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.

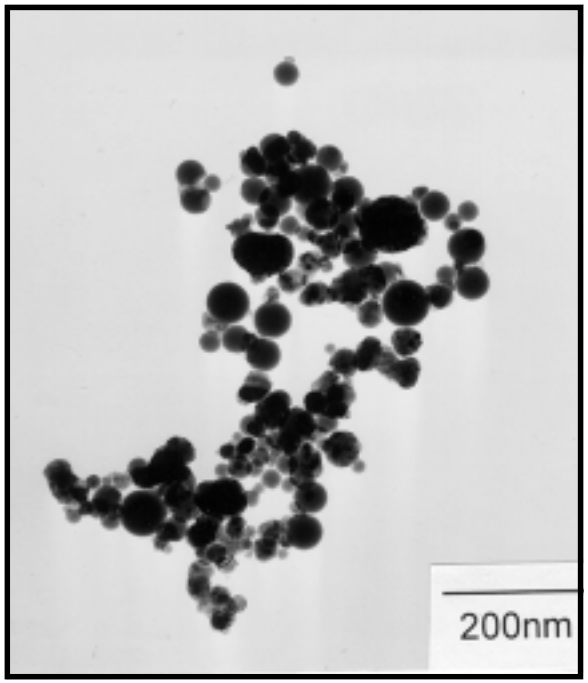
The performance ceramics industry produces and sells more than $18 billion of ceramic products annually and is one of the fastest growing segments of all industries listed in the Standard Industrial Classification (SIC) coding system. The performance ceramics industry is enabling growth within the electronics, 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.

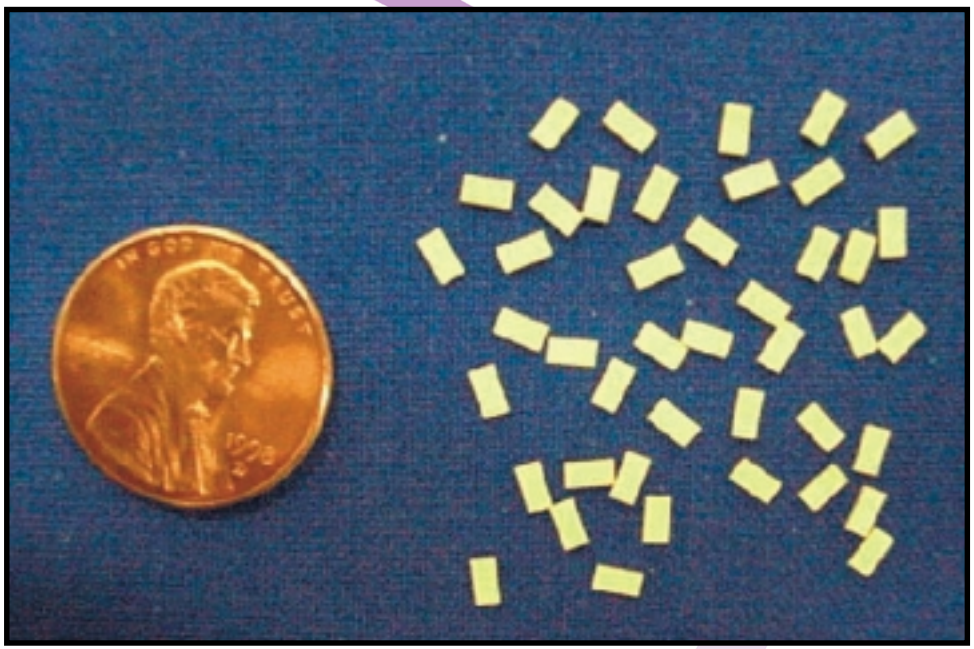
NRC's manufacturing method for performance ceramics offers the following advantages over conventional techniques: (1) it eliminates the formation of secondary gaseous, liquid, or solid wastes; (2) it reduces the processing, containment, and treatment of solvents and resulting vapors by more than 10 fold; (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

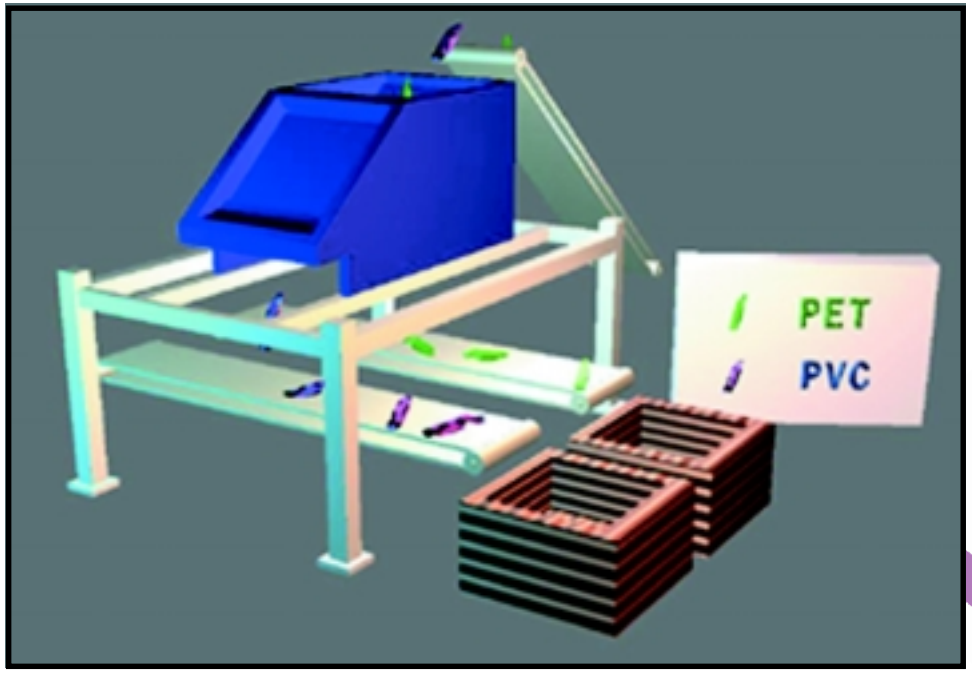
National Recovery Technologies, Inc.
Nashville, Tennessee

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 approximation 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., wallboard, 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 woodwork, 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^2).

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^2 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.**

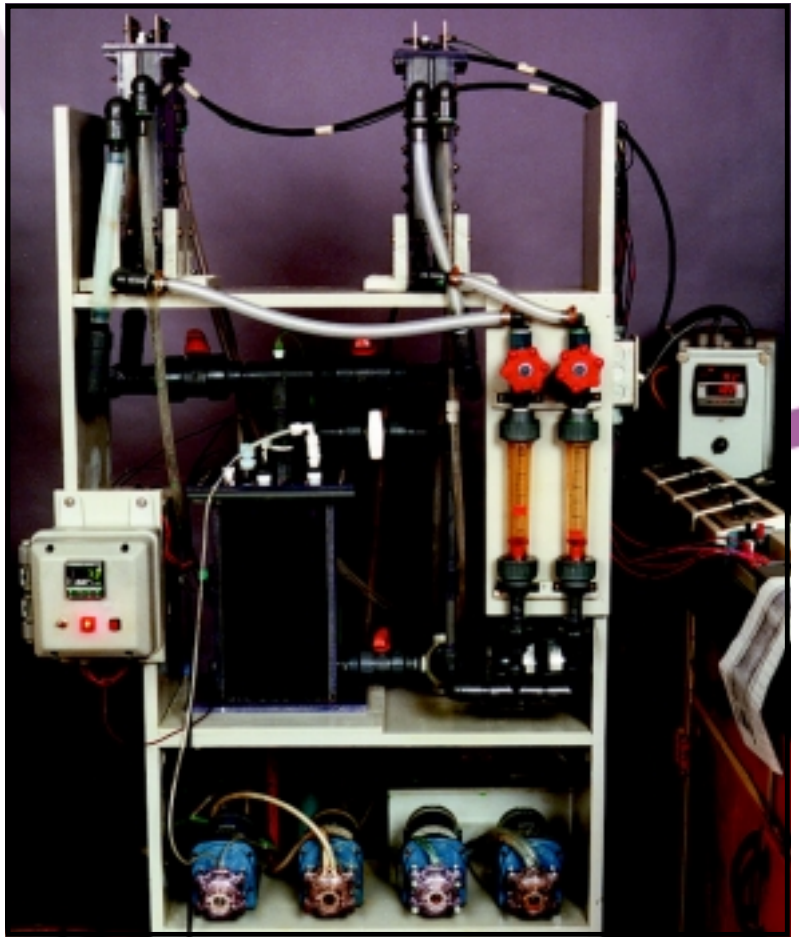
Electrolytic Regeneration of Acid Cupric Chloride Printed Circuit Board Etchant

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 ($CuCl_2$/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 peroxide 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

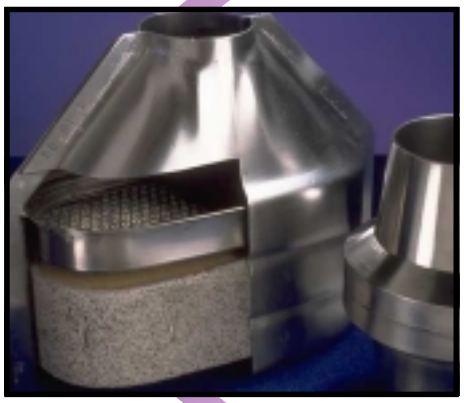
Through EPA's SBIR Program, Precision Combustion, Inc., (PCI) has developed the Microlith® Fast Lightoff Catalytic Converter that offers an economical approach to significantly reduce automotive combustion emissions. Motor vehicles are responsible for up to half of the smog-forming VOCs and nitrogen 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 emissions, 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 350º in less than 1/20th the time required for a conventional monolith.

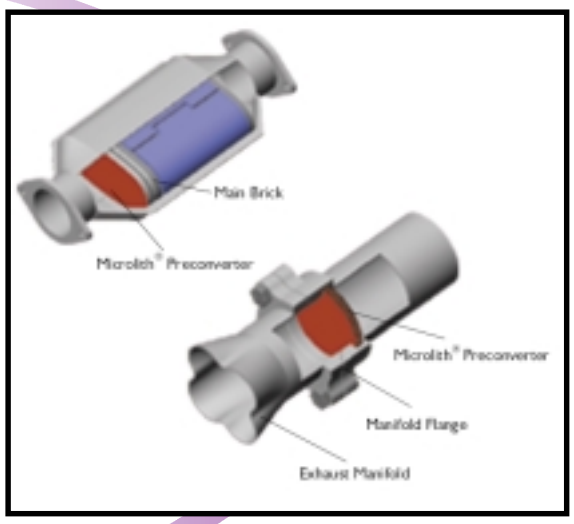
Award of the EPA SBIR contract helped PCI attract substantial industrial investment that has advanced the Microlith® technology along the path of large-scale production. Because commercialization of a technological innovation in the automotive industry typically requires many years and millions of dollars, 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.



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 (oleophylic), 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. SeaSweep® 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

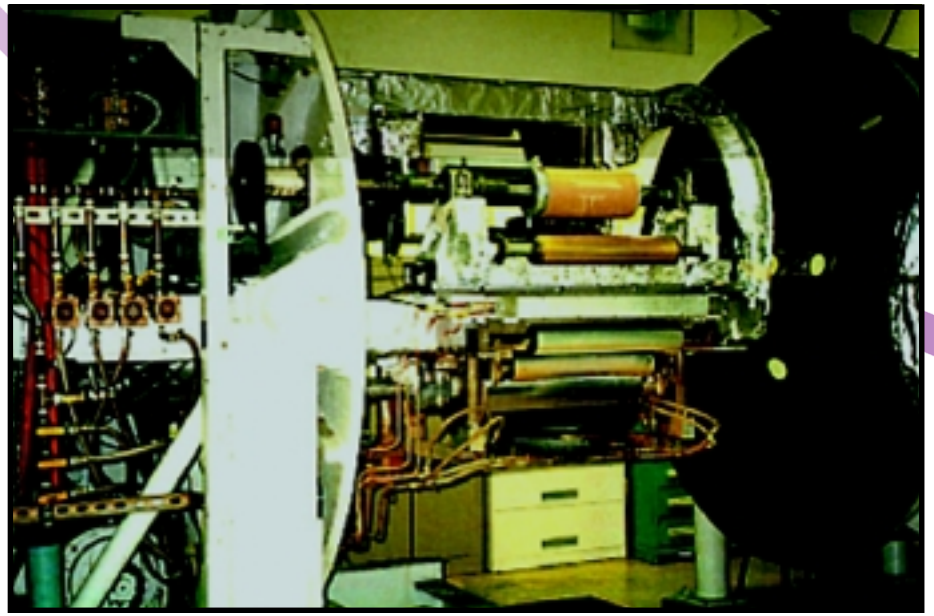
Sigma Technologies International, Inc.
Tucson, Arizona

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 deposited 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.

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

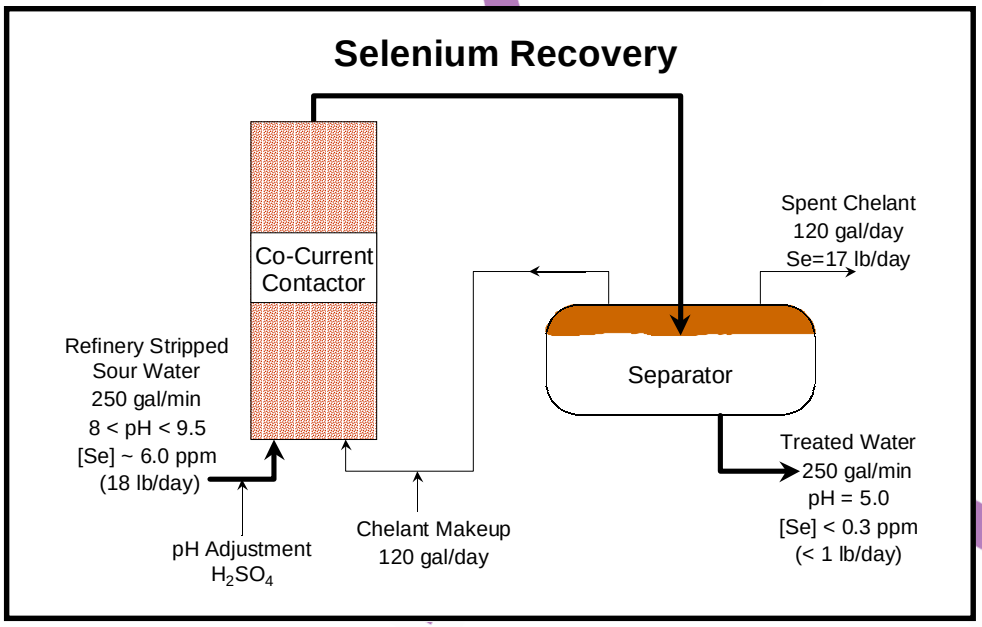
TDA Research, Inc.
Wheat Ridge, Colorado

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

The 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.

The 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.

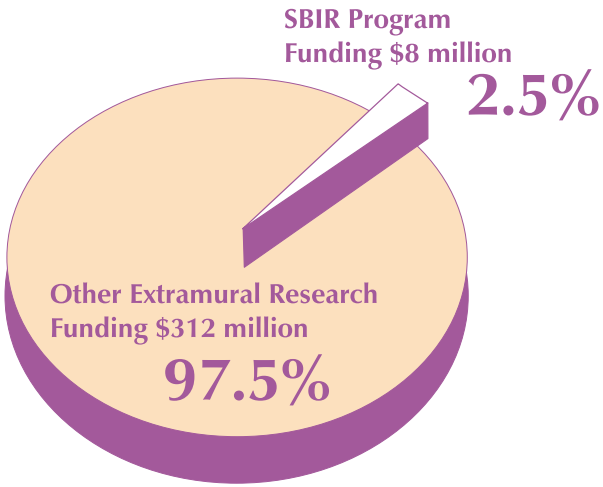
Agencies participating in the Program are required to issue a solicitation that sets the SBIR process in motion. The solicitation lists and describes the research topics to be addressed and invites companies to submit their proposals for consideration. Each of the 10 federal agencies participating in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

Phase 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.

The 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.

EPA 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

The 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_x, VOCs, SO_2, and Toxic Air Emissions

Development of innovative, cost-effective techniques that prevent or control emissions of nitrogen oxides (NO_x), 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 recclables; 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-depleteing 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.

From 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.

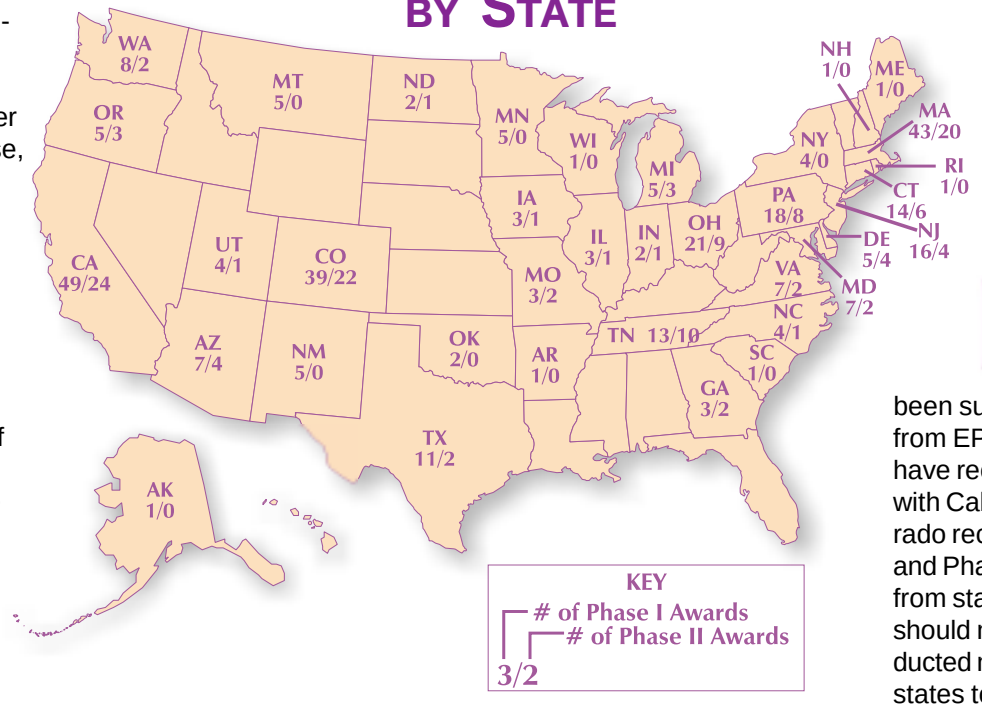
An ever-increasing number of SBIR participants are succeeding in commercializing their new products and technologies. In addition to the 17 technology success stories described in this report, about 30 additional SBIR-developed technologies are expected to be commercialized in the near future. This is 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.

The 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.

EPA'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

EPA'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.

Despite 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:

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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

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