution prevention capability at a cost-effective price with a return on investment of less than 12 months.**
- **FaraTech's system also saves the average electroplater thousands of dollars in sludge disposal costs and water and sewer expenses.**
- **Two E-CHANGE™ Systems for acid copper applications are being built—one for a limited production printed wiring board manufacturing facility and the other for a government research facility. An additional E-CHANGE™ System is undergoing a Beta test at a specialty wire manufacturing facility for a lead-tin solder process.**

# ZERO-WASTE DRY PLATING

IONEDGE CORPORATION  
FORT COLLINS, COLORADO

IonEdge Corporation, with the funding provided by EPA's SBIR Program, has developed and commercialized an innovative metal plating technology that results in "zero-waste." It eliminates most of the air emissions, wastewater, and solid and hazardous wastes associated with zinc and cadmium plating. One EPA study noted that electroplating effluents are the single largest source of natural water contamination in the United States (Electroplating Wastewater Sludge Characterization, EPA-600/52-81-064). Much of the waste from conventional electroplating operations is associated with contaminated rinse waters, which require treatment and subsequent disposal of a hazardous sludge in an approved landfill. IonEdge's process eliminates the costs and liabilities related to the transport and disposal of hazardous sludges; waste treatment savings are estimated to exceed \$1,000 per day for the average electroplater. Because IonEdge's plating process takes place in a sealed chamber, it also minimizes operator exposure to hazardous particle emissions and eliminates solid waste by facilitating *in situ* recycling of the metals used in the plating process. In addition, this dry plating process uses less chemicals, requires 75 percent less energy, and reduces water consumption by an order of magnitude in comparison to conventional electroplating processes.

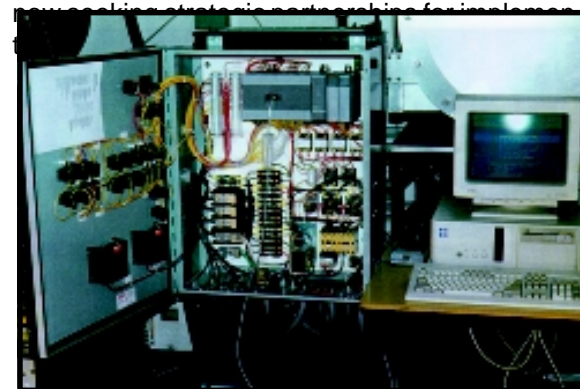
Zinc and cadmium coatings are electroplated on steel hardware components used in the defense, aerospace, automotive, and construction industries to protect them from corrosion in natural environments. The electroplating process is occupationally and environmentally hazardous because it requires the use of toxic liquids and generates large quantities of contaminated wastewater and solid and hazardous wastes.

To address environmental and occupational issues related to electroplating, IonEdge achieved zero-waste plating by using the novel concept of a vapor bath inside a vacuum in lieu of the conventional liquid bath in air. Furthermore, special technological features of the IonEdge process allow for material recycling. Only the parts exiting the chamber are plated, leaving the chamber and racks free of deposits. The sealed chamber operation also minimizes operator exposure to hazardous particle emissions. The dry-plating line consists of only four process steps as opposed to a dozen bath operations in conventional electroplating, and a waste treatment facility is unnecessary.

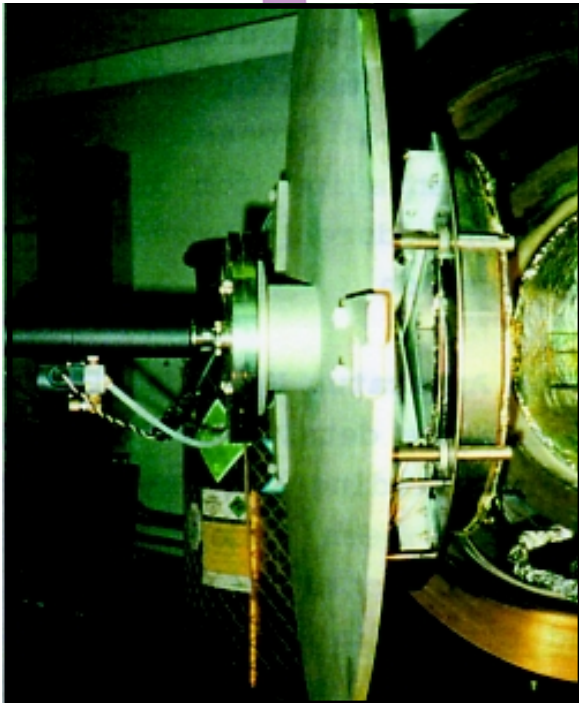
A rack plating apparatus using IonEdge's process has been in production for more than 2 years. For a batch of parts, the start-to-finish process time for the degrease-to-chromate operation is about 30 minutes. The quality of IonEdge's cadmium coatings has been acceptable according to standard federal and U.S. military specifications, and the coatings have performed well in more than 7,000 hours in salt-fog tests. The apparatus and process developed during the EPA SBIR project were upgraded and improved to meet customers' requirements in pilot production. In-process improvements and adjustments were made to maintain

product quality and to achieve process repeatability. Test samples from three prospective customers were coated on the pilot line. The quality of these coatings was evaluated and approved by all three customers.

This success led to the first commercial sale of the dry-plating process to an aerospace customer who requested IonEdge to set up three additional processes to complete the customer's plating line. The expanded plating line and processes have been certified for coating aerospace parts, and IonEdge continues to provide coating services to the aerospace industry. During 1998 alone, more than 50,000 steel components were cadmium dry plated on this plating line. These components are now in service in commercial airplanes, jet fighters, helicopters, and missiles. IonEdge is preparing a business plan for expanding the dry-plating line to increase the throughput by an order of magnitude (in the range of 2,000 parts of 1-inch size/hour). Simultaneously, a full commercial production plating line will be installed for high-volume parts processing (10,000 parts/hour), which will allow customers to evaluate the full economic benefits of the dry-plating process. IonEdge is



## SBIR Impact



IonEdge achieved zero-waste plating by using the novel concept of a vapor bath inside a vacuum in lieu of the conventional liquid bath in air. This technology eliminates most waste associated with plating; reduces chemical, water, and energy consumption; and significantly reduces waste treatment costs.

- IonEdge has developed a zero-waste dry plating process that eliminates most of the air emissions, wastewater, and solid and hazardous wastes associated with zinc and cadmium plating.
- IonEdge's dry plating process eliminates the need for conventional toxic plating bath liquid chemicals and minimizes the liabilities related to the transport and disposal of hazardous sludges.
- The zero-waste dry plating process is economical—it requires 75 percent less energy, reduces water usage by an order of magnitude, and results in waste treatment cost savings of approximately \$1,000 per day, for an average electroplater.
- IonEdge's in-house dry plating line has been certified for use by an aerospace company. IonEdge is seeking strategic partnerships for implementation of a plan to expand the dry plating line to increase throughput by an order of magnitude, along with installation of a full commercial production line for high-volume processing (10,000 parts/hour).



# SOLVENT-FREE POLYMERIZATION PROCESS

KSE, Inc.

AMHERST, MASSACHUSETTS

KSE, Inc., through funding provided by EPA's SBIR Program, has developed a polymerization process that produces methyl vinyl ether and maleic anhydride (MVE/MAN) copolymers without the use of benzene. Benzene is regulated as hazardous under the Clean Air Act, the Safe Drinking Water Act, the Resource Conservation and Recovery Act, and the Clean Water Act. EPA has classified benzene as a known human carcinogen of medium carcinogenic hazard. Long-term exposure to benzene at various levels has been determined to be carcinogenic by the U.S. Department of Health and Human Services, and it also may be harmful to the immune system.

Benzene and other toxic chemicals have been used as solvents for decades. A particularly important example is the use of benzene as the polymerization solvent in the synthesis of copolymers of MVE/MAN. Approximately 150 million pounds of benzene are consumed annually in the manufacture of the 25 million pounds of MVE/MAN copolymer that are produced in the United States each year. The copolymer product from this process is centrifuged and then dried—both steps resulting in benzene emissions. MVE/MAN copolymer product has been sold containing up to 2 percent benzene by weight. KSE's solvent-free polymerization process could eliminate the use of

this 150 million pounds of benzene, the health risks associated with benzene emissions during the polymerization process, and the health risks associated with residual benzene in consumer products that are manufactured with MVE/MAN copolymer. It is used, for example, in the manufacture of the most widely used denture adhesive in the United States. The copolymer reacts with saliva to produce a strong adhesive between false teeth and gums.

The copolymer from KSE's innovative process has been subjected to extensive polymer property tests to demonstrate that it is functionally identical to the copolymer produced from the classical benzene technology. Laboratory tests, using methods certified by the Food and Drug Administration, have shown the copolymer to be of ultra-high pu-

rity, containing nondetectable benzene at a quantitative limit of 10 ppb. In addition to eliminating benzene from the MVE/MAN copolymer, KSE's process has been demonstrated to be more efficient and cost-effective than classical benzene technology. The reaction rate of the KSE process is much faster, leading to more than a 10-fold improvement in reactor cycle time. Fewer solvent separation steps are required in the KSE technology, and the copolymer drying step is faster and more energy efficient than that of the classical benzene technology.

Before committing to purchase copolymer produced using KSE's process, customers have required that long-term product qualification tests be performed on replicate batches of commercial production of the copolymer to confirm that the co-



KSE, Inc.'s solvent-free polymerization process produces MVE/MAN copolymers without the use of benzene. This innovative process reduces the environmental and health risks associated with MVE/MAN copolymers, and it is more efficient and less costly than classical benzene technology.

polymer can successfully be converted into the desired product (e.g., denture adhesive). The EPA SBIR funding provided KSE the critical resources needed to initiate a large-scale manufacturing optimization and test program to prove the copolymer product efficacy through customer qualification testing—a step that would not have been possible without this funding.

Product qualification tests, conducted by major consumer products companies, concluded that the performance of KSE's copolymer is excellent. ChemDesign Corporation, a subsidiary of the Bayer Corporation, has signed a letter of intent to manufacture the copolymer. Plant production of the copolymer is expected to begin in 1999.

By combining EPA funding with private-sector resources, KSE has successfully commercialized its solvent-free polymerization process, which will reduce the health and environmental risks associated with the production and use of MVE/MAN copolymers and provide a more efficient and cost-effective method of production the copolymer. The production cost of the KSE benzene-free copolymer is substantially less than the current selling prices of \$4 to \$6 per pound for existing commercial MVE/MAN copolymers produced using the classical benzene technology.

## SBIR Impact

- **KSE, Inc., has developed a polymerization process that produces methyl vinyl ether and maleic anhydride (MVE/MAN) copolymers without the use of benzene.**
- **Health and environmental risks associated with the use of benzene in the production of MVE/MAN copolymer are eliminated.**
- **Health risks associated with residual benzene in consumer products manufactured with MVE/MAN copolymer are eliminated.**
- **KSE's process is more efficient and less expensive than the classical benzene technology.**
- **ChemDesign Corporation, a subsidiary of Bayer Corporation, has signed a letter of intent to manufacture MVE/MAN copolymer using KSE's process. Production is expected to begin in 1999.**

# CONTROL DEVICE FOR PARTICULATE EMISSIONS

LSR TECHNOLOGIES, INC.

ACTON, MASSACHUSETTS

With funding from EPA's SBIR Program, LSR Technologies, Inc., has developed the Core Separator, a mechanical dust collecting device that removes micron- and submicron-sized particles from gas streams. Historically, mechanical collectors have been ineffective in removing particles with diameters of less than 10 microns.

It is likely that particulate matter will be regulated as a criteria air pollutant (i.e., pollutants causing human health impacts due to their release from numerous sources) under the Clean Air Act. EPA has proposed tightening the National Ambient Air Quality Standards for the allowable levels of particulate matter, decreasing the size of the particles that must be removed from gas streams from 10 microns to 2.5 microns. Unlike other mechanical collectors, the Core Separator is capable of removing dust particles with diameters of less than 10 microns; it even can remove a high percentage of particles in the micron range. This is equivalent to the performance of a medium-efficiency electrostatic precipitator (ESP) and better than the performance of a high-energy Venturi scrubber. Yet, the Core Separator still has the traditional advantages of mechanical collectors such as simplicity, reliability, compactness, and low maintenance.

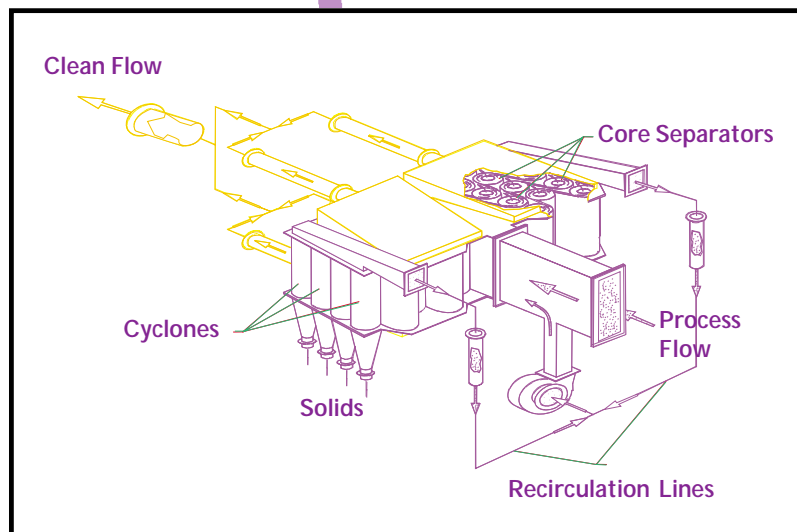
The Core Separator system includes two conventional components, a cyclone collector for extracting solids and a fan for flow recirculation. A complete system is actually a multitude of cylin-

drical units, each with a single inlet for the stream to be treated and two outlets. One outlet is for the clean gas stream and the other contains a highly concentrated recirculation stream. The dust-laden recirculation stream is fed to a cyclone and returned again by means of the fan. The Core Separator component cleans the inlet stream and detains dust particles in the system. Because its efficiency is very high, most particles do not leave the system. They recirculate until collected by the cyclone. Two factors govern the performance of Core Separators: (1) high separation efficiency of the separator component, and (2) the interaction between individual components. To achieve high separation efficiency, a proper bleed-flow ratio (i.e., ratio of the recirculation flow to the total flow) is required. By controlling bleed flow, the tangential and radial velocities are controlled independently to maintain them in the desirable range.

High efficiency in the Core Separator results from low particle reentrainment. The system is de-

signed to avoid formation of toroidal vortices. Because the Core Separator component functions as a separator and not a collector, a flow U-turn within the device can be avoided. It is entirely cylindrical, and surfaces promoting formation of vortices are moved away from the clean outlet. This theory has been verified by actual testing and through computer modeling using computational fluid dynamics (CFD) to study flow fields. It should be noted that each of these factors individually cannot prevent vorticity; however, working together they achieve what each cannot do independently. The conflicting processes of separation and solids collection are accomplished separately and in different components. The interaction between components is the principal means of attaining high system efficiency.

There is strong demand for the Core Separator both as an air pollution control device and as a means to recover valuable product material. More than 50 Core Separators have been sold in the United States and abroad, and at least one com-



LSR Technologies' Core Separator System consists of a series of cylindrical units, each with a single inlet for the stream to be treated and two outlets. One outlet is for the clean gas stream and the other is for the highly concentrated recirculation stream. The dust-laden recirculation stream is fed to a cyclone where solids are extracted and returned again by means of the fan, which facilitates flow recirculation.



pany using the technology for recovery of chemical catalysts has experienced a payback period of less than 6 months. In 1996, the Core Separator was selected for the prestigious R&D 100 Award, signifying it as one of the world's best new technology-based products of the year. This product is quite significant in light of the fact that very few advances have occurred in particulate control technology in recent years.

Another emerging industrial application for the Core Separator is as a control device for collecting particulate matter upstream of regenerative thermal oxidizers (RTOs), which are used in the production of wood products for the building industry (e.g., medium density fiberboard, particleboard, and oriented strandboard). The Core Separator currently is being demonstrated for wood dryer applications and could emerge as the "Best Available Control Technology" (BACT) for these processes.



More than 50 Core Separators, such as the one at the asphalt plant above, have been installed in the United States and other countries to remove dust particles from gas streams.

R&D 100  
Award  
1996



## SBIR Impact

- **LSR Technologies' Core Separator can remove micron- and submicron-sized particles from gas streams.**
- **By removing micron-sized particles from gas streams, the Core Separator reduces particulate matter emissions and the human health and environmental effects associated with this criteria air pollutant.**
- **More than 50 Core Separators have been sold in the United States and abroad. These units are attributed with a major reduction of particulate air emissions. For example, stack compliance testing has shown particulate emissions to be below 100 mg/nm<sup>3</sup> when used on coal-fueled boilers.**
- **A Core Separator installation used for recovery of chemical catalysts by a Fortune 500 company has produced a payback in less than 6 months.**

# MONOMER RECOVERY IN POLYOLEFIN PLANTS

MEMBRANE TECHNOLOGY AND RESEARCH, INC.  
MENLO PARK, CALIFORNIA

Membrane Technology and Research, Inc. (MTR), with support from EPA's SBIR Program, has developed and commercialized a membrane process to recover valuable monomer feedstocks in polyolefin plants.

Polyethylene and polypropylene manufacture are the largest production processes in the United States, generating raw materials that are the basis of many plastic products. More than 100 polyolefin manufacturing plants are operating in this country, producing 30 billion pounds of polymer each year with an additional 200 plants worldwide. Most of these plants produce gas streams that are flared, wasting valuable feedstocks and contributing to emissions of VOCs. An estimated 100,000-200,000 tons of recoverable monomer are flared at U.S. polyolefin plants each year, which accounts for most of the VOCs emissions from these plants. VOCs are regulated as a criteria air pollutant under the Clean Air Act.

MTR's membrane process recovers essentially all of the monomer feedstock, solvent, and nitrogen from the vent gas resulting from resin purge operations for reuse in the polyolefin plant. Use of MTR's innovative process will eliminate the release of the VOCs and will provide the average

polyolefin plant an annual recovery value of about \$1 million.

In a typical olefin polymerization process, monomer plus catalyst, various comonomers, solvents, and stabilizers are contacted at high pressure in a reactor. The polymer product of the olefin reaction contains significant amounts of monomer and other organics, which must be removed before the polymer can be used. In most plants, the raw polymer is passed to large resin purge bins where nitrogen removes the absorbed monomer and processing solvents. The waste gas from these resin purge operations represents an important recycling and recovery opportunity. The vent gas from a typical resin purge bin contains 500-1,000 pounds per hour of recoverable nitrogen.

Before the development of the monomer/nitrogen separating membranes by MTR, no acceptable method of treating the vent gas was available. Condensation under pressure is costly and not effective; lean oil absorption technology has been tried, but it is not commercially accepted. MTR's membrane process recovers essentially all of the valuable monomer feedstock, solvent, and nitrogen from the vent gas for reuse in the plant. The membrane unit fractionates the vent gas into two streams—a monomer/solvent-rich stream and a nitrogen stream. The organic components are recycled as a concentrated gas or a condensed liquid to the polymerization reactor. The 97-99+ percent nitrogen stream is reusable in the degassing step, thereby reducing nitrogen consumption. MTR's process is closed loop; therefore, no secondary waste streams are produced.



This MTR system was installed at a Huntsman Corporation Polypropylene Plant for recovery and direct recycle of propylene monomer.

Membrane separation systems to treat the large vent gas streams generated in polyolefin plants require several hundred square meters of membrane. Development of the capability to produce large membrane modules was the breakthrough that allowed MTR to build systems large enough to treat polyolefin plant vent streams.

The first monomer recovery system, incorporating 50 modules and about 280 square meters of membrane, was installed in 1996, at a new polypropylene plant for Dutch State Mines (DSM), The Netherlands. By recovering monomer and minimizing nitrogen consumption, DSM expects to save about \$1 million annually, yielding a system payback period of 1 to 2 years. Since then, several systems have been installed as retrofits in existing plants or in new plants in the United States and overseas. MTR has opened an office in Houston to market its technology to American polyolefin plants and to service those systems already installed. MTR's systems are sold under the company's VaporSep product line that is broadly applicable to recovery of VOCs from gas streams.

In recognition of the significance of this olefin recovery technology, MTR was awarded the 1997 Kirkpatrick Chemical Engineering Achievement Award. This biennial award, presented by the Chemical Engineering journal since 1933, recognizes the most noteworthy chemical engineering technology commercialized throughout the world during the preceding 2 years.

Kirkpatrick  
Chemical  
Engineering  
Achievement  
Award  
1997



## SBIR Impact

- **MTR has developed a membrane process that recovers valuable monomer feedstock, solvent, and nitrogen from waste gas streams of polyolefin manufacturing plants.**
- **MTR's technology eliminates most of the VOCs emissions from polyolefin plants by eliminating the flaring of waste streams containing recoverable monomer.**
- **The first monomer recovery system was installed at a new polypropylene plant in The Netherlands in 1996. By recovering monomer and minimizing nitrogen consumption, the plant should save about \$1 million annually, yielding a system payback period of 1 to 2 years.**
- **Since 1996, several systems have been installed as retrofits in existing plants or in new plants in the United States and other countries. This success has allowed MTR to transition to a manufacturing company in addition to retaining its commitment to developing new technologies. More employees have been added as a result.**



# HAZARDOUS SOLVENT-FREE MANUFACTURING OF ELECTROCERAMIC POWDERS

NANOMATERIALS RESEARCH CORPORATION  
LONGMONT, COLORADO

Nanomaterials Research Corporation (NRC), with funding provided by EPA's SBIR Program, has developed and commercialized an innovative manufacturing technology for performance ceramics. NRC's process improves device quality while preventing pollution by reducing the amounts of raw materials, solvents, and binders required for production of these ceramics in comparison to conventional manufacturing techniques.

The performance ceramics industry produces and sells more than \$18 billion of ceramic products annually and is one of the fastest growing segments of all industries listed in the Standard Industrial Classification (SIC) coding system. The performance ceramics industry is enabling growth within the electronics, utilities, medical devices, optics, and telecommunications industries, and the market for such ceramics is expanding in conjunction with this growth. More than 1 billion ceramic devices (e.g., capacitors, thermostats, varistors, inductors, resistors, and IC substrates) are produced and sold each week. Anticipated growth in the market for ceramic devices will further extend the role of performance ceramics.

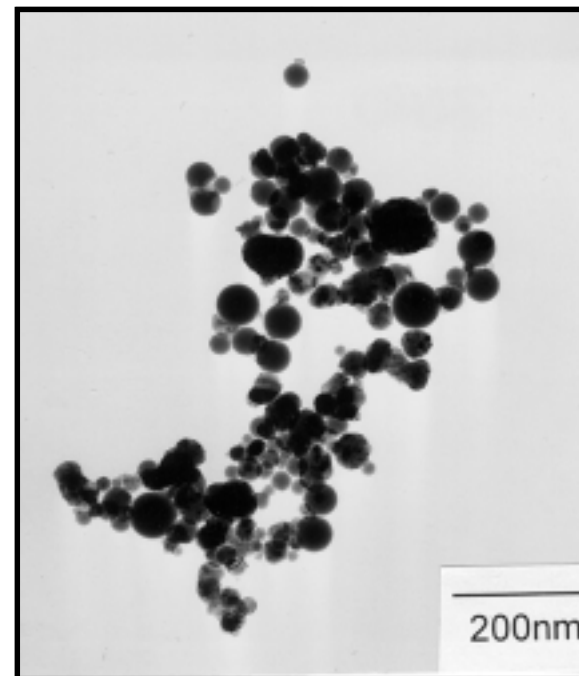
Performance ceramics are typically produced by solvent-based techniques that inadvertently lead to processing, containment, and treatment of hazardous solvents and byproducts. Given the commercial importance of the electroceramic industry, it is imperative that environmentally benign manufacturing techniques are developed to prevent pollution at its source while providing performance improvements to customers.

NRC's manufacturing method for performance ceramics offers the following advantages over conventional techniques: (1) it eliminates the formation of secondary gaseous, liquid, or solid wastes; (2) it reduces the processing, containment, and treatment of solvents and resulting vapors by more than 10 fold; (3) it reduces energy requirements by recovering mass and heat through process integration; and (4) it produces performance ceramics of significantly improved quality (i.e., monodisperse, nanosize particles with extraordinary properties).

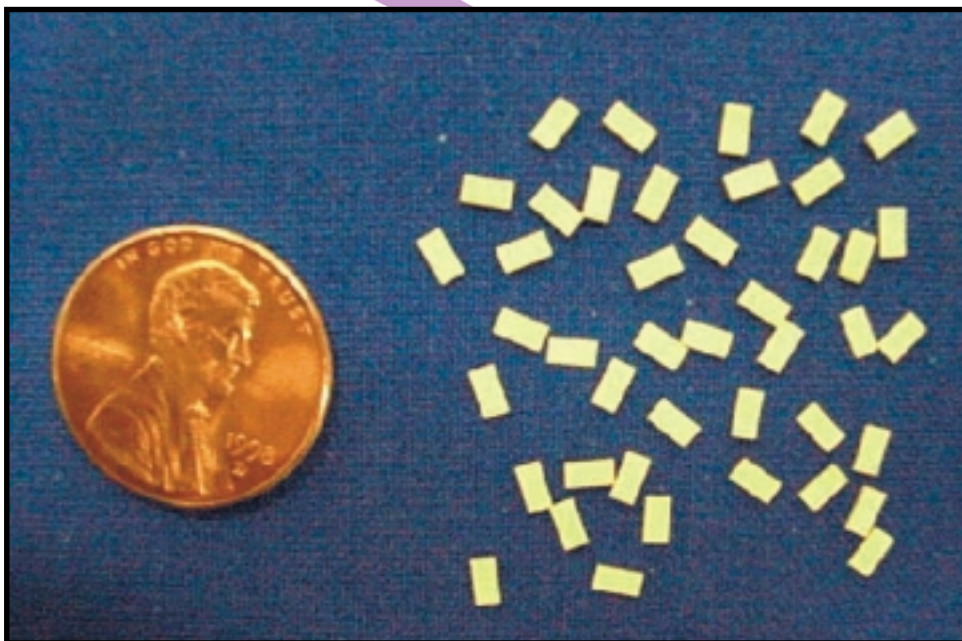
NRC has demonstrated that devices produced from nanosized electroceramics are nanostructured and meet the needs of high performance components that will be essential for the anticipated era of nanodevices and molecular electronic components. Manufacturing of these devices is being scaled up by NRC to serve surface-mount electronics, cellular telecommunications, power components for utilities, laptop computers, and biomedical products. The market for nanostructured components should exceed \$100 million/year in less than 5 years.

Since the company was founded in 1994, NRC has experienced an average annual growth of

more than 100 percent. NRC currently has 60+ employees and expects to hire additional staff in 1999.



Nanopowders of performance ceramics produced by NRC.



Nanotechnology electronic devices from nanopowders of performance ceramics manufactured using NRC's innovative manufacturing technology.

### SBIR Impact

- NRC has developed and commercialized a manufacturing technology for performance ceramics that improves device quality while preventing pollution at its source by reducing the amounts of raw materials, solvents, and binders required for processing.
- This technology enables the manufacture of nanoscale electronic grade powders needed in next generation miniature electronics. The market for nanostructured components is expected to exceed \$100 million/year in less than 5 years.
- NRC is scaling up the manufacturing process to produce 100,000 nanostructured components per week from electroceramic nanoscale powders.

# SORTING OF POSTCONSUMER PLASTICS RESINS

**NATIONAL RECOVERY TECHNOLOGIES, INC.**  
**NASHVILLE, TENNESSEE**

National Recovery Technologies, Inc. (NRT), with funding provided by EPA's SBIR Program, has developed and commercialized an innovative process for sorting post-consumer plastic containers.

NRT's process is capable of sorting plastics by polymer with high accuracy and at the high-speed throughputs required for cost-effective recycling. Plastics constitute about 9 percent by weight of municipal solid waste, and they occupy approximately one-fourth of the volume of the waste stream. The cost of transporting and disposing of plastics in landfills is very expensive due to their light weight and large volume. In addition, plastics in landfills are highly resistant to degradation. Therefore, the EPA has recommended recycling as the preferred management method for plastics over alternative landfill or incineration methods.

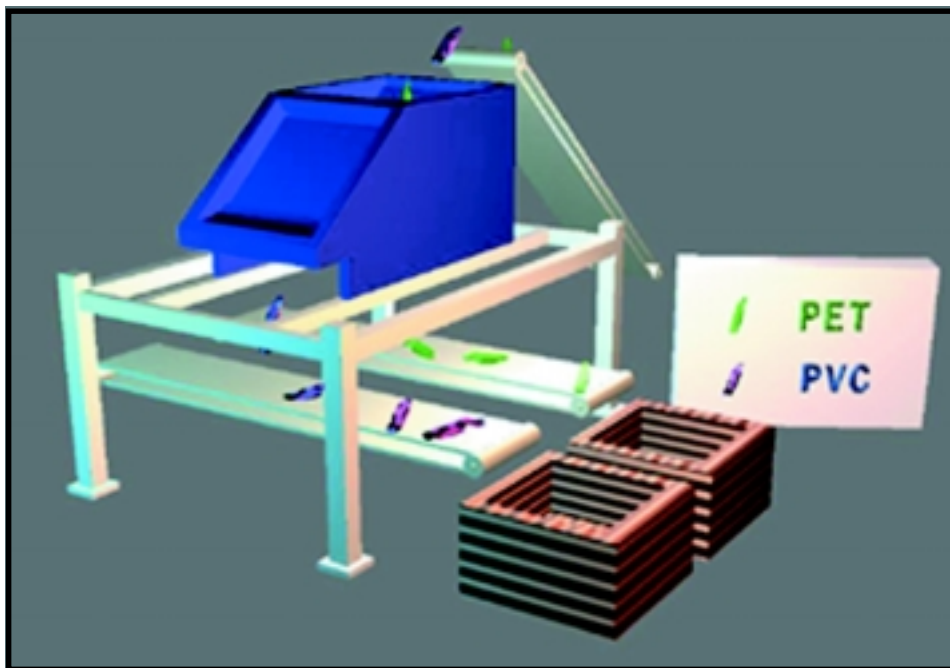
For plastics recycling to be economically viable, the recycled resins must be of high quality and be priced competitively with virgin resins. To produce high-quality recycled resins that can replace virgin resins, it is necessary that the recycled resins be cost-effectively sorted to high-purity specifications. In particular, it is necessary that the plastics be sorted by individual polymer while minimizing processing costs. The new NRT sorting process satisfies these requirements by coupling high-speed

spectroscopy for positive polymer identification, concurrent parallel processing for rapid identification, quick real-time sorting response, and precision air jet selection of materials. Because NRT's sorting process facilitates plastics recycling, it supports EPA's goal to reduce the quantity of waste requiring disposal.

Previously, some post-consumer packaging container resins were sorted automatically according to their visual color characteristics and visual light transmission properties, resulting in a pseudo-polymer sort. However, this is only an approxima-

tion and until the introduction of NRT's technology, it only was possible to sort plastics into a few major constituents and only at relatively low accuracy requiring significant manual sorting for quality control. Another system using expensive x-ray technology currently is used to sort PVC plastics from PET plastics; however, its accuracy is somewhat limited and is not applicable to other polymers.

NRT's new technology overcomes the inaccuracies and limited applicability inherent in existing technologies by providing rapid positive identifica-



NRT's technology facilitates accurate, high-speed sorting of post-consumer resins by polymer type. It couples high-speed spectroscopy for accurate polymer identification with concurrent parallel processing for rapid identification to enable cost-effective sorting to high-purity specification.



tion of plastics by polymer type according to its infrared (IR) spectral fingerprint. Each polymer has a unique IR fingerprint and, therefore, can be readily distinguished and sorted from other polymers.

Current automated systems are complicated and require a high level of technical sophistication to reconfigure system sorting characteristics. Consequently, it has been difficult for operators to control these systems to the level and precision necessary to optimize performance. NRT's technology eliminates this problem by introducing a user friendly man-machine interface, which incorporates a touch screen graphical interface that allows the operator to easily set system sorting parameters and control system operation.

The first two commercial systems were installed recently in U.S. recycling facilities. NRT expects that this innovative sorting system will be applied in the recycling industry worldwide, both in new applications and in replacement of older generation automated sorting systems currently in use.

## SBIR Impact

- **NRT has developed a highly accurate, high-speed process for sorting post-consumer plastics resins by polymer type.**
- **The new technology enables low-cost automated sorting of post-consumer plastics for recycling, which significantly improves the economics for plastics recycling.**
- **NRT's new technology is cost effective for low- and high-volume applications, making automated sorting of plastics affordable for community materials recovery facilities.**
- **The first two commercial systems have been installed at recycling facilities in the United States.**
- **Negotiations are in process for installation of additional units in the United States, Europe, and Japan.**

# NITON XL-309 DUAL DETECTOR LEAD PAINT ANALYZER

**NITON CORPORATION**  
**BEDFORD, MASSACHUSETTS**

NITON Corporation, through the support of EPA's SBIR Program, has developed and commercialized a unique instrument to detect lead in paint that solves the problems encountered with existing x-ray fluorescent analyzers. The NITON XL-309 Dual Detector produces rapid, accurate measurements of lead in paint, independent of the composition, thickness, and substrate (e.g., wall-board, wood, brick) of the paint. The instrument can detect and measure lead even when the lead is below the surface. The NITON Detector is compact, lightweight, and battery operated. It is faster than other analyzers; small enough to fit into wood-work, window wells, pipes, and valves; and has the lowest cost per measurement in the industry.

Lead in paint has been associated with a number of environmental and health risks. Exposure of pregnant women to lead can result in premature birth, low birth weight, or abortion. Lead exposure in infants and young children may lead to decreased intelligence scores, decelerated growth, and hearing problems. Also, exposure of adults and children to high levels of lead may cause brain and kidney damage. The Residential Lead-Based Paint Hazard Reduction Act directed the Department of Housing and Urban Development (HUD), the Occupational Safety and Health Administration (OSHA), and the EPA to establish a

coordinated effort to eliminate lead hazards, including the elimination of lead-based poisoning hazards in federally owned or subsidized housing built before 1978. NITON's device will help detect and subsequently eliminate the health risks associated with lead-based paint.

Historically, accurate measurements of the concentrations of lead in paint have been difficult to obtain because readings from existing analyzers were strongly dependent on the composition and thickness of the substrate. All existing x-ray fluorescence detectors determine the lead concentration by measuring lead x-rays excited by a cobalt source, which is very difficult to shield from external radiation. The NITON Detector uses a cadmium source to enter the lead paint, and the instrument is able to measure the concentration of lead in paint even when covered by layers of nonlead paint of unknown thickness and composition. The NITON method eliminates substrate problems because the background x-rays are far removed and so low that the method is free from the problem of "read-through" (i.e., the measurement of an elevated lead concentration due to the fluorescing of lead on a surface different from the one being examined). Read-through is a common problem with lead measurements of doors and window sashes that are painted on both sides because the high-energy radiations penetrate the wood.

The NITON instrument is able to identify lead buried beneath 15 or more coats of nonlead paint by combining two complementary measures of the lead concentration in paint: (1) NITON's patented silicon diode technique that is independent of substrate and read-through, and (2) a cadmium-zinc-telluride diode that is independent of paint

thickness or paint layering. Combining the strengths and weaknesses of each of the two methods makes the NITON XL-309 instrument an ideal lead detector.

The EPA SBIR funding helped NITON develop and commercialize the XL-309 Dual Detector. It was introduced to the market in October 1996, at LEAD TECH, the annual convention on lead mitigation. In the 2 months following the convention, NITON received more than 70 orders for the XL-309. NITON estimated that sales in 1997 of the XL-309 Dual Detector were three times that of the single detector units sold in 1995.



NITON's XL-309 Dual Detector Lead Paint Analyzer gives a fast accurate reading for the first time on deeply buried lead paint, with no read-through. It is well suited for measuring low levels of lead (i.e., 0.1 to 2.0 mg/cm<sup>2</sup>).

**R&D 100  
and  
Lead Tech  
Product of the Year  
Awards  
1995**



In recognition of its technological innovation, NITON was a finalist for the 1994 Discovery Award and received the prestigious R&D 100 Award in 1995. NITON also received the Lead Tech Product of the Year Award in 1995.



NITON's XL-309 Dual Detector Lead Paint Analyzer fits in window wells, mullions, and decorative molding with a 1 cm x 2 cm window located at the front edge of the XL.

### SBIR Impact

- **NITON has developed and successfully commercialized the NITON XL-309 Dual Detector that produces accurate measurements of lead in paint independent of the composition, thickness, and substrate of the paint.**
- **The NITON XL-309 will help detect and subsequently eliminate the health risks associated with lead-based paint.**
- **In 3 seconds or less, the XL-309 gives a positive HUD action-level reading on paint with a lead concentration of more than 2.0 mg/cm<sup>2</sup> within 95 percent confidence; in 10 seconds or less, it will give a negative HUD reading, with 95 percent confidence, where no lead is present.**
- **Within 2 months of introducing the XL-309 to the market, more than 70 detectors had been ordered. NITON reported that sales in 1997 were three times that of the single detector units sold in 1995.**



# ELECTROLYTIC REGENERATION OF ACID CUPRIC CHLORIDE PRINTED CIRCUIT BOARD ETCHANT

OXLEY RESEARCH, INC.  
NEW HAVEN, CONNECTICUT

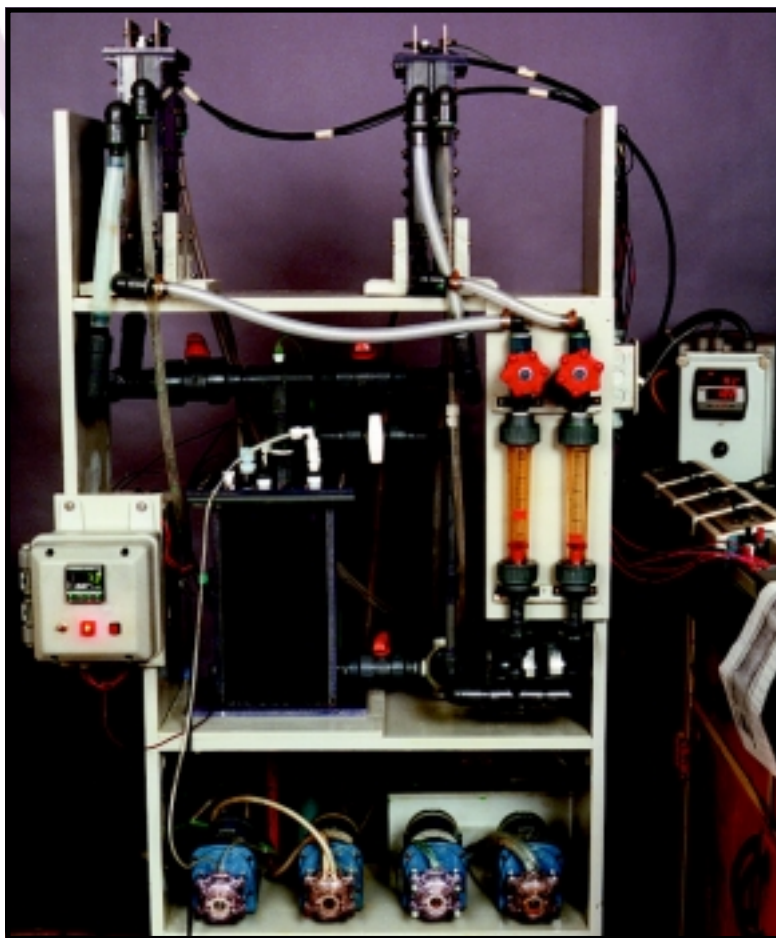
The online electrolytic regeneration process developed by Oxley Research, with funding from EPA's SBIR Program, restores acid cupric chloride etchant used in printed circuit (PC) board production without the use of oxidizing chemicals and without producing excess etchant. In many plants, the spent etchant is the largest waste stream generated. Printed circuit board fabricators in the United States currently dispose of approximately 15 million gallons of excess cupric chloride etchant each year, and that amount is growing at a rate of 12-15 percent annually. The spent etchant is stored in drums and shipped offsite for reclamation; however, transportation of the spent etchant and its ultimate disposition may pose environmental risks and result in increased liability for the manufacturing facility. In addition to eliminating the use of chemical oxidizers and reducing purchases of chemicals to regenerate etchant, Oxley Research's technology allows fabricators to avoid the transportation, reclamation, and disposal costs as well as the potential liability associated with chemical regeneration and excess and spent etchant disposal. It also offers the added cost benefit resulting from the direct sale of the copper

plated out from the etchant. Oxley Research estimates a cost savings of over \$100,000 per year and a payback period of less than 2 years, following installation of the regeneration equipment.

Acid cupric chloride etchant ( $\text{CuCl}_2/\text{HCl}$ ) is used for more than 50 percent of PC board production worldwide. Currently, most PC board fabricators regenerate their etchant solutions chemically, using oxidizers such as chlorine and hydrogen per-

oxide that reoxidize cuprous chloride back to cupric chloride. This produces an increase in etchant inventory because the copper etched off the boards is converted to cupric chloride solution.

During the development of its electrolytic regeneration technology, Oxley Research had to overcome two major obstacles to develop an efficient process for regeneration of acid cupric chloride etchant. These obstacles included: (1) the large



Preprototype-scale acid cupric chloride regenerator system developed by Oxley Research, Inc.

difference in concentrations of cupric and cuprous chloride in the etching solution, and (2) the inherent tendency for copper to plate dendritically from acid cupric chloride solutions. By solving these challenges, Oxley's process led to copper that has both high purity and a substantially better resale value than the dendritic sludges produced by competitive processes. Oxley Research obtained two U.S. patents for its process in 1995 and 1998, respectively.

The goal of the SBIR project was to design, fabricate, and test an engineering prototype of Oxley's regenerator process. Based on feedback from PC board equipment fabricators and users, Oxley determined that the prototype should be a 2.5 kg/hr size unit (approximately one-half commercial size). Oxley's strategy was to partner with an equipment manufacturer that would provide funds for construction and testing of the prototype in consideration of licensing rights. Oxley Research currently is working with a company that has agreed to fund construction and testing of the prototype system as well as provide funding for filing patents for the process in several East Asian countries.

Cost benefits from Oxley's electrolytic regeneration technology will accrue from the following two sources: (1) avoidance of the transportation, chemical, and other costs associated with chemical regeneration and excess etchant disposal; and (2) a direct credit resulting from the sale of copper. Oxley's regenerator cost analysis indicates that at high-end use rates, payback would be less than 2 years. Oxley's marketing goal is to capture one-half of the U.S. market over a 10-year period, which translates to sales of 31 to 45 systems (6 kg/hr size modules) each year.

## SBIR Impact

- **Oxley Research has developed an electrolytic regeneration process that restores acid cupric chloride etchant solutions used in printed circuit board production without the need for chemicals and without producing excess etchant.**
- **Oxley's process eliminates the health and environmental risks associated with chemical regeneration of etchant as well as the transportation and disposal of spent and excess etchant.**
- **This process allows fabricators to avoid the transportation, chemical, and other costs associated with chemical regeneration and excess etchant disposal; another cost benefit results from the direct sale of the copper plated out from the etchant.**
- **Oxley's regenerator cost analysis indicates that at high-end use rates, payback would be less than 2 years.**
- **Oxley's marketing goal is to capture one-half of the U.S. market, which is estimated to be approximately 310 to 450 regenerators, over a 10-year period.**

# MICROLITH® FAST LIGHTOFF CATALYTIC CONVERTERS

PRECISION COMBUSTION, INC.  
NEW HAVEN, CONNECTICUT

Through EPA's SBIR Program, Precision Combustion, Inc., (PCI) has developed the Microlith® Fast Lightoff Catalytic Converter that offers an economical approach to significantly reduce automotive combustion emissions. Motor vehicles are responsible for up to half of the smog-forming VOCs and nitrogen oxides as well as 50 percent of the hazardous air pollutants in the United States. In addition, motor vehicles release up to 90 percent of the carbon monoxide found in urban air. VOCs, carbon monoxide, and nitrogen oxides are regulated by the Clean Air Act as criteria air pollutants. Hydrocarbon emissions are regulated as hazardous air pollutants under the Clean Air Act.

As automotive emissions in the United States become more strictly enforced, there is the need for technological innovation to reduce emissions levels. Current technology for auto emissions control consists of ceramic-based catalytic converters in the exhaust system. Although these catalytic converters are 95 percent effective once they reach operating temperature (after "lightoff"), they are ineffective during the first 1 to 2 minutes following engine startup. As a result, approximately 80 percent of automotive hydrocarbon and carbon monoxide emissions are released during the initial period of a typical drive. Because PCI's Microlith® preconverter helps control these startup emis-

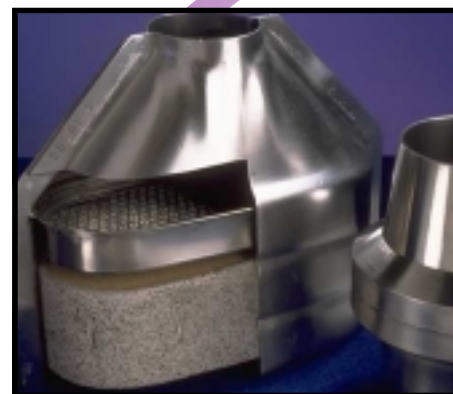
sions, it is capable of achieving an 80 percent reduction in emissions of hydrocarbons and carbon monoxide, and a 50 percent reduction of nitrogen oxide emissions compared to a conventional catalytic converter alone.

PCI's Microlith® catalytic converter includes novel substrate geometry, which offers high mass and heat transfer, together with a complementary coating system. The resulting reactor is small and lightweight and exhibits ultra-rapid thermal response. The improved mass transfer provides high conversion efficiency, allowing substantial reduction in converter volume, weight, and the amount of precious metal required. The high heat transfer and lower weight of the substrate provide very rapid thermal response, reaching inlet gas temperatures within a second.

As a lightoff converter, or preconverter, used in conjunction with a conventional main converter, Microlith® offers the potential for achieving Ultra Low Emission Vehicle (ULEV) performance using a device one-fourth the volume of conventional advanced technology lightoff converters with much less precious metal. PCI also has developed a smaller, less expensive lightoff converter that achieves Low Emission Vehicle (LEV) performance. Compared to current vehicles, the lower emissions achievable with a Microlith® lightoff converter allow passenger cars and light duty trucks to operate with greater than 80 percent reduction of hydrocarbons and carbon monoxide, and 50 percent reduction of nitrogen oxide emissions. The effectiveness and durability of the Microlith® have been demonstrated in prototype tests conducted at the Ford Motor Company (successfully demonstrated ULEV emissions from an Escort), other major auto manufacturers, and automotive

suppliers. Comparative laboratory tests between conventional ceramic monolith and Microlith® substrates have shown that with a 20-fold reduction in converter volume, the Microlith® substrate delivers equivalent mass transfer-limited conversion. The Microlith® catalytic converter also reaches 350° in less than 1/20th the time required for a conventional monolith.

Award of the EPA SBIR contract helped PCI attract substantial industrial investment that has advanced the Microlith® technology along the path of large-scale production. Because commercialization of a technological innovation in the automotive industry typically requires many years and millions of dollars, PCI has focused its efforts on tailoring the technology for specific product application, manufacturing process development, and provision of high-quality samples for testing to potential customers and partners. The United States and Western Europe lightoff converter market is estimated at \$2 billion and 40 million units annually. PCI's commercialization plan includes a joint venture with one or more established automo-



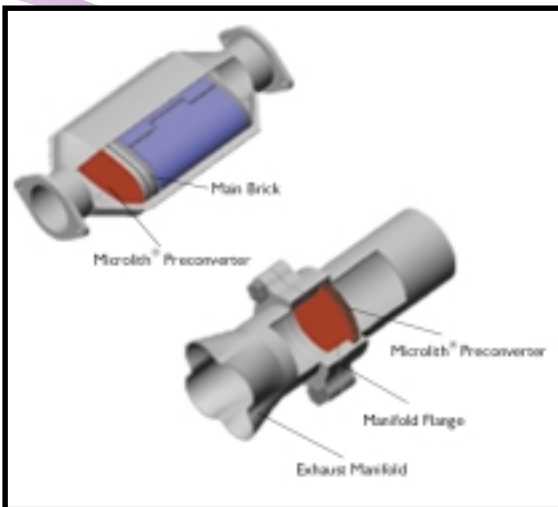
On the left is PCI's automotive Microlith® converter and main converter assembled in an integrated can. To the right is a model of a stand-alone Microlith® automotive preconverter.



tive exhaust component suppliers with the mission of achieving a major market share in the automotive sector. PCI has seven issued patents on this technology and others pending. PCI already has received investment for spinoff applications (e.g., industrial fume abatement, clean burners, etc.) from private industry as well as the National Aeronautics and Space Administration (NASA) and the U.S. Air Force.

In recognition of its significant achievement in developing the Microlith® and other innovative environmental technologies, PCI received EPA's prestigious Environmental Technology Innovator Award in March 1998. Later that year, PCI also was selected as a recipient of the Tibbetts Award and was named as a member of the Connecticut "Fast Fifty," in recognition of its status as one of the fastest growing technology companies in that state.

Tibbetts,  
Environmental  
Technology  
Innovator,  
and  
Connecticut  
"Fast Fifty"  
Awards



One of the advantages of PCI's Microlith® preconverter is its small size, which allows design flexibility in mounting and positioning. Two positions are shown above.

## SBIR Impact

- **PCI has developed the Microlith® Fast Lightoff Catalytic Converter that when used in conjunction with a conventional main converter is capable of achieving a greater than 80 percent reduction in emissions of hydrocarbons and carbon monoxide, and a 50 percent reduction of nitrogen oxide emissions. The Microlith® is substantially smaller in volume and weight than conventional converters and requires considerably less precious metal.**
- **The effectiveness and durability of the Microlith® preconverter have been demonstrated in prototype tests at the Ford Motor Company and other auto manufacturers.**
- **The EPA SBIR award helped PCI attract substantial industrial investment—\$8 for every \$1 of EPA SBIR funding.**
- **PCI's commercialization plan includes a partnership with one or more established automotive exhaust component suppliers with the mission of achieving a major market share; by the year 2005, PCI projects that sales for the Microlith® will be significant.**

# ENVIRONMENTALLY BENIGN OIL ABSORBENT

SEA SWEEP, INC.  
DENVER, COLORADO

Sea Sweep, Inc., with funding provided by EPA's SBIR Program, has developed and commercialized an innovative absorbent called Sea Sweep® that functions both on land and water to absorb spilled oil and chemicals. The absorbent is made using a patented process that involves heating sawdust to a temperature at which the oil-like pyrolysis products render it very attractive to oil (oleophilic), but so repellent to water (hydrophobic), that it floats for many days. It absorbs the oil or chemical immediately upon contact, and will float indefinitely in water, preventing environmental damage to marine life and bird species. Sea Sweep® can absorb up to four times its weight in oils and chemicals in less than 1 minute and it will not leech. Nonsaturated Sea Sweep® is nontoxic, biodegradable, and harmless to microorganisms and wildlife.

There are many absorbents on the market that attract oil and chemicals to their surface, but release them easily (leach), like a mop. Sea Sweep's absorbent is unique in that oils or chemicals are taken into the interior of the particles (an absorbent), like the action of a sponge, where the oil and chemicals are held and do not leach. Sea Sweep® absorbs spilled oils and chemicals, and it is easily retrieved from spill sites, which helps prevent damage to shorelines and beaches. In addition, Sea Sweep® helps bacteria attack the spilled oil or chemical.

SBIR funding enabled Sea Sweep to evaluate the performance of the new absorbent using various types of sawdust to determine which is most effective for absorbing oils and chemicals. Sea Sweep found that softwood sawdust is optimal in performance, availability, and cost. The tests also demonstrated that Sea Sweep® absorbs almost all chemicals, including antifreeze and some strong acids.

In 1993, the Sea Sweep products were selected by R&D Magazine as one of the 100 most technologically significant new products of the year. At the Clean Seas '93 International Conference, Sea Sweep was the only commercial company to be awarded a gold medal "for its praiseworthy efforts in conjunction with the preservation of a Clean Marine Environment." In 1997, Sea Sweep, Inc., received a Gold Medal from the United States Defense Supply Center identifying Sea Sweep® as one of the Center's "Best Value" products.

Oil spills from vessels and facilities (both onshore and offshore) are regulated by the Clean Water Act. Sea Sweep® has been recognized by the EPA in the National Contingency Plan for use in recovering oil spills in U.S. navigable waters. Sea Sweep® also is a listed product on the U.S. Coast Guard National Strike Force Response Resources Inventory. In addition, Sea Sweep's absorbent is licensed by the California State Water Control Board as an oil spill cleanup agent for use in California marine waters.

Internationally, Sea Sweep's absorbent has received approval for use by the United Kingdom River Authority, Thames Region; the Greek Ministry of Merchant Navy, Directorate of Marine Environment Protection and Ministry of Industry, Energy, and Technology; the Chilean Oceanographic Institute and the Chilean Navy; the Ministry of the Environment in Malta; and the Argentina Coast Guard. Sea Sweep® also has received an LR-type approval



Sea Sweep® is used around the world to clean up oil spills of all sizes and can be recycled as a petroleum product. Here, William Mobek prepares a demonstration in Indonesia.

**Clean Seas  
International  
Conference  
Gold Medal  
and R&D 100  
Awards  
1993**



from Lloyds Register of Shipping in London; it is the only spill absorbent to hold this distinction.

Sea Sweep® currently is marketed in the United States, Europe, South America, Australia, New Zealand, Japan, Indonesia, and the Persian Gulf.

## **SBIR Impact**

- **Sea Sweep, Inc., has developed an innovative absorbent that functions both on land and water to absorb spilled oils and chemicals.**
- **Nonsaturated Sea Sweep® is nontoxic, biodegradable, and harmless to microorganisms and wildlife. It is capable of absorbing up to four times its weight of oils and chemicals in less than 1 minute and it will not leach. Sea Sweep® also floats indefinitely making it easy to collect with screens or skimmers.**
- **In 1993, Sea Sweep® was selected by R&D Magazine as one of the 100 most technologically significant new products of the year.**
- **Sea Sweep is licensed by the State of California and has been recognized by the U.S. EPA as an oil spill cleanup agent. It also is a listed product on the U.S. Coast Guard National Strike Force Response Resources Inventory.**



# SURFACE FUNCTIONALIZATION OF PACKAGING FILMS TO PROMOTE ADHESION OF AQUEOUS-BASED INKS

SIGMA TECHNOLOGIES INTERNATIONAL, INC.  
TUCSON, ARIZONA

Sigma Technologies International, Inc., with funding from EPA's SBIR Program, has developed inexpensive, high-speed, inline technology and equipment for treatment (i.e., functionalization) of film surfaces to promote adhesion of solventless and aqueous-based inks. This new technology offers the environmental benefit of reducing the dependence of the packaging film printing industry on solvent-based inks.

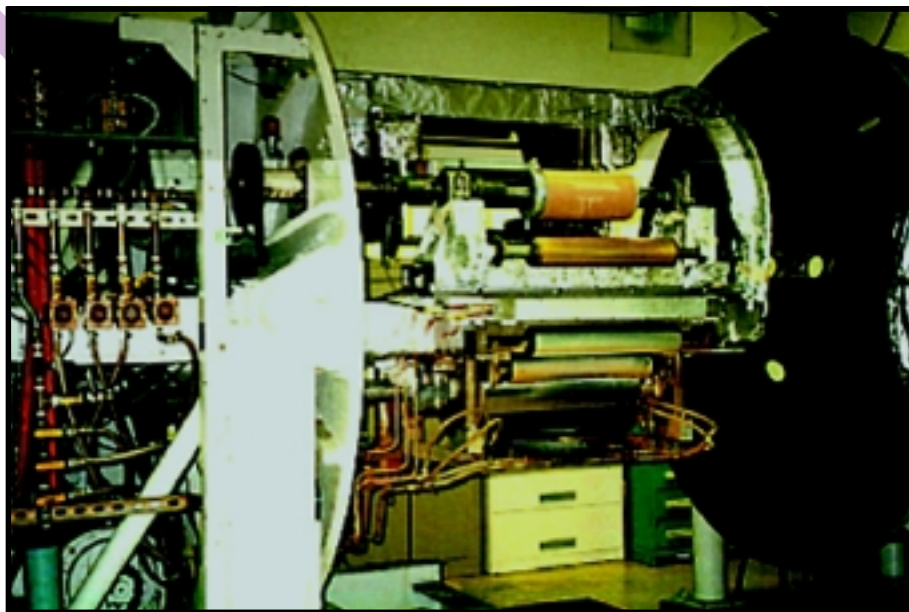
Use of solvent-based inks results in the release of VOCs (particularly toluene) to the atmosphere. Toluene has been near the top of the Toxic Release Inventory list in recent years, with tens of millions of pounds released annually. Solvent-based inks are responsible for approximately 50 percent (by weight) of the VOCs emissions from a typical printer, and VOCs are regulated as criteria air pollutants under the Clean Air Act. Sigma Technologies' surface functionalization technology provides packaging film industry printers and converters with a pollution prevention alternative to the use of solvent-based inks. Use of this technology will eliminate the release of VOCs associated with the use of solvent-based inks. It also eliminates the need to dispose of waste solvent-based inks as hazardous wastes.

Surface functionalization is achieved by an appropriate combination of plasma treatment and thin

(submicron) acrylate coating within a vacuum environment. Functionalization is performed inline at high speed using Sigma Technologies' proprietary equipment. The process begins with plasma treatment of one surface of the plastic film using a moderate energy flux with a suitable gas mixture. As the plastic film continues through the web processing machinery, it can be metalized and coated or coated directly with a very thin layer of an acrylate-based monomer that is 100 percent active (i.e., no solvents). The monomer is depos-

ited on the surface of the plastic film, then passed in front of an electron beam where the monomer is rapidly and completely polymerized. The functionalized film then is ready for printing, labeling, or other processing.

Sigma Technologies also has developed radiation-curable, acrylate monomers that either repel or attract water. Monomer blends can be tailored to meet the specific surface energy requirements of the client.



Sigma Technologies has developed an innovative technology for functionalization of film surfaces to promote adhesion of solventless and aqueous-based inks. This is the vacuum chamber in which most of the surface functionalization experiments are performed.

In addition to eliminating the use of solvent-based inks, Sigma Technologies' surface functionalization process is more efficient for clients who metalize plastic packaging film following plasma treatment. Functionalization of packaging films increases the "sticking coefficient" for the metal in comparison to untreated film. That is, the percentage of the evaporated metal that condenses and adheres to the surface of the film is a little higher for films that have been plasma treated. More efficient metal deposition means less metal is wasted, and waste disposal costs are reduced.

EPA SBIR funding was pivotal to the success of Sigma Technologies' commercialization efforts. The Phase I project helped compile credible data and important findings, which resulted in R&D commitments from clients who are major players in the packaging film industry to run concurrently with the Phase II EPA SBIR effort. The SBIR funding, combined with the private sector efforts, helped Sigma Technologies to overcome technical and financial obstacles during Phase II and to achieve successful commercialization of their equipment design and technology concept.

## SBIR Impact

- **Sigma Technologies has developed inexpensive, high-speed, inline technology and equipment for surface functionalization of plastic film that promotes adhesion of aqueous-based and solventless inks.**
- **The technology eliminates the use of solvent-based inks by packaging film printers, preventing the release of VOCs to the atmosphere as well as the need to dispose of waste solvent-based inks as hazardous wastes.**
- **Functionalization of packaging films increases the metal "sticking coefficient" for metalized plastic packaging film, reducing the amount of metal wasted and the resulting disposal costs.**
- **EPA SBIR funding helped Sigma Technologies obtain R&D commitments from major players in the packaging film industry to accelerate commercialization of this technology.**
- **The acrylate coating technology can be tailored to provide almost any surface energy desired on a plastic film substrate.**

# RP-1 POLYMER IDENTIFICATION SYSTEM FOR SORTING PLASTICS

SPECTRACODE, INC.  
WEST LAFAYETTE, IN

SpectraCode, Inc., was awarded an EPA SBIR contract to develop the RP-1 Polymer Identification System, a laser-based device that will enable recyclers to easily identify and sort a wide range of plastics. The current technology for identifying dismantled plastic materials is slow and dependent on operator accuracy. SpectraCode's RP-1 is a new spectroscopic device that is capable of identifying the chemical composition of plastic parts at rates that could ultimately exceed 100 pieces per second (500 tons per day).

A number of industries are making advances to bring plastic products with high recycle content to market. To succeed, these initiatives need a reliable stream of recovered plastic feedstock. Polymers of different composition are incompatible when melted together. Therefore, cost-effective methods to sort plastics by individual polymer are needed. Because the RP-1 reduces the cost of plastics recycling and improves the purity of recovered product streams, it will help facilitate the recycling of billions of pounds of plastics that are being landfilled or incinerated every year due to the lack of accurate separation that is needed to avoid cross contamination during collection. This

technology supports EPA's goal to reduce the quantity of waste requiring disposal.

The RP-1 system is an industry-ready device for the manual, point-and-shoot identification of plastic components, feedstocks, and plastic scrap. The RP-1 device consists of a hand-held probe, which looks like a hair dryer, connected to a mobile console. The probe illuminates a solid object with a laser and collects the light scattered from the sample, much like a bar-code scanner. The device uses the principle of Raman spectroscopy to read the information encoded in the molecular structure of the plastic itself and thereby identify its chemical composition. When a part is illuminated with the laser output of the probe, it causes the sample's molecules to vibrate. The vibrations in turn cause the light to scatter in a pattern that is specific for each type of plastic. The scattered light is recorded and analyzed by a computer,

which displays the result on a color monitor located on the console. The entire identification cycle requires less than 1 second. By eliminating the need to locate and read resin identification codes, a single RP-1 system could increase a worker's rate of manual sorting by more than a factor of four.

The instrument is simple to use because it has no moving parts and it does not require precleaning, processing, or precise positioning of the plastic waste material. The RP-1 uses SuperFocal imaging of the scattered light from the plastic waste to provide an unsurpassed depth of field (5 mm) that eliminates the need for precise sample alignment. Applications for which the RP-1 was designed include the screening of production and packaging waste and the identification and sorting of commercial and post-consumer plastic waste in community recycling centers and transfer stations.



SpectraCode's RP-1 system is being used to identify the plastic backing on an automobile headlight. This technology can identify plastics so they can be sorted for recycling, including plastics that currently are impossible or difficult to sort.



R&D 100  
Award  
1998



The RP-1 device can be used to sort a wide range of plastics. For example, it can be used to sort plastic components in cars, synthetic fiber resins in carpets, and a number of plastics used in the building and construction industry. It also can be used to sort plastic films such as those found in dry cleaning bags, shrink wrap, and packaging material. Only a small fraction of these materials currently are recycled, primarily because of the difficulties identifying and separating the various types of plastics. With simple user modification, SpectraCode's device can be used for manual process control as a probe for feedstock identity and purity.

SpectraCode has installed RP-1 systems at two large-scale recycle facilities and in the Detroit Vehicle Recycling Development Center, a joint research facility of General Motors, Ford, and Chrysler. Ford Motor Company's automotive component operations, now known as Visteon, has supported development of the RP-1 and is using the product in its recycling efforts. About 75 percent of the typical Ford vehicle is recyclable at the end of its working life and the company believes that the RP-1 device will help increase that percentage in the future. SpectraCode is marketing the RP-1 to other automobile manufacturers and large-scale recyclers as well as plastic molders and resin formulators that can use the diagnostic capabilities of the RP-1 for process control.

In recognition of SpectraCode's technological achievement, the RP-1 device was named one of the 100 most technologically significant products and processes of 1998 by R&D Magazine.

## SBIR Impact

- **SpectraCode has successfully developed and commercialized the RP-1, a laser-based device that is capable of identifying the chemical composition of plastic parts at rates that could exceed 100 pieces per second (500 tons per day).**
- **The RP-1 device will help facilitate the recycling of billions of pounds of plastics that are being landfilled or incinerated every year. It supports EPA's goal to reduce the quantity of wastes requiring disposal.**
- **The RP-1 system has added value to plastic recycling processes by reducing manpower costs and improving the purity of recovered product streams.**
- **SpectraCode's RP-1 currently is used for automotive component recycling and is slated for introduction as a new-parts process-control diagnostic by a major manufacturer of injection-molded plastic components.**
- **In 1998, R&D Magazine selected SpectraCode's device as one of the year's 100 most technologically significant products.**

# SELENIUM REMOVAL FROM REFINERY WASTEWATERS

TDA RESEARCH, INC.

WHEAT RIDGE, COLORADO

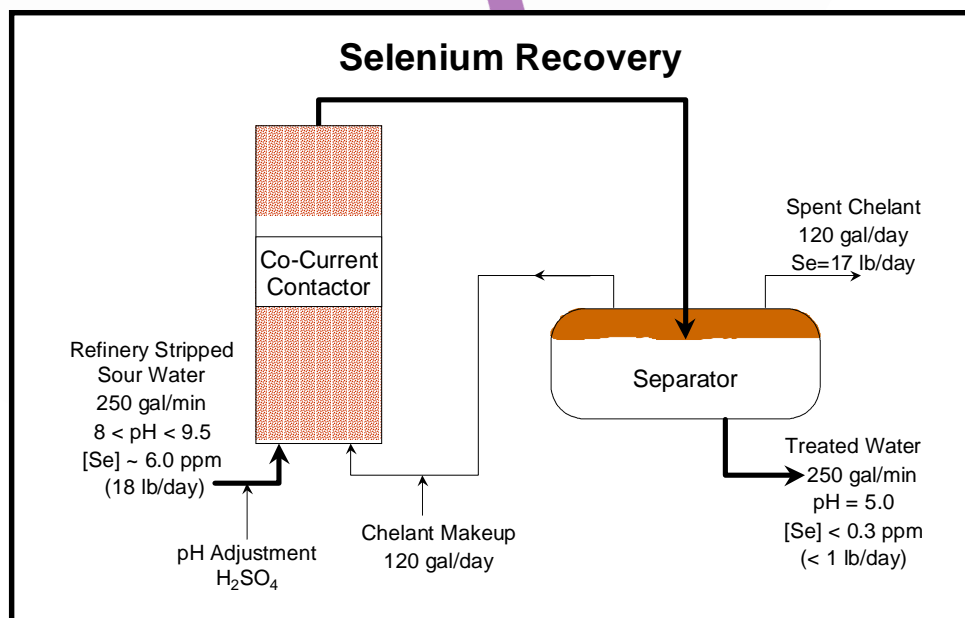
TDA Research, Inc. (TDA), with funding provided by EPA's SBIR Program, has developed and commercialized a process for the effective removal of selenium from petroleum refinery wastewaters. According to the Toxic Release Inventory, selenium releases to land and water totaled over 1 million pounds from 1987 to 1993. Petroleum refinery wastewaters are among the largest sources of selenium-contaminated waters in the San Francisco Bay area because of the types of crude oil processed in these refineries. Portions of the San Francisco Bay estuary have been classified by the EPA as impaired due to the presence of selenium and its toxic effects on waterfowl. Selenium is known to accumulate in living tissues and can cause human health effects at exposures above the Maximum Contaminant Level of 0.05 ppm. As a result, the San Francisco Bay Regional Water Quality Control Board has set the selenium discharge limit for petroleum refineries to 0.05 ppm. Conventional iron co-precipitation has been used on the end-of-pipe combined biotreated refinery effluent (which has not been effective in meeting this limit). One of the primary sources of selenium in refinery wastewaters is from sour water streams. TDA's process was developed specifically for the treatment of petroleum refinery stripped sour water prior to its combining with other wastewater streams in the biological treatment system. Annual operating costs for TDA's process are about the same as co-precipitation;

however, TDA's technology realizes a savings in capital costs of approximately 85-90 percent and generates 1/100 the waste of conventional iron co-precipitation.

The oxidation state of selenium depends on the particular refinery process stream and ranges from the reduced selenocyanate in stripped sour water streams to the oxidized selenite and selenate in the combined biotreated effluent. This poses a particular problem in removing selenium from refinery wastewaters because the efficacy of the treatment process is highly dependent on the oxidation state of selenium. Although conventional iron co-precipitation is 80-90 percent effective on selenite, it is ineffective on selenocyanate and selenate.

TDA's process to remove selenium from stripped sour water addresses these limitations of current technology. The process involves mixing the stripped sour water with an organic soluble chelant that is highly selective for selenocyanate. The chelant binds the selenium and removes it to the organic phase, where it can be recovered by conventional oil recovery techniques. The selenium-loaded organic chelant can be managed in a number of ways including disposal in a liquid fuels disposal program.

The economics of TDA's process are competitive with conventional iron co-precipitation approaches. For example, a TDA system sized to treat a 250 gallon per minute (gpm) refinery stripped sour water stream containing 6 ppm of selenium would



TDA Research's extraction process effectively removes selenium from refinery stripped sour water, which is one of the primary sources of selenium in refinery wastewaters. The process involves mixing the stripped sour water with an organic soluble chelant that is highly selective for selenocyanate. The chelant binds the selenium and removes it to the organic phase, where it can be recovered using conventional oil recovery techniques.

cost less than \$2.5 million in capital expenditure and approximately \$1 million in annual operating costs. By comparison, due to its ineffectiveness on selenocyanate, an iron co-precipitation process at the end of the pipe would have to be sized to treat a 1,500 gpm final biotreated effluent containing 1 ppm of selenium. Such a system would cost \$15-25 million in capital expenditure and approximately \$1 million in annual operating costs.

The real advantage of the TDA process is in the reduced amount of waste generation that requires final disposal. The iron co-precipitation process would generate approximately 90 tons/day of sludge that would need stabilization prior to disposal in a California Class I hazardous waste landfill. The TDA process, on the other hand, would generate approximately 0.5 ton/day of a spent liquid organic that could be managed in many less expensive ways.

In 1997, TDA commercialized its technology for the removal of selenium from refinery wastewaters. This technology was implemented at a California refinery where it was used to deal successfully with a major spike in selenium discharge that would have shut down the refinery within 3 days if it had not been controlled.

## SBIR Impact

- **TDA's process effectively removes selenium from petroleum refinery wastewaters, enabling refineries in the San Francisco Bay area to comply with the 0.05 ppm selenium discharge limit established by the San Francisco Regional Water Quality Control Board.**
- **TDA's process can be implemented with an 85-90 percent savings on capital costs compared to conventional iron co-precipitation.**
- **TDA's process significantly reduces the amount of waste that requires final disposal. Iron co-precipitation would generate about 90 tons/day of sludge that would require stabilization prior to disposal in a hazardous waste landfill. The TDA process would generate only 0.5 ton/day of a spent liquid that could be managed in many less expensive ways**
- **TDA has installed this technology at one California refinery and is actively marketing the process to other petroleum refineries.**





## Appendix: EPA's SBIR Program

**T**he 1982 Small Business Innovation Development Act created the SBIR Program to leverage the ingenuity and wealth of resources available in small companies, and their ability to transform research and development results into new products. The Act noted that, while small business is the principal source of significant innovation in the United States, the vast majority of federally funded R&D is conducted by large businesses, universities, and government laboratories. According to a Bureau of the Census survey, small firms receive only 11 percent of their R&D funds from the federal government, as compared to the 26 percent received by large companies. The SBIR Program is designed to redirect some of this federal funding to the small business community.

**T**he basic purpose of the Act was to strengthen the role of small enterprises in federally funded R&D and thus help the Nation develop a stronger base for technical innovation and wider commercialization of the ideas generated in the laboratories, research facilities, and factory floors of small hi-tech companies.

**A**gencies participating in the Program are required to issue a solicitation that sets the SBIR process in motion. The solicitation lists and describes the research topics to be addressed and invites companies to submit their proposals for consideration. Each of the 10 federal agencies participating in the SBIR Program issues annual solicitations for Phase I and Phase II pro-

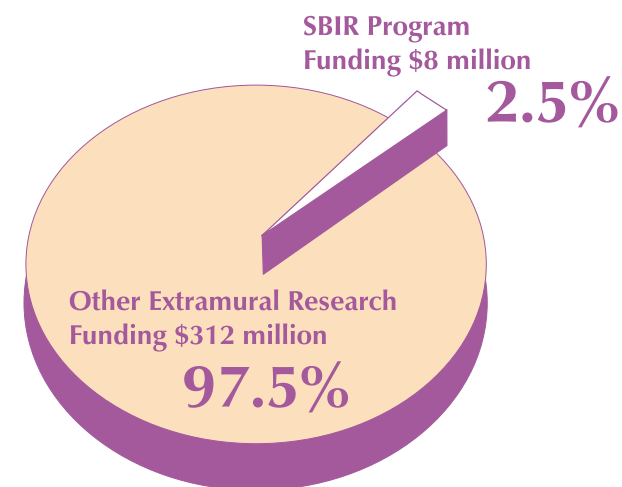
posals. Under Phase I of EPA's SBIR Program, small science and technology-based firms investigate the scientific merit and technical feasibility of the proposed technology. EPA awards firm-fixed-price Phase I contracts of up to \$70,000 and the period of performance for these contracts is typically 6 months. Through this phased approach to SBIR funding, EPA can determine whether the research idea, often on high-risk advanced concepts, is technically feasible, whether the firm can do high-quality research, and whether sufficient progress has been made to justify funding a larger Phase II effort.

**P**hase II contracts are limited to small businesses that have successfully completed their Phase I contracts. The objective of Phase II is to further develop the concept proven feasible in Phase I and complete the R&D required to commercialize the technology or product. Competitive awards are based on the results of Phase I and the scientific and technical merit and commercialization potential of the Phase II proposal. Under Phase II, EPA can award contracts of up to \$295,000 and the period of performance is typically 2 years. Companies that receive Phase II contracts can request additional funds from EPA if they are able to leverage third-party financial support to accelerate commercialization during Phase II.

**T**he EPA SBIR Program is funded by setting aside 2.5 percent of the Agency's extramural research budget each year. EPA's SBIR budget is approximately \$8 million and the Agency expects to award about 40-50 Phase I contracts and 15-20 Phase II contracts every year.

**F**PA issues its Phase I solicitation once each year. This solicitation, which is available electronically on the Internet and in hardcopy by mail, identifies the relevant research topics that should be addressed by companies responding to the request for proposals. The proposed research must address a single research topic, or an important segment of a topic, described in the EPA SBIR solicitation.

DISTRIBUTION OF EPA'S EXTRAMURAL  
RESEARCH BUDGET



## EPA SBIR PROGRAM PROPOSAL AND AWARD DATA (1990-1998)

### *SBIR Award Profile (Dollars in Thousands)*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Total Amount of Phase I Awards	\$1,586	\$1,522	\$2,041	\$1,699	\$1,905	\$3,027	\$1,934	\$2,444	\$2,583	\$18,741
Total Amount of Phase II Awards	\$1,649	\$2,099	\$2,250	\$3,148	\$2,950	\$4,151	\$2,924	\$3,149	\$2,246	\$24,566

### *Agency Solicitation Profile*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
Number of Phase I Proposals Received	434	367	427	442	382	476	338	393	326	3,585
Number of Phase I Awards	32(7%)	31(8%)	41(10%)	34(8%)	35(9%)	47(10%)	28(8%)	35(9%)	37(11%)	320
Number of Phase II Proposals Received	24	28	27	41	29	27	41	24	30	271
Number of Phase II Awards	11(46%)	14(50%)	15(56%)	21(51%)	18(62%)	19(70%)	13(32%)	14(58%)	10(33%)	135



**T**he annual EPA SBIR solicitation typically includes the following research topic areas:

### DRINKING WATER TREATMENT

Development of innovative techniques for removing organic and inorganic contaminants (e.g., ammonium perchlorate, pesticides, arsenic, nitrate, sulfate), particulates, pathogens, and emerging pathogens; removing pathogenic microorganisms; removing or preventing disinfection byproduct precursors; controlling pathogens; maintaining water quality between the treatment plant and user; and managing residuals from drinking water treatment.

### MUNICIPAL WASTEWATER TREATMENT, SEPTAGE, AND BIOSOLIDS MANAGEMENT

Development of techniques and technologies to improve existing municipal wastewater treatment processes as well as treatment and management of septage and sewage sludge, particularly those that enhance the reliability, efficiency, and cost-effectiveness of existing processes.

### INDUSTRIAL WASTEWATER TREATMENT

Development of innovative methods to improve existing industrial wastewater processes, contain and treat uncontrolled air and un-sewered wastewater from animal waste, manage runoff from mine wastes, treat drainage from abandoned factories and coal mines, treat and dispose of liquid dye baths from textile finishing operations, monitor and treat bilge/ballast water within vessels, and treat and recycle animal manure.

### STORMWATER MANAGEMENT AND WET WEATHER POLLUTION CONTROL

Development of innovative methods to treat and control stormwater runoff, including cost-effective technologies for preventing toxic pollutants from entering storm or combined sewer/drainage systems, monitoring technologies and equipment to measure the characteristics and impacts of wet weather flows (WWF), and high-rate and high-efficiency treatment technologies for existing and new wastewater treatment plants.

### REHABILITATION OF URBAN INFRASTRUCTURE SYSTEMS

Development of innovative techniques to repair and maintain water distribution and sewerage systems, including new sewer materials and techniques for sewer construction and maintenance; technologies to construct, maintain, and repair new and existing urban utility and water distribution systems infrastructure; and new pipe materials, relining techniques, and innovative materials for water distribution systems.

### PREVENTION AND CONTROL OF INDOOR AIR POLLUTION

Development of methods to determine the nature of indoor air emissions and how they contribute to human exposure as well as cost-effective tools, techniques, and technologies to prevent or reduce individual exposure to indoor air pollutants. Areas of interest include: methods to prevent biocontaminant growth in the indoor environment; techniques to prevent/avoid dermal and/or ingestive exposure

to hazardous chemicals on surfaces in the indoor environment; improved air cleaners that remove volatile organic compounds and small particulates; improved air filters for heating, ventilating, and air conditioning systems; techniques for conditioning outdoor ventilation air; and new products that reduce availability of harmful contaminants in the indoor environment.

### PREVENTION AND CONTROL OF NO<sub>x</sub>, VOCs, SO<sub>2</sub>, AND TOXIC AIR EMISSIONS

Development of innovative, cost-effective techniques that prevent or control emissions of nitrogen oxides (NO<sub>x</sub>), fine particles, volatile organic compounds (VOCs), sulfur dioxide, or toxic air pollutants from stationary or mobile sources. Of particular interest to EPA are approaches and systems that can be used to control combinations of these pollutants.

### RECYCLING OF MUNICIPAL SOLID WASTE

Development of innovative methods for the collection, separation, and processing of recyclable materials into usable goods. Areas of interest include: storage, collection, and transport of recyclables from residences and commercial locations; processes to separate recyclables and to remove contaminants from recyclable materials; onsite and en route processing of recyclables; technologies for improving quality control for recyclable materials; alternative/new uses and products for recyclable materials; innovative recycling of organics; and redesigning of products to enhance their recyclability.

### TREATMENT, RECYCLING, AND DISPOSAL OF HAZARDOUS AND NONHAZARDOUS SOLID WASTES AND SEDIMENTS

Development of innovative approaches to manage solid waste and sediments, including improved treatment and disposal methods, innovative techniques to prevent or detoxify wastes prior to disposal, recovery and recycling techniques, and methods for improved operation and control of high-temperature waste combustion incinerators.

### REMEDIATION OF CONTAMINATED SOIL, SEDIMENTS, AND GROUNDWATER

Development of innovative, cost-effective methods for the treatment or extraction of hazardous waste contaminants, using physical, chemical, or biological techniques. Areas of interest include: chemical detoxification; physical methods for subsurface mixing to enhance mobilization and mass transfer; biotreatment methods; *in situ* treatment of soils, sediments, and sludges; improved methods for treatment of heavy metals by reducing their bioavailability in soils; approaches for detecting, degrading, and removing dense nonaqueous phase liquids (DNAPLs) from groundwater; and improved nutrient and chemical reagent delivery systems for biological or chemical methods.

### POLLUTION PREVENTION AND CLEAN TECHNOLOGIES

Development of innovative techniques to: (1) reduce the amount of hazardous substances or pollutants entering any waste stream or otherwise released to the environment prior to recycling, treatment, or disposal; and (2) reduce the hazards to public health and the environment associated with such releases. Areas of interest include: in-process recycling techniques, cost-effective

methods to separate useful materials from other components in a process stream, new bulk materials and coatings with long life and reduced environmental impact, improved sensor and multivariate control of manufacturing equipment and systems to reduce waste and emissions, and changes in the composition of end products that facilitate changes in the manufacturing process or use of raw materials, or result in a reduced environmental impact from use and/or disposal.

### ADVANCED MONITORING AND ANALYTICAL TECHNOLOGIES

Development of more accurate, cost-effective approaches to environmental monitoring and measuring, including portable measurement technologies that can be used in the field, improved measurement of microbial pathogens in drinking water systems, improved measurement of disinfection byproducts, and devices to yield continuous data in pollutant concentrations in environmental media (including remote sensing devices).

### TECHNOLOGIES AND ALTERNATIVES FOR OZONE-DEPLETING COMPOUNDS

Development of safer alternatives to substances that harm the stratospheric ozone layer, including better and more efficient fire suppressants and systems, more reliable fire detection methods, alternatives to ozone-depleting adhesives and coating removers, and low-temperature refrigerants or alternative technologies.

### GLOBAL CLIMATE CHANGE

Development of innovative methods to prevent and control releases of greenhouse gas (GHG) emissions such as methane, carbon dioxide, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and

sulfur hexafluoride. Areas of interest include: new, environmentally safe chemicals and intelligent controls to reduce GHG emissions; techniques to reduce, detect, collect, and utilize waste methane; improved instruments and methods to measure GHG emissions; improved control of aluminum production to reduce perfluorocarbon emissions; improved processes for utilizing biomass or other renewable energy sources; and new insulation materials or processes to replace uses of sulfur hexafluoride.

**F**rom FY 1990 to FY 1998, EPA awarded 455 SBIR contracts to fund research and development at small businesses across the country. Of these 455 SBIR awards, 320 were Phase I contracts totaling \$18.7 million, and 135 were Phase II contracts totaling \$24.6 million. Some of the Program's notable accomplishments are described in the following paragraphs.

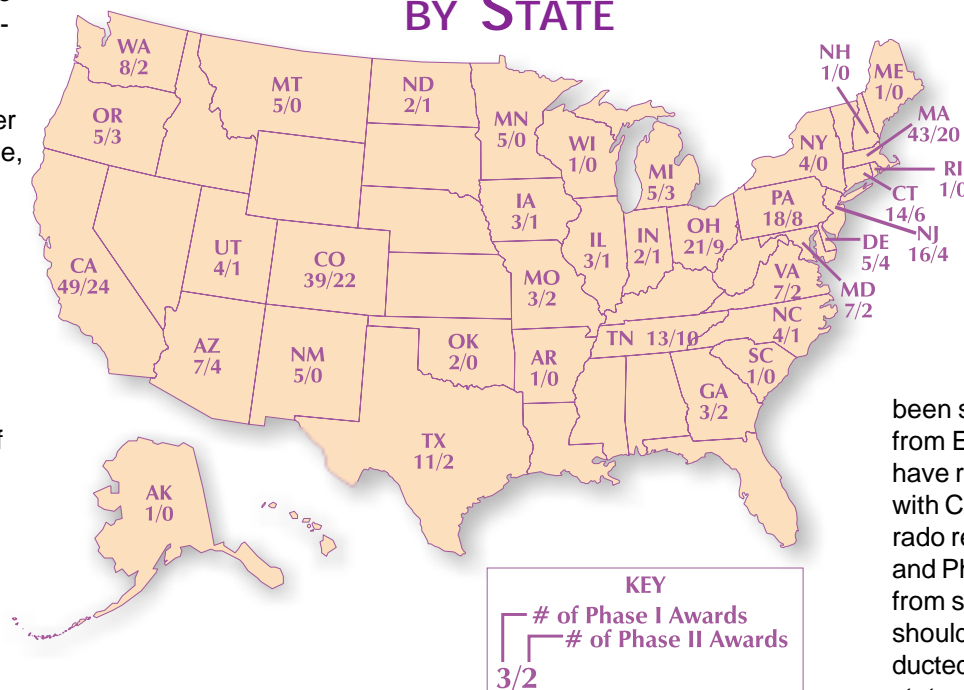
**A**n ever-increasing number of SBIR participants are succeeding in commercializing their new products and technologies. In addition to the 17 technology success stories described in this report, about 30 additional SBIR-developed technologies are expected to be commercialized in the near future. This is consistent with the results of studies conducted by the Small Business Administration and the General Accounting Office. These studies have indicated that one in four SBIR participants commercialize their technologies within 6 years of receiving their Phase II SBIR awards. These technologies have yielded millions of dollars in revenue for small developers, with the added benefits of creating jobs, stimulating economic growth, and enhancing U.S. competitiveness in the environmental technology industry.

**T**he innovative technologies and products that have been developed with the assistance of EPA's SBIR Program are:

- Helping companies comply with increasingly stringent emissions standards,
- Allowing firms to avoid the use of toxic and hazardous materials in production processes,
- Enabling companies to recover and recycle materials for reuse, and
- Providing companies the option of selecting environmentally friendly products.

**E**PA's SBIR awardees have received a number of prestigious awards in recognition of their innovation, accomplishments, and contributions to society. These awards include the R&D 100 Award, the Tibbitts Award, the Discovery Award, Popular Science's Best of What's New Award, the Lead Tech Product of the Year Award, the Governor's Award for Energy Efficiency, EPA's Outstanding Small Business Enterprise Award, EPA's Environmental Technology Innovator Award, the New Englander Award, the Massachusetts Small Business Innovation Research Award, and the Connecticut Technology "Fast Fifty" Award.

## GEOGRAPHIC DISTRIBUTION OF EPA SBIR AWARDS (FY1990-FY1998) BY STATE



SBIR Phase I Awards for FY1990-FY1998	320	\$18.74 million
SBIR Phase II Awards for FY1990-FY1998	135	\$24.57 million

**E**PA's SBIR Program is highly competitive. Due mainly to limited funds, only about 10 percent of the small businesses submitting Phase I proposals to the Agency are awarded an SBIR contract. From 1992 to 1997, 79 of 113 companies awarded Phase I contracts were newcomers to EPA's SBIR Program. **In 1998, 20 of 37 companies were newcomers to the Program.** Over the past 6 years, an average of 87 percent of the small companies receiving a Phase I award from EPA submitted a Phase II proposal. Of these companies submitting Phase II proposals, an average of about 50 percent receive Phase II awards.

**D**espite rigorous competition, hundreds of small firms from across the country have been successful in winning SBIR contracts from EPA. Companies in 36 different states have received EPA SBIR awards since 1990, with California, Massachusetts, and Colorado receiving the largest number of Phase I and Phase II awards. However, companies from states with few or no SBIR awards should not be discouraged. EPA has conducted new outreach efforts aimed at those states to encourage more small firms to participate in the Agency's SBIR Program.





## SBIR Program Contacts

The EPA SBIR Program is managed by the Environmental Engineering Research Division (EERD) of the National Center for Environmental Research and Quality Assurance (NCERQA) within EPA's Office of Research and Development. For information on the Program, contact:

### PROGRAM REPRESENTATIVES

Jim Gallup  
Tel: (202) 564-6823  
Fax: (202) 565-2447  
Email: [gallup.jim@epa.gov](mailto:gallup.jim@epa.gov)

Marshall Dick  
Tel: (202) 564-6828  
Fax: (202) 565-2447  
Email: [dick.marshall@epa.gov](mailto:dick.marshall@epa.gov)

Michael Bender  
Tel: (202) 564-6829  
Fax: (202) 565-2447  
Email: [bender.michael@epa.gov](mailto:bender.michael@epa.gov)

Stephen A. Lingle  
Director, Environmental Engineering  
Research Division  
Tel: (202) 564-6820  
Fax: (202) 565-2446  
Email: [lingle.stephen@epa.gov](mailto:lingle.stephen@epa.gov)

### EPA SBIR SOLICITATIONS

NCERQA Web Site at  
<http://www.epa.gov/ncerqa> (select Small Business)  
or  
EPA Helpline 1-800-490-9194  
or  
Contracts Management Division (MD-33)  
U.S. Environmental Protection Agency  
Research Triangle Park, NC 27711

### EPA SBIR PROJECT ABSTRACTS

NCERQA Web Site (abstracts for past 5 years) at  
<http://www.epa.gov/ncerqa> (select Small Business)  
or  
FEDRIP (abstracts from 1982 to present)  
Tel: (703) 487-4929

### FOR INFORMATION ON SBA'S RESOURCES FOR SBIR Awardees CONTACT:

U.S. Small Business Administration  
Office of Technology  
409 Third Street, SW  
Washington, DC 20416  
Tel: (202) 205-6450  
<http://www.sba.gov/SBIR/sbir.html>

This report was prepared for the Engineering Research Division of the National Center for Environmental Research and Quality Assurance (NCERQA) under Contract No. 68-D7-0010.