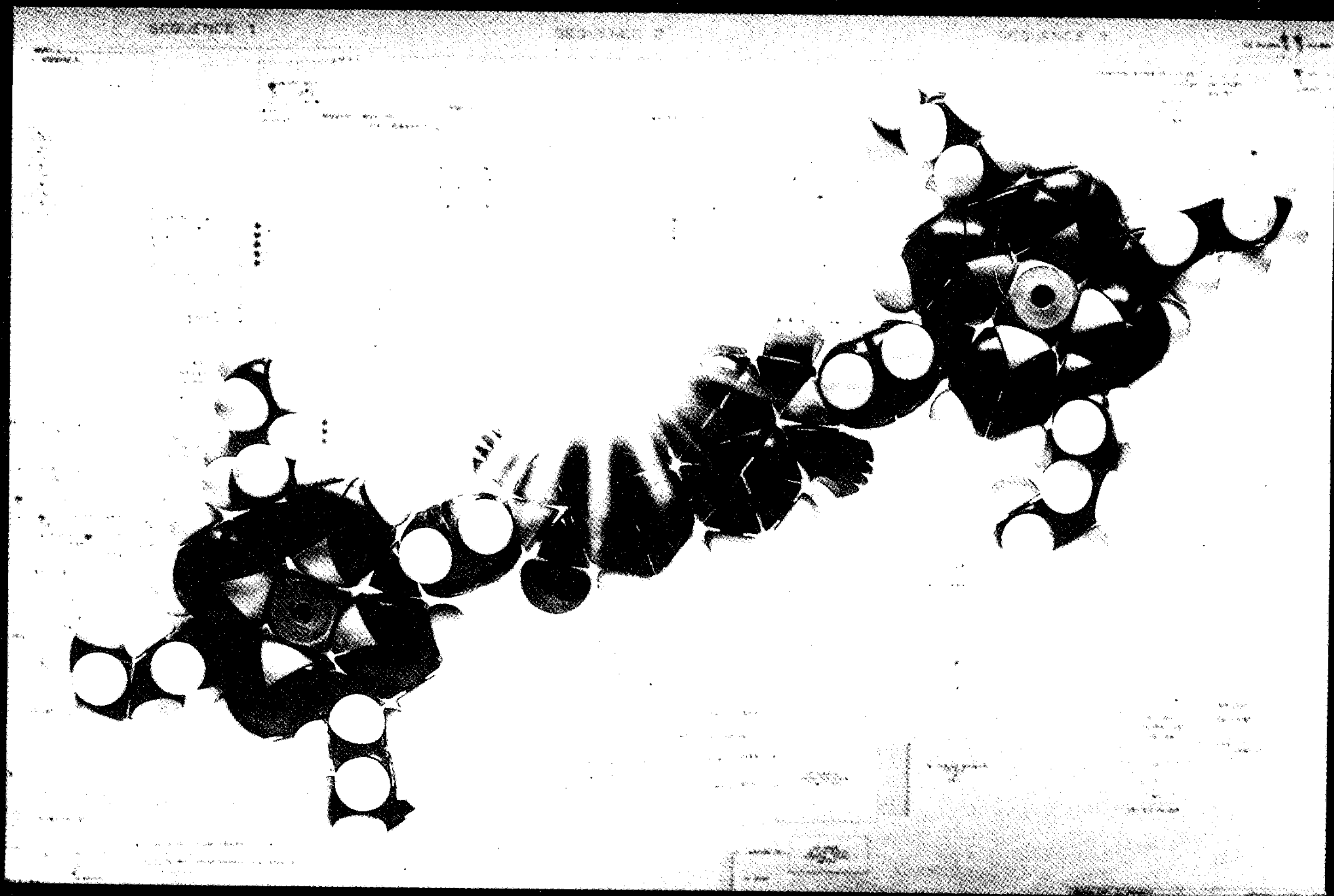
DOE/ER-0596T

Advanced Energy Projects FY 1993 Research Summaries

September 1993



U.S. Department of Energy
Office of Energy Research
Office of Basic Energy Sciences
Division of Advanced Energy Projects

Cover photograph courtesy of Michael R. Wasielewski, Argonne National Laboratory

Molecular optical switches based on laser-driven electron movement have speed, size, and energy efficiency advantages over conventional technology. Superimposed on a diagram for a circuit, using current component technology, is shown a laser beam striking a molecular switch based on a porphyrin-perylene-porphyrin electron Donor-Acceptor-Donor array. The DAD molecular switch can be used for ultra high speed optical signal control and information processing. The significance of the development of this molecular switch was underlined by a 1993 R&D 100 award sponsored by R&D Magazine. (See abstract #7 on page 13.)

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U.S. Department of Energy
Office of Energy Research
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Division of Advanced Energy Projects
Washington, DC 20585

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DIVISION OF ADVANCED ENERGY PROJECTS

PROGRAM OVERVIEW

CHARTER

The Division of Advanced Energy Projects (AEP) provides support to explore the feasibility of novel, energy-related concepts that evolve from advances in basic research. These concepts are typically at an early stage of scientific definition and, therefore, are beyond the scope of ongoing applied research or technology development programs. The AEP also supports high-risk, exploratory concepts that do not readily fit into a program area but could have applications that may span scientific disciplines or technical areas.

The Division provides a mechanism for converting basic research findings to applications that eventually could impact the Nation's energy economy. AEP does not support ongoing, evolutionary research or large scale demonstration projects. Technical topics include physical, chemical, materials, engineering, and biotechnologies. Projects can involve interdisciplinary approaches to solve energy-related problems.

SCOPE

Projects supported by the division arise from unsolicited ideas and concepts submitted by researchers. The portfolio of projects is dynamic and reflects the broad role of the Department in supporting research and development for an improved energy economy. To illustrate this diversity, FY 1993 projects may be grouped in the following areas:

- Novel Materials for Energy Technology
- Renewable and Biodegradable Materials
- Exploring Uses of New Scientific Discoveries
- Alternate Pathways to Energy Efficiency
- Alternative Energy Sources
- Innovative Approaches to Waste Treatment and Reduction

FUNDING

Projects are supported for a specified period of time, which is typically three years. In Fiscal Year 1993, the average annual funding level for an AEP project was $285,000 and the average funding period was slightly less than 36 months. It is expected that, following AEP support, each concept will be sufficiently developed and promising to attract further funding from other sources in order to realize its full potential.

SUBMISSION GUIDELINES

Unsolicited proposals can be submitted by universities, industrial organizations, non-profit research institutions, or private individuals. The Division also considers ideas or concepts submitted by researchers at national laboratories.

PREPROPOSALS

Before a formal proposal is prepared, the proposer should submit a summary (3-5 pages) of the proposed work to the Division for consideration. The summary should be sufficiently detailed to enable an informed decision as to whether the proposed work would be programmatically suited to the charter of the Division of Advanced Energy Projects. It should include descriptions of the proposed method and its potential benefit to energy. The summary should also contain estimates of the funding period and of the annual funding level. If possible, some discussion of anticipated follow-on funding options should be provided.

PROPOSALS

After an AEP programmatic interest has been established, a proposal must be submitted consistent with the guidelines specified in the document, DOE/ER-0249, "Application Guide for the Office of Energy Research Financial Assistance Program - 10 CFR Part 605." Each proposal must contain:

- A cover page.
- A 200-300 word abstract describing the essence of the project.
- A technical discussion of the proposed concept and a description of the proposed work. While the discussion should be brief, there is no formal limitation on the number of pages allotted to this section of the proposal. Since this section provides the basis for the evaluations by technical reviewers, the proposer should make certain to adequately cover all aspects of the proposed project that are relevant to forming a judgment of the projects overall merit.
- A statement of work specifying all tasks to be performed in the course of the proposed work. (See Appendix A.)
- Description of available facilities.
- Resumes of key personnel.

- Statement of all current and pending support for proposed and related research, and a description of research support for all projects that involve the principal investigator(s) and the period of time devoted to each project.

- A cost estimate for the proposed effort.

PROPOSAL EVALUATION

Awards are based on the results of an evaluation process which usually involves a review by external reviewers. Regardless of the outcome of the evaluation, proposers receive copies of reviewers' reports.

Questions asked of the reviewers depend on the subject and may include the following:

1. What is the scientific and technical merit of the proposed effort?

2. Is the proposed concept new? How does it compare with other work in the field?

3. Are there basic flaws or major shortcomings in the scientific or technical arguments underlying the concept?

4. Are the technological and/or material requirements associated with the proposed concept within present or near term capabilities?

5. Is there anything about the concept that makes its economics manifestly untenable, even under reasonably optimistic assumptions?

6. Is the anticipated benefit to the public high enough to warrant the Department of Energy's involvement in the R&D effort?

7. How well does the proposed research match the AEP charter?

FURTHER INFORMATION

Inquiries should be directed to:

Dr. Walter M. Polansky, Director
Division of Advanced Energy Projects
U.S. Department of Energy
ER-16, GTN
Washington, D.C. 20585

Phone: 301-903-5995
Fax: 301-903-6067 (or x-7363)
(Facsimile cover sheet given in Appendix E)

This book was compiled by Sue Ellen Stottlemyer

SUMMARIES OF PROJECTS ACTIVE IN FY 1993

There were 45 research projects in the Division of Advanced Energy Projects during Fiscal Year 1993 (October 1, 1992 - September 30, 1993). The abstracts of these projects are provided to illustrate the program in Advanced Energy Projects. Further information on a specific project may be obtained by contacting the principal investigator, who is listed below the project title. Projects completed during FY 1993 are indicated.

Alfred University
Alfred, NY 14802

1. Combustion Synthesis and Engineering of Nanoparticles for Electronic, Structural and Superconductor Applications

Gregory C. Stangle
607/871-2798

	Funding Profile
Date Started: November 1, 1992	FY 93 - $225,000
Anticipated Duration: 3 Years	FY 94 - $186,000
	FY 95 - $196,000

Ultrafine particles are currently difficult to produce in commercial quantities and to use in the development of dense materials with precisely controlled microstructures. The investigation will: 1) produce nanoparticles of multicomponent oxide ceramic materials by a combustion synthesis technique that is readily scaled up; 2) apply proven, in-house grain-boundary engineering methods to fine-tune microstructure evolution during densification; 3) use conventional and rapid sintering techniques to densify consolidated nanoparticle compacts; and 4) characterize the material at each stage. Expected results include: a) the synthesis of nanoparticles of complex composition for use in several applications (such as $YBa_2Cu_3O_{7-x}$, a high-temperature superconductor with uses, e.g., in magnetic flux trapping and high-speed capacitor applications; yttria-stabilized zirconia for, e.g., high surface toughness materials for high-temperature applications; and $BaTiO_3$, a material expected to possess superparaelectric properties when nanocrystalline); b) the development and reduction to practice of a generic, widely applicable process; and c) the evaluation of the energy efficiency and commercialization potential of the process. The proposed study will be interdisciplinary, bringing together the areas of ceramic, electrical and chemical engineering, and will enlist three U.S.-based companies to aid in focusing the research toward the commercialization of successful research results.

Ames Laboratory
Ames, IA 50011

2. Design of Materials with Photonic Band Gaps

Kai-Ming Ho, Institute for Physical Research and Technology
515/294-1960

	Funding Profile
Date Started: February 15, 1992	FY 92 - $299,000
Anticipated Duration: 3 Years	FY 93 - $314,000
	FY 94 - $297,000

This joint theoretical and experimental program is intended to design, fabricate and characterize a new class of composite materials which possess forbidden ranges of frequencies, in which electromagnetic waves cannot propagate in any direction. These materials are called "photonic crystals" and the forbidden frequencies are called "photonic gaps", and they can be regarded as photonic analogues of electronic semiconductors with electronic gaps. This class of material will exhibit many interesting physical properties, and will find important practical applications in lasers, mirrors, resonators, filters, and quantum optical devices. The theoretical effort will be directed at designing periodic dielectric structures that give the optimal frequency gap for various applications with special emphasis on the fabricability of these structures, especially in the sub-micron length scale where these materials will find applications in optical measurements. The main purpose of the experimental effort is to fabricate the structures designed by theory in the micron and sub-micron length scales, using micro-fabrication patterning and etching techniques. The structural and optical properties of these micro-structures will be characterized and studied using optical techniques. The effect of disorder, defects and structural imperfections on the propagation of electromagnetic waves through these photonic crystals will also be studied both theoretically and experimentally.

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

3. Application of Aqueous Biphasic Extraction to Radioactive Waste Treatment

David S. Chaiko, Chemical Technology Division
708/252-4399

	Funding Profile
Date Started: December 1, 1990	FY 91 - $475,000
Anticipated Duration: 3 Years	FY 92 - $485,000
	FY 93 - $495,000

Aqueous biphase extraction systems will be developed as a means of treating radioactive wastes. The separation concept involves the selective partitioning of either solutes or colloid-size particles between two immiscible aqueous phases. Wet grinding of plutonium residues to an average particle size of one micron will be used to liberate the plutonium from the bulk of the particle matrix. The processing goal is to produce a plutonium concentrate that will more effectively integrate with existing and developing chemical recovery processes. Coupling physical beneficiation with chemical processing will result in a substantial reduction in the volume of mixed wastes generated from dissolution recovery processes. As a part of this project, applications of aqueous biphase extraction will be explored that include the separation and recovery of dissolved species such as metal ions and water-soluble organics.

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

4. High-Flux, Large-Area Carbon-Cluster Beams for Thin-Film Deposition and Surface Modification

Dieter M. Gruen, Materials Science Division
708/252-3513

	Funding Profile
Date Started: March 15, 1992	FY 92 - $445,000
Anticipated Duration: 3 Years	FY 93 - $400,000
	FY 94 - $355,000

The discovery of the fullerenes, and particularly of C_{60}, buckminsterfullerene, is an important scientific development. These kinetically stable carbon cluster molecules, allotropes of carbon, are in fact thermodynamically unstable with respect to diamond and graphite by ~5 kcal/mol C. The fact that C_{60} has a vapor pressure of $\sim 10^{-3}$ Torr at 500°C opens up the possibility of generating high-flux, high-energy carbon-cluster ion beams for thin-film deposition (including diamond films) and surface modification. A microwave-driven electron cyclotron resonance (ECR) plasma source will be used to generate the fullerene ion beams. The ECR source combines high-ionization efficiency with low-electron temperatures (5-10eV). Typical ion current specifications for argon are 30 mA/cm^2 with a uniformity of ± 5% over a 4" diameter area. The mass transport associated with a similar current of singly ionized C_{60} would correspond to 150 amps of atomic ions. The substrate impact energy will be controlled independently of the plasma parameters by biasing the substrate. End-Hall optics will be combined with the ECR plasma to provide additional control of beam characteristics. The ECR facility will be used to synthesize and characterize, by a variety of techniques, diamond films, diamond-like films, and carbon-implanted layers on large areas with high-deposition rates. The effort is directed toward producing high-quality films at low-substrate temperatures in a manner that can be adapted to industrial processes.

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

5. New Ion Exchange Materials for Environmental Restoration and Waste Management

E. Philip Horwitz, Chemistry Division
708/252-3653

	Funding Profile
Date Started: December 1, 1990	FY 91 - $440,000
Anticipated Duration: 3 Years	FY 92 - $430,000
	FY 93 - $435,000

The objective of this program is to synthesize, characterize, and evaluate a new class of cation exchange resins. The new resins will contain the geminally substituted diphosphonic acid functional group. Ion exchange resins containing geminally substituted diphosphonic acid groups should have vastly superior properties compared to commercially available cation exchange resins and should find wide-scale applications in environmental restoration (e.g., groundwater cleanup) and in waste management (e.g., minimization of waste volume). Alkyl-1,1-diphosphonic acids are among the most powerful complexing agents for polyvalent metal ions in aqueous solution, particularly at $pH<2$. But, heretofore, it has not been possible to synthesize resins containing diphosphonic acid groups, because of the difficulty of introducing this group into a preformed polymer matrix. The synthesis of resins with the diphosphonic acid groups will be accomplished by the polymerization of vinylidene-1,1-diphosphonic acid (VDPA) or by the copolymerization of VDPA with suitable comonomers (e.g., acrylamide/bis-acrylamide or styrene/divinylbenzene). This approach represents a major departure from the traditional methods for preparing ion exchange materials whereby the exchangeable functional groups are introduced onto a preformed polymer matrix.

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

6. Development of an Ion Replacement Electrorefining Method

Zygmunt Tomczuk, Chemical Technology Division
708/252-7294

Funding Profile

Date Started: February 15, 1992 — FY 92 - $450,000

Anticipated Duration: 3 Years — FY 93 - $450,000

FY 94 - $450,000

The objective of this project is to investigate promising methods for carrying out a new metal separation and purification process called ion replacement electrorefining. The challenge and program focus lie in developing a counter electrode that can serve in a sequential and, if possible, reversible manner as a cathode during metal dissolution and an anode during metal separation/deposition. The development work will be conducted with a view toward one particularly important application - the separation of spent metallic nuclear reactor fuel (or any nuclear waste material in metallic form) into its elemental constituents. The key goal is to produce a clean separation between actinide and non-actinide elements. One potential use for the ion replacement electrorefining method is the reprocessing of spent metal fuel from an Integral Fast Reactor (IFR), but it is also adaptable to the separation of transuranic elements from spent fuel and waste generated by the light water nuclear reactor (LWR) industry and the defense nuclear programs. In the case of the IFR, the proposed process represents an attractive alternative towards commercialization, in the sense that it offers a simplification of the conventional pyrometallurgical electrorefining process under development within the IFR Program. For LWR and defense waste applications, the ion replacement electrorefining method could be used in conjunction with processes that incorporate reduction of actinide element compounds (usually oxides) to a metallic form.

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

7. Ultrafast Molecular Electronic Devices

Michael R. Wasielewski, Chemistry Division
708/252-3538

Funding Profile

Date Started: October 1, 1991 — FY 92 - $445,000

Anticipated Duration: 3 Years — FY 93 - $425,000

FY 94 - $405,000

The objective of this project is to apply the fundamental chemistry of ultra-fast photo-initiated electron transfer reactions to produce high speed, energy efficient molecular electronic devices. These molecules will act as opto-electronic switches on a picosecond time scale. The molecular switches are designed around electron donor-acceptor molecules that possess well-defined, easily controlled structures. Photo-excitation of these molecules with visible light results in very efficient charge separation reactions that set the on or off state of the molecular switch. Two types of molecular switch will be developed. The first type is a bistable electron transfer switch which will use a light pulse of one color to store information in the solid state in the form of a long-lived charge separation, and a light pulse of a second color to recover it. The second type of switch is a field effect switch which will use the electric field generated by one charge separated electron donor-acceptor pair to influence the on or off state of a second donor-acceptor pair. These switch molecules will be assembled in ordered arrays on surfaces using self-assembled monolayer and liquid crystal polymer technology to produce electro-optic devices. Potential applications of this technology are optical computing, wavelength selective gates and switches, laser detectors, electro-optic devices, modulators, and memories.

University of Arizona
Tucson, AZ 85721

8. Creation and Destruction of C_{60} and Other Fullerene Solids

Donald R. Huffman, Department of Physics
602/621-4804

	Funding Profile
Date Started: March 1, 1993	FY 93 - $302,000
Anticipated Duration: 3 Years	FY 94 - $301,000
	FY 95 - $302,000

This work will focus on the creation and destruction of fullerenes, for the purposes of producing new materials of interest to the Department of Energy. It is now known that, besides the famous C_{60} molecule (buckminsterfullerene), hundreds of other fullerenes, with masses of up to 600 carbon atoms, are also synthesized in the Krätschmer-Huffman process. The physics underlying the creation of the fullerenes is poorly understood and the major portion of this work will be a systematic study of the process. This will involve construction of a new, fully-instrumented smoke-chamber, that will be used in a methodical exploration of fullerene yield versus production conditions. Mass-spectral analysis will be an indespensable part of this study. As part of the work, an existing time-of-flight mass-spectrometer at the University of Arizona will be upgraded for optimum performance with fullerene samples. Recent reports of the successful seeding of CVD-grown diamond films using thin films of C_{70}, and of the room-temperature conversion of solid C_{60} into diamond powder via non-hydrostatic compression, indicate that some of the first important commercial applications of the fullerenes may involve their destruction as a means of synthesizing high-performance materials. The second major portion of this work will be a systematic study of the destruction and modification of the various fullerenes by chemical reaction, electromagnetic radiation, and electron bombardment. Transmission electron-microscopy (TEM) and electron-energy-loss spectroscopy (EELS) will be very valuable in analyzing the results of these destructive tests, and a portion of the proposed funding will support this work at a TEM / EELS facility located at the University of Arizona.

Brookhaven National Laboratory
Upton, NY 11973

9. Energy Related Applications of Cluster Impacts

Lewis Friedman, Chemistry Department
516/282-4325

Date Started: April 1, 1991	Funding Profile
Anticipated Duration: 3 Years	FY 91 - $440,000
	FY 92 - $585,000
	FY 93 - $490,000

The impacts of accelerated cluster ions on solid surfaces generate transient highly compressed assemblies of energetic atoms. These atomic assemblies are unique in that very large amounts of energy are concentrated in the motion of the atoms rather than in the atomic electrons so that cooling processes are slower than with systems heated by lasers, electron beams or high-velocity ion beams. The direct deposition of energy into the motion of target atoms produces a non-random directional distribution of translational energy in the target atoms. As a consequence, a very small fraction of the target atoms may acquire sufficient translational and/or vibrational energy to drive nuclear fusion reactions. A study of the effects of cluster impacts on solid surfaces in economical laboratory scale experiments can illuminate mechanisms of the ablative processes normally relied upon to compress and heat plasmas in inertially confined fusion. In addition, the direct application of cluster beams in place of heavy ion beams to heat inertially confined plasmas can be investigated. Most of the proposed experimental work will build on the foundation already established in studies of fusion reactions induced by singly-charged accelerated cluster ions. Studies will focus on the exploitation of multicharged ions to extend the range of velocities and sizes of the projectiles used to initiate cluster impact phenomena. The major objectives of this project are to study the properties of condensed matter under extreme conditions of pressure and energy density and to evaluate the potential of cluster impacts for use in the economical development of fusion energy.

Brooklyn College of City University of New York
Brooklyn, NY 11210

10. Solar Detoxification of Aquatic Systems With Porous Photocatalysts

Micha Tomkiewicz, Physics Department
718/951-5357

	Funding Profile
Date Started: November 15, 1991	FY 92 - $118,000
Anticipated Duration: 3 years	FY 93 - $127,000
	FY 94 - $131,000

The objective of this project is two fold: (a) To investigate the feasibility of using a porous structure of a side bandgap semiconductor as a portable photocatalyst for photodegradation of organic pollutants in an aqueous environment; and (b) establish the correlation between the morphology of the porous photocatalyst and its efficiency in the photocatalytic process. Initially, efforts will be concentrated on the photocatalytic decomposition of two classes of organic materials: (a) Hydrocarbons, both light aliphatic and light aromatics, such as benzene and toluene. This work will be aimed primarily at water decontamination due to oil spills. (b) Salicylates. These are soluble ionic compounds that are being proposed in some quarters to serve as standards for the efficiency of various water purification schemes. The initial choices for the photocatalyst are porous TiO_2 films or beads that will be prepared either by the sol-gel method or by thermal decomposition of organic titanates, to make them low density enough to float in an aqueous environment. The principal tools in analyzing the porosity and the pore structure will be image processing in conjunction with optical and electron microscopies, small-angle x-ray scattering and impedance measurements. The reactants and the reaction products will be analyzed by absorption spectroscopy, by gas and liquid chromatography, and by electrodes specific to oxygen and carbon dioxide. Slow kinetic studies will be conducted by monitoring the time evolution of disappearance of the reactants and appearance of the products. Kinetic studies on a faster time scale will be conducted by flash-photolysis absorption measurements and time resolved luminescence. Parallel to the experimental work, computer simulations of the photocatalytic process on random porous photocatalysts and on porous deterministic fractals will be conducted.

University of California, Los Angeles
405 Hilgard Avenue
Los Angeles, CA 90024

11. Experimental, Theoretical and Computational Study of Frequency Upshift of Electromagnetic Radiation Using Plasma Techniques

Chan J. Joshi, Electrical Engineering Department
310/825-7279

Date Started: January 15, 1991

Anticipated Duration: 3 Years

Funding Profile

FY 91 - $250,000

FY 92 - $250,000

FY 93 - $250,000

In this project, a new class of coherent electromagnetic radiation generation devices that, in principle, can cover the range of frequencies from microwaves to the vacuum ultra-violet, will be investigated both theoretically and experimentally. In this method the frequency of the incident e.m. wave is upshifted by suddenly lowering the refractive index of the medium through which the wave is propagating. This can be done by rapidly ionizing the medium and forming a plasma. Various regimes will be investigated: *(a) Spatially uniform ionization (or flash ionization).* If the source wave (ω_s,k_s) is propagating through a medium that is uniformly ionized in time, then the wavenumber of this source wave k_s is fixed, but the frequency can change to $\omega = \sqrt{\omega_s^2+\omega_p^2(t)}$ where ω_p is the plasma angular frequency. This technique is particularly useful for generating tunable e.m. radiation in the mm wave range. *(b) Frequency upshift by a moving ionization front.* By sending an ionization front, it is also possible to upshift the source wave frequency. If the plasma is underdense in the fronts frame, the upshifted frequency is $\omega = \omega_s(1+\frac{\omega_p^2}{4\omega_s^2})$. If the plasma frequency is greater than the source frequency, this technique can generate frequency upshifts that are much greater than the flash ionization technique. This technique is suited to generate far-infrared and infrared radiation. An applications study will also be undertaken to identify technologies which would likely be impacted by these sources.

University of California, Los Angeles
405 Hilgard Avenue
Los Angeles, CA 90024

12. Study of a Fourth Generation, High Brightness, Picosecond Pulse, Synchrotron Radiation Source*

Claudio Pellegrini, Department of Physics
310/206-1677

Funding Profile

Date Started: December 1, 1991

FY 92 - $137,000

Anticipated Duration: 18 Months**

The goal of this project is the study of a storage ring for synchrotron radiation production capable of achieving simultaneously high brightness and a short pulse duration, in the picosecond range. Existing storage rings can only produce radiation with limited brightness; a new generation now under construction has been designed to increase the brightness, thus largely extending the usefulness of these sources. However, no ring existing or under construction has the capability of producing picosecond pulses, while preserving the brightness, and increasing the peak current. Recent theoretical results on the possibility of operating a storage ring near transition, a Quasi Isochronous Ring, and of using a new type of nonlinear magnetic lenses, the modified sextupoles, indicate the possibility of achieving these results, extending even more the capability of synchrotron radiation sources. This program will explore these new concepts, develop a design of this new type of source, and evaluate its characteristics.

*Project Completed
**Includes 6 month no-cost extension

University of California, Los Angeles
405 Hilgard Avenue
Los Angeles, CA 90024

13. Synchronous Picosecond Sonoluminescence: Developing and Characterizing a New Light Source

Seth J. Putterman, Department of Physics
310/825-2269

Funding Profile

Date Started: December 15, 1991 — FY 92 - $388,000

Anticipated Duration: 3 Years — FY 93 - $275,000

FY 94 - $194,000

It has recently been discovered at the UCLA acoustics laboratory that the passage of a sound wave through a liquid leads to the ultra-precise clock-like emission of flashes of light. The power of the individual flashes is greater than 1 milliwatt and their width is less than 100 picoseconds. This effect is due to a spontaneous yet controllable concentration of sound energy by a factor of one trillion. The goal of this project is to perform those measurements which will elucidate the mechanism responsible for this off-equilibrium phenomenon (that has been named synchronous picosecond sonoluminescence). Toward this goal, the time and spatial resolution of the flashes will be measured along with the time development of the spectrum. Correlations and possible coherence will be searched for in the radiated light. Efforts will be made to measure the spectrum of microwave, radio frequency and far ultra-violet radiation. The degree of synchronicity will also be probed. These efforts will lead to the development of a variable width, variable intensity picosecond light pulser. By understanding the novel cooperative effects that cause synchronous picosecond sonoluminescence, insight will be gained as regards the means whereby large controllable energy concentrations could be achieved in other systems.

University of California, Santa Barbara
Santa Barbara, CA 93103

14. Photo-Induced Electron Transfer From a Conducting Polymer to Buckminsterfullerene: A Molecular Approach to High Efficiency Photovoltaic Cells

Paul Smith, Materials Department
805/893-8104

	Funding Profile
Date Started: August 15, 1993	FY 93 - $171,000
Anticipated Duration: 3 Years	FY 94 - $429,000
	FY 95 - $300,000

The recently-discovered photoinduced electron transfer, with subpicosecond transfer rate, in composites of a conducting polymer, MEH-PPV, and a molecular acceptor, buckminsterfullerene, C_{60}, opens a new direction and a new opportunity for photovoltaic research. Since the charge transfer takes place ~1000 times faster than the radiative and/or non-radiative decay of photoexicitations, the quantum efficiency for charge transfer and charge separation is near unity. Photoinduced electron transfer across the donor-acceptor rectifying heterojunction offers potential for solar cell applications, using materials that exhibit a unique combination of properties: electronic and optical properties of semiconductors and metals in combination with the attractive mechanical properties and the processing advantages of polymers. The potential advantages of an all-polymer heterojunction solar cell include the following: low cost (literally fabricated from solution); large area; and flexible (components are polymers that can be solution cast onto polymer substrates). The goal of the proposed research is to build upon this novel molecular approach to photoinduced charge separation and charge transfer, with quantum efficiency approaching unity, and to create a research and development program that will enable the production of efficient, flexible, "plastic" solar cells that can be implemented in large areas.

University of Colorado
Boulder, CO 80309

15. Parallel Nanometer Scale Fabrication*

Kenneth Douglas, Department of Physics
303/492-7543

Date Started: September 15, 1989	Funding Profile
Anticipated Duration: 4 Years**	FY 89 - $359,000
	FY 90 - $279,000
	FY 91 - $300,000

The thrust of this research is to explore fabrication of structures at the highest possible spatial resolution in which features are defined on the nanometer length scale by single molecules. Two-dimensional protein crystals will be used as the patterning elements for nanometer fabrication, employing masking and templating operations. Hundreds of two-dimensional biomolecular arrays, having lattice parameters in the 3-30 nanometer range, are available as patterning elements. The nanostructures to be fabricated will include patterned 1 nanometer thick metal films having, for example, arrays of 10 nanometer dimension holes, metal island arrays of nanometer periodicity, and biomolecular-solid state nanohetero-structures. By employing periodic patterns, structural fluctuations and defects can be effectively investigated, for example the placement of 1 nanometer dimension metal grains by molecules of the template. The research goal is to understand phenomena that limit nanometer fabrication at the molecular level, to extend the limits of fabrication resolution, and to develop applications of molecular fabricated nanostructures. This parallel technology will enable the efficient parallel manipulation of surfaces. The ability to structure surfaces on the nanometer molecular length scale makes it possible to profoundly alter their fundamental properties such as chemical reactivity, adsorption characteristics, and electrical and optical behavior. Such a technology would contribute broadly to the advance of interfacial chemistry, physics, and materials science.

*Project Completed
**Includes 12 month no-cost extension

Colorado State University
Fort Collins, CO 80523

16. Capillary Discharge Extreme Ultraviolet Lasers

Jorge J. Rocca, Electrical Engineering Department
303/491-8371

Date Started: December 15, 1990	Funding Profile
Anticipated Duration: 38.5 Months*	FY 91 - $170,000
	FY 92 - $130,000
	FY 93 - $130,000

The project objective is to explore the generation of soft x-ray laser radiation in a capillary discharge. A hot and highly ionized plasma column with a large length-to-diameter ratio (l/d=10-100) will be generated by a rapid discharge into a capillary structure. A compact 800 kV, 150 kA pulser will provide the excitation. At the end of the current pulse, rapid cooling of the plasma is expected to occur as a consequence of electron heat conduction to the capillary walls and plasma radiation. Under optimized plasma conditions, collisional recombination of the capillary plasma is expected to lead to amplification at extreme ultraviolet and soft x-ray wavelengths. Experiments will be conducted to demonstrate gain, focusing first in the 3-2 transition of hydrogenic ions. The initial experiment will explore gain in the 18.2 nm transition of hydrogenic carbon in a polyethylene capillary. The proposed capillary laser scheme offers the potential for compact, simple and efficient soft x-ray laser sources.

*Includes 2.5 month no-cost extension

University of Houston
Houston, TX 77204-5502

17. Research on Magnet Replicas and the Very Incomplete Meissner Effect

Roy Weinstein, Institute for Particle Beam Dynamics
713/743-3600

	Funding Profile
Date Started: January 15, 1991	FY 91 - $351,000
Anticipated Duration: 3 Years*	FY 92 - $341,000

The aim of this project is to produce permanent magnets comprised of superconductors (SCs) that work at or near liquid nitrogen temperatures (77 K). These magnets show promise for applications in motors, generators, charged particle beam steering, industrial particle separators, MRI, and other constant field applications. One advantage of these magnets is that much higher fields are possible than for ferromagnets. A second is that the SC magnets can accurately copy the fields used to activate them, thus making possible magnet replicas. In addition, SC magnets are lighter than iron, cost less than an electromagnet, and consume negligible energy. The SC magnet replicas are made of bulk pieces of high temperature superconductor, and so do not require the availability of wire, which is difficult to produce from these materials. Both chemical and radiation methods are being used to produce materials capable of storing high field. Stored fields have been increased by factors of over 1,000 in the past two years. Presently, stored fields in 1 cm^3 samples are already three-times stronger than samarium-cobalt magnets. Methods of improving stability have been found. A small motor has been run using a magnet replica.

*Includes 12 month no-cost extension

University of Illinois at Chicago
Chicago, IL 60680

18. Molecular Design Concept for X-Ray Laser Research

Charles K. Rhodes, Department of Physics
312/996-4868

	Funding Profile
Date Started: December 15, 1990	FY 91 - $300,000
Anticipated Duration: 3 Years	FY 92 - $300,000
	FY 93 - $300,000

The goal of the project is the construction of an x-ray laser in the kilovolt regime. Recent experimental results indicate that a new technique for the generation of strong amplification of x-ray wavelengths is feasible. It involves the combination of (a) a new ultrahigh brightness subpicosecond laser technology; and (b) a recently discovered unique mode of strong-field interaction, particularly applicable to molecules. A concept of molecular x-ray laser design emerges from these considerations that matches the mode of excitation to the structure of the molecular system. The molecular approach enables the combination of very highly electronically excited conditions with an environment characteristic of dense cold matter, a general situation exceptionally conducive to x-ray amplification. Both high efficiency and wavelength tunability are intrinsic features of this method. A program of research is being conducted to evaluate this method for the production of x-ray amplification in the kilovolt region.

Lawrence Berkeley Laboratory
Berkeley, CA 94720

19. Metallic Multilayer and Thin Film Fabrication

Ian G. Brown
510/486-4174

Date Started: April 1, 1991

Anticipated Duration: 3 Years

Funding Profile

FY 91 - $288,000

FY 92 - $337,000

FY 93 - $270,000

The application of pulsed metal plasma gun techniques to the fabrication of metallic superlattices, multilayers and thin films will be investigated. Multilayer structures will be synthesized that are of relevance to x-ray optical devices, to magnetic and magneto-optical recording media, and to the fabrication of high temperature superconducting thin films. The quality and characteristics of the thin film structures formed in this way will be explored. This means of fabrication of metallic multilayer systems is new and has not yet been examined except in preliminary testing at this laboratory. At the same time, interest in artificial metallic superlattices from a fundamental scientific perspective, and in metallic multilayer structures from the standpoint of applied technology, is growing rapidly. It is important to explore and develop the application of this new technique to these fields. The proposed program will make immediate application of the method within the three fields mentioned above (x-ray optics, magneto-optics and superconducting thin films) via collaborations with materials science research groups at this laboratory.

Lawrence Berkeley Laboratory
Berkeley, CA 94720

20. Cyclotron Mass Spectrometer for Tracer Studies

Ka-Ngo Leung
510/486-5011

Date Started: April 1, 1991

Anticipated Duration: 3 Years

Funding Profile

FY 91 - $290,000

FY 92 - $245,000

FY 93 - $225,000

A compact research cyclotron will be developed which uses permanent magnets and axial ion injection. The new instrument will be used as an ultrasensitive accelerator mass spectrometer (AMS) for applied tracer studies. This device can take the place of bulky, cumbersome and much more expensive tandem Van de Graaff accelerators usually employed in AMS applications and, in fact, can be made "portable". Thus this new machine has the potential for great practical benefit primarily by permitting detection or monitoring of minute quantities of hazardous substances and contaminants in exhausts and effluents. Moreover, the instrument is predicted to have sufficient sensitivity to detect ^{14}C isotopes as tracers after enormous dilution, opening the door to a large variety of environmental, biomedical and archeological applications. To facilitate ^{14}C tracer work, the effort also includes optimization of a C^- ion source that uses gaseous CO or CO_2 instead of solid graphite sputtering. It is expected that at the end of the project, the cyclotron mass spectrometer system will be developed well enough and its utility demonstrated to permit transfer to industry.

Lawrence Livermore National Laboratory
Livermore, CA 94550

21. Pulsed Plasma Processing of Effluent Gases

J. N. Bardsley
510/422-6008

Date Started: July 10, 1992

Anticipated Duration: 3 Years

Funding Profile

FY 92 - $222,000

FY 93 - $108,000

FY 94 - $330,000

FY 95 - $330,000

A study will be carried out of the science underlying the use of pulsed electrical discharges for the simultaneous removal of NO_x, SO_2 and soot from diesel engine exhausts. The goals involve major advances in the understanding of breakdown mechanisms in coronal discharges, the elucidation of the chemical reaction schemes responsible for the conversion of the pollutants to benign molecules, experimentation with novel devices, and preliminary analysis of the scaling laws, economic and environmental considerations relevant to the transfer of this technology from the laboratory. The research will be performed by a multidisciplinary team from the Physics, Electrical Engineering, and the Chemistry and Materials Science Departments.

Lawrence Livermore National Laboratory
Livermore, CA 94550

22. Demonstration of Three Dimensional X-Ray Holography*

James E. Trebes
510/423-7413

Funding Profile

Date Started: January 1, 1992

FY 92 - $226,000

Anticipated Duration: 1 Year

X-ray holography is rapidly developing as a potential tool for studies of macromolecular assemblies in live biological objects. Operating at soft x-ray wavelengths (45-23 Å) offers the potential for generating high-resolution images of biological structures in physiological normal conditions with less dose than required for electron microscopy. The experimental results to date have resulted in holographic images with good transverse resolution (<1000 Å), but with essentially no depth resolution. Macromolecular structures such as the higher order structure or DNA in live cells will require 3-D imaging with both good transverse as well as depth resolution. A method of obtaining this 3-D resolution is holographic tomography. In this technique, several holograms of the same object are produced from different directions. The images from each hologram are combined in the holographic reconstruction process to produce a three dimensional image with a depth resolution comparable to the transverse resolution. The major advantages of this approach are that it exploits the predominantly forward scattering of x-rays by biological microstructures and that it samples a wide range of spatial frequencies in the object. The goal of this project is to demonstrate x-ray holographic tomography for the first time and determine the minimum number of views required for the production of high resolution holographic images. In addition, the minimum number of detected x-rays required for each view will be determined. This project will be carried out using an existing Fourier transform x-ray holography system on the National Synchrotron Light Source at Brookhaven National Laboratory. Successful completion of this project will provide the data base necessary for the design of holographic systems capable of creating three-dimensional, high-resolution images of biological microstructures.

*Project Completed

Los Alamos National Laboratory
Los Alamos, NM 87545

23. Synthesis and Properties of High Strength Nanolayered Composites

Michael Nastasi
505/667-7007

Funding Profile

Date Started: February 15, 1993

Anticipated Duration: 3 Years

FY 93 - $150,000
FY 94 - $315,000
FY 95 - $330,000

The objective of this project is to synthesize and evaluate ultra high strength vapor-deposited nanoscale materials both in the monolithic and composite form. Such materials have been shown to posses strengths that are within a factor of three or four of the theoretical shear strength $\approx\mu/15$, where μ is the shear modulus. Synthesis of nanoscale materials presents the opportunity to develop a basic understanding of the deformation and fracture mechanisms that operate close to the theoretical limit of strength of materials to enable a new technological breakthrough, namely mechanical miniaturization. The availability of the fine-scale ultra high strength materials would provide the basis for fabricating, among others, miniature activators, springs, and diaphragms, for biomedical or sensor applications. The primary performance task will be to synthesize ductile materials with ultra high strength for application in mechanical miniaturization.

Los Alamos National Laboratory
Los Alamos, NM 87545

24. Experimental and Theoretical Studies of Inertial-Electrostatic Confinement

Richard A. Nebel
505/667-7721

Funding Profile

Date Started: November 1, 1991 — FY 92 - $400,000

Anticipated Duration: 3 Years — FY 93 - $400,000

FY 94 - $392,000

A comprehensive study of inertial-electrostatic confinement (IEC) will be conducted. IEC is a plasma confinement scheme for fusion applications based on electrostatic fields. Unlike conventional magnetic confinement fusion, IEC devices produce fusion via non-Maxwellian beam-beam interactions; the kinetic energy of the beam ions being approximately the same as the potential on the grid. Experimental work complemented and guided by theoretical analysis will be pursued. The experimental effort will be centered at the University of Illinois. Experimental diagnostics will glean data to determine the spatial dependence of both the neutron-emission source and the associated electrostatic potential. These data will be used to assess and improve the understanding of IEC and to test new physics concepts that may enhance ion compression and collision rates in such devices. The computational strengths of Los Alamos National Laboratory (LANL) together with the phenomenological modeling capabilities of Energy/Matter Conversion Corp., (EMC2) will be used to achieve this mission. A three-dimensional semi-implicit Particle-In-Cell (PIC) code is currently being developed at LANL that is appropriate for modeling both the IEC experiments and conventional as well as newly developed phenomenological physics models of interest in their interpretation. Possible instabilities will be studied in order to determine their effect upon the electrostatic confinement. The primary goals will be to determine conditions for maximum ion confinement and to define appropriate experimental regimes for their test.

Los Alamos National Laboratory
Los Alamos, NM 87545

25. Pulsed Microwigglers for Innovative Free-Electron Lasers

Roger W. Warren
505/667-1988

	Funding Profile
Date Started: June 1, 1991	FY 91 - $300,000
Anticipated Duration: 3 Years	FY 92 - $350,000
	FY 93 - $350,000

A pulsed microwiggler will generate a very strong wiggler field of short period. It will allow light of short wavelength to be generated by an free-electron laser (FEL) system that uses an unusually low energy accelerator that is, therefore, compact and inexpensive. This will lead to a new generation of FELs, revolutionizing the technology. The development will enable new applications for which FELs were previously considered too expensive and cumbersome. Development of such a wiggler will require extensive computer simulations, novel wiggler designs (both to generate fields of the required shape and magnitude and to allow heat to be extracted efficiently), advanced fabrication techniques (to achieve the required precision), state of the art power supplies (high, pulsed currents), and unusual test equipment (to measure fields inside the small wigglers). These developments can be divided into several stages that can be attacked sequentially. It is planned to design, build, and test such a microwiggler and use it in an existing FEL system at Los Alamos to generate UV light.

Massachusetts Institute of Technology
Cambridge, MA 02139

26. Superconducting Bitter Magnets

Leslie Bromberg, Plasma Fusion Center
617/253-6919

Date Started: May 1, 1993

Anticipated Duration: 3 Years

Funding Profile

FY 93 - $300,000

FY 94 - $300,000

FY 95 - $300,000

A novel process for manufacturing high temperature superconducting magnets using thick-film superconducting material on structural plates is described. This technique is similar to that used in constructing BITTER magnets. The superconductor is manufactured in the required shape, avoiding the need to develop ductile wires. The structural metal plate serves as the material as well as the quench protector. A dielectric with high electrical resistivity is placed between the conductor and the metal plate (copper, aluminum, composite materials). This method can be utilized for manufacturing solenoidal, toroidal, saddle, and other types of magnets with both high-T_c and low-T_c superconductors. This project will address issues faced in this type of magnet construction (quench protection, materials compatibility, stability, and cooling). A theoretical program to gain understanding on these issues will be carried out. Experiments will be conducted to determine the feasibility of manufacturing magnets using this technique. Several methods for manufacturing the superconductor will be tested. Interaction with the manufacturers to improve the performance of superconducting materials for this application will be maintained. It is expected that in the final phase of this program, magnets will be constructed and tested. A team arrangement between the Plasma Fusion Center at the Massachusetts Institute of Technology (MIT) and the Superconductivity Technology Center at the Los Alamos National Laboratory (LANL) has been established.

University of Michigan
Ann Arbor, MI 48109

27. Development and Applications of the Positron Microscope

David W. Gidley, Department of Physics
313/936-1134

Funding Profile

Date Started: January 15, 1990 — FY 90 - $173,000

Anticipated Duration: 4 Years* — FY 91 - $175,000

FY 92 - $175,000

The operation of the first positron microscopes in 1988 demonstrated a totally new contrast mechanism for microscopic imaging. Specifically, the positron reemission microscope images anti-matter positrons that have been implanted into a sample and subsequently reemitted from its surface. Image contrast, determined by the sample's positron reemission probability, depends on the unique behavior of positrons in solids. The goal of this research is to move this new technology beyond the current demonstration phase (3,000-10,000 Å resolution) by constructing and operating a 100 Å resolution instrument. This device would allow the assessment of the technique's ultimate capabilities, as well as allow investigation of several outstanding problems which the proposed microscope should make a unique contribution to solving. These problems include: (a) analysis of sub-25 Å films by positron tunneling microscopy; (b) unique applications in surface catalysis including, for example, analysis of systems with high Z substrates where electron microscopic techniques fail; (c) analysis of operation and failure modes of microelectronic devices; and (d) imaging of selected biological systems, such as lipids and proteins in cell membranes. A program complementary to this has been initiated at the Idaho National Engineering Laboratory to construct a positron beam with a minimum intensity of 10^{10} positrons/sec. A beam of such intensity would be required for several applications including use in a sub-10 Å resolution microscope that would be constructed if, based on the results of this project, it is judged to be feasible and useful.

*Includes 12 month no-cost extension

University of Michigan
Ann Arbor, MI 48109

28. Feasibility of a Novel Approach for Fast, Economical Determination of Radiation Damage in Nuclear Reactor Cores

Gary S. Was, Department of Nuclear Engineering
313/763-4675

Date Started: November 1, 1992

Anticipated Duration: 3 Years

Funding Profile

FY 93 - $156,000

FY 94 - $145,000

FY 95 - $149,000

The objective of this project is to determine the feasibility of using proton irradiation as a radiation damage tool, resulting in order-of-magnitude savings in time and cost over current methods to study radiation damage. The feasibility will be established through the application of proton irradiation to the determination of the mechanism of irradiation assisted stress corrosion cracking (IASCC) in light water reactors (LWRs). The technique is ideally suited to this major industry problem. The emphasis of the technical program will be on the role of grain boundary chemistry and microstructural changes on IASCC. High energy proton irradiation has recently been shown to produce grain boundary segregation of the major alloying elements and impurities, and a microstructure that is comparable to that produced by neutron irradiation in a fraction of the time and at a fraction of the cost. This program is designed to uncover the effects of grain boundary impurity segregation, chromium depletion, and the irradiated microstructure on IASCC. It involves both experimental and computational efforts that have been developed in our laboratory. The plan also calls for investigation of the dose, dose rate, temperature and injected hydrogen effects and comparison with available neutron irradiation data. The combination of microstructure characterization with its dependence on critical irradiation parameters will provide both a better understanding of the role of irradiation in the mechanism, as well as an assessment of the feasibility of using proton irradiation to study neutron irradiation in LWR cores. Collaborations with industry and national laboratories have been established to exchange materials that will allow us to benchmark results of proton irradiation against neutron irradiation and to determine the irradiation conditions that produce the best match. Because the time and cost involved in these experiments is a small fraction of that required for neutron irradiation, the technique will provide a more cost-effective and time-efficient method of studying radiation change in core structures and in assessing new materials.

University of Missouri
Columbia, MO 65211

29. A Study of Potential High Band-Gap Photovoltaic Materials for a Two Step Photon Intermediate Technique in Fission Energy Conversion

Mark A. Prelas, Nuclear Engineering Program
314/882-3550

	Funding Profile
Date Started: December 1, 1990	FY 91 - $305,000
Anticipated Duration: 3 Years	FY 92 - $294,000
	FY 93 - $317,000

The efficiency of modern day power plants is limited by the steam cycle that they employ. Future power plants may be able to improve upon the efficiency of the steam cycle, provided that other energy conversion techniques become available. One such energy conversion method is excimer channeling. Excimer channeling is a method of efficiently creating a narrow band photon spectrum directly from the products of nuclear reactions. This narrow band photon spectrum can be used in an energy conversion cycle based upon photovoltaic reactions. This project addresses the issue of photovoltaic materials that can interface with the narrow band photon spectrum in the excimer channeling energy conversion method. Photovoltaics are generally thought to be inefficient because of their association with solar cells. Solar cells are photovoltaic cells that convert the broad band photon spectrum of the sun directly into electricity at an efficiency of 10% to as much as 20%. Conversion of photons into electricity could be very efficient (as high as 85%) if the photon spectrum were sufficiently narrow, such as that produced by excimer channeling, and matched to the bandgap of the photovoltaic material. Development of high bandgap photovoltaic materials that match the excimer channeling photon spectrum is the goal of this research program. This effort centers on materials with bandgaps exceeding 5 eV. High bandgap crystals will be synthesized, doped to form P-N junctions, characterized by various surface analysis methods, made into photovoltaic cells, the cells' characteristics tested, and the cells' tolerance to various types of electromagnetic radiation assessed.

Northeastern University
Boston, MA 02115

30. Further Development of the Pneumatic Method to Harness Low-Head Hydropower and of its Experimental Implementation in the State of Maine

Alexander M. Gorlov
617/437-3825

Date Started: December 15, 1990	Funding Profile
	FY 91 - $94,000
Anticipated Duration: 3 years*	FY 92 - $81,000

The objective of the project is a further theoretical study of the pneumatic method to harness low and ultra low head hydropower and to demonstrate that such an approach can be economically and environmentally efficient for riverine power installation. The concept was originally offered in 1978-1980 for harnessing tidal power. The principal idea of the method is to utilize air turbines instead of conventional hydroturbines by means of converting energy of the flowing water into energy of compressed air. A pneumatic hydropower plant would cause minimal environmental distortion in the river and require substantially less land taking for a water pool than a conventional hydroturbine installation. There are two primary aspects of the research project: (a) to complete an analysis of air chamber parameters, mechanical and energy losses, air turbine operation; and (b) to perform a feasibility study of a pneumatic power installation for a selected riverine site in the state of Maine.

*Includes 12 month no-cost extension

Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831

31. Novel Composite Coatings for High Temperature Friction and Wear Control

Theodore M. Besmann, Metals and Ceramics Division
615/574-6852

Date Started: November 1, 1991	Funding Profile
Anticipated Duration: 3 Years	FY 92 - $428,000
	FY 93 - $250,000
	FY 94 - $260,000

The development of improved, self-lubricating materials is critical for enabling progress in many industrial sectors: transportation, industrial machinery, business machines, aerospace, and defense. Its impact on the economy will therefore be large and diverse, spanning devices from high-temperature turbine engines to moving parts in heat-treatment systems for integrated circuitry. Chemical vapor deposition (CVD) techniques offer the opportunity to create very uniform self-lubricating composites which slowly wear away to expose pockets of lubricants which then spread across the surface. In CVD, gaseous reactants are allowed to flow over a heated substrate where they react and deposit a solid coating. Solid lubricants have higher use temperatures and higher load-bearing capacities than do liquid lubricants. Consequently, they find use in applications where liquid lubricants prove inadequate. It has been noted that because buckminsterfullerene (C_{60}), is a spherical macromolecule and is thought to be very stable and slow to react with other substances, it should make an excellent lubricant. This project utilizes the controlled wear of a hard matrix to reveal the embedded high-temperature, solid lubricant. Such a composite coating would be produced by CVD, which has been demonstrated capable of producing multiphase coatings of controlled composition and microstructure. The C_{60} phase cannot be simultaneously formed during deposition, as can other of the proposed lubricants. The material can be incorporated into a coating, however, by entrainment in the coating gases.

Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831

32. Synthesis of Advanced Composite Ceramic Precursor Powders by the Electric Dispersion Reactor

Michael T. Harris, Chemical Technology Division
615/574-5962

	Funding Profile
Date Started: July 1, 1991	FY 91 - $201,000
Anticipated Duration: 3 Years	FY 92 - $179,000
	FY 93 - $365,000
	FY 94 - $325,000

The use of high-intensity-pulsed electric fields for droplet size control in dispersed liquid systems is being investigated. This technology has been utilized in a device called the electric dispersion reactor (EDR) to carry out the synthesis of micron-sized particles for the production of precursor powders of advanced ceramic materials. In this approach, pulsed electric fields are employed to create dispersions of microscopic conducting (aqueous-based) drops in nonconducting (organic) liquids. Each of these droplets becomes a localized microreactor where reactants in the organic phase diffuse into the aqueous droplets in which precipitation and gelation occur, while water and reaction products diffuse into the organic phase. The particle morphology is altered by varying reactant compositions in the liquid-liquid system while achieving intraparticle stoichiometric consistency. This leads to the production of high-quality precursor powders that, in turn, yield dense, consistent green-body material. Furthermore, this method requires far less energy expenditures than conventional approaches that rely on such inefficient operations as solids blending, mixing, and grinding to accomplish the formation of mixed-oxide precursor material.

Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831

33. Biocatalytic Design by Chemical Modification

Jonathan Woodward, Chemical Technology Division
615/574-6826

Date Started: October 1, 1991

Anticipated Duration: 3 Years

Funding Profile

FY 92 - $285,000

FY 93 - $260,000

FY 94 - $235,000

The overall goal of this project is to demonstrate that the generation of a biocatalyst with multiple active sites is possible by the chemical modification of a single enzyme and, once formed, it will have utility in the generation of energy and the degradation of polymeric and monomeric compounds. The model enzyme chosen to study is cellobiohydrolase I (CBH I), the major component of the cellulase enzyme mixture produced by the fungus, *Trichoderma reesei.* This enzyme catalyzes the hydrolysis of cellulose to cellobiose and can be purified relatively easily and quickly in preparative quantities. If, besides being an hydrolase, oxidase activity could be conferred upon CBH I, then it is conceivable that naturally occurring cellulosic substrates (lignocellulose) could be biodegraded (requiring both oxidation and hydrolysis) by a single biocatalyst by abolishing or reducing the pretreatment requirement. Consequently, there would exist a good possibility for a dramatic reduction in the costs and energy requirements associated with the enzymatic degradation of cellulose that could contribute to an energy-efficient and cost-effective waste management and bioprocessing system. The reason for this is that current pretreatment methods are costly and energy intensive, requiring capital investment as well as routine operational costs. Objectives of the research include: (a) the purification of gram quantities of CBH I; (b) the attachment of redox-active inorganic groups to the polypeptide of CBH I; (c) a comparison of the kinetic properties of native and modified CBH I, including the determination of their substrate specificity; (d) the demonstration of the efficient biodegradation of various lignocellulosic biomass sources by the modified enzyme; and (e) a comparative economic analysis of an enzymatic hydrolysis of lignocellulose to glucose process employing conventional pretreatment techniques or chemically modified biocatalysts.

Princeton University
Princeton, NJ 08544-1009

34. Optimally Controlled Interior Manipulation of Solids

Herschel Rabitz, Department of Chemistry
609/258-3917

	Funding Profile
Date Started: November 19, 1992	FY 93 - $329,000
Anticipated Duration: 3 Years	FY 94 - $349,000
	FY 95 - $299,000

In the processing of solid state materials, manipulation or modification is usually confined to their accessible exterior surfaces. This project is concerned with the development of a technique for modification of the interior solids without the necessity of opening up the material. The technique is based on the concept of designing and creating temporally and spatially tailored laser pulses that deposit energy on the surface for the purpose of launching an intense acoustic wave that focuses within the solid. Taking account of the relatively large illumination area on the surface and the focusing nature of the acoustic waves, it should be possible to minimally disrupt the surface while still attaining significant degrees of interior modification at the target volume. A central feature of this new materials processing method is its reliance on destructive and constructive interference between the ensuing shear and compressional acoustic waves. The delicacy of this method calls for the use of optimal design and control techniques for the temporal and spatial shaping of the laser beams. The research will consist of a theoretical design effort that closely interacts with a laboratory program for implementation of the design concepts. The research will be conducted in a series of steps, starting with low intensity focusing and proceeding to the regime where permanent solid interior alteration is possible. In accord with this sequential development, theoretical design work will move from the linear to the nonlinear regimes of solid mechanics and the laboratory studies will involve increasing laser pulse intensities and complexities of pulse shapes. The overall purpose of the research is to establish the feasibility of achieving interior manipulation of solids. Particular attention will be paid to discerning the flexibility as well as limitations of the physical process. An established capability for interior manipulation of solids would open up many opportunities including interior annealing, induced phase transitions, induced chemical reactions, crack arresting, controlled defect site generation, and interior welding.

Purdue University
1295 Potter Engineering Center
West Lafayette, IN 47907

35. Zeolite Catalysis in Conversion of Cellulosics

George T. Tsao, Laboratory of Renewable Resources Engineering
317/494-7024

	Funding Profile
Date Started: February 15, 1992	FY 92 - $255,000
Anticipated Duration: 3 Years	FY 93 - $235,000
	FY 94 - $244,000

The use of zeolite catalysts may improve conversion of cellulosics in two important ways, namely (a) reduction of glucose inhibition of cellulase activities; and (b) efficient conversion of xylose into xylulose and then ethanol. This project will study adsorption of carbohydrates, hydrolysis of oligosaccharides, and aldose-ketose isomerization catalyzed by zeolites under various conditions. High pressure liquid chromatography, nuclear magnetic resonance and infrared measurements will be used to detect sugars and to examine their interactions with the zeolites. These studies will help to elucidate the mechanism, kinetics, diffusion, and equilibrium of the reactions as they are affected by the presence of zeolites. Zeolite-promoted reactions including isomerization and oligomer hydrolysis can be coupled with biological reactions including enzymatic hydrolysis and yeast fermentation for the above-mentioned improved overall conversion of cellulosics.

Rensselaer Polytechnic Institute
Troy, NY 12180-3590

36. Cationically Polymerizable Monomers Derived From Renewable Sources

James V. Crivello, Department of Chemistry
518/276-6825

	Funding Profile
Date Started: February 1, 1991	FY 91 - $310,000
Anticipated Duration: 3 Years	FY 92 - $235,000
	FY 93 - $248,000

The objective of this project is to make use of a wide range of products obtained from plant sources as monomers for the direct production of polymers that can be used for a wide range of plastic applications. In particular, high-volume American agricultural products such as soybean, cotton or linseed oils or forestry products such as lignin and cellulose are targeted for use either directly or with very slight modification for the production of the plastics. The monomers thus obtained will be rapidly and efficiently converted to polymers using ultraviolet light or heat employing unique catalysts developed in this laboratory. It is expected that these catalysts provide a low energy and pollution-free means for the direct fabrication of the plastics. Furthermore, the polymers that are formed are expected to be prone to biodegradation and to pose little long term accumulation or pollution hazard.

Science Research Laboratory
1150 Ballena Boulevard, Suite 100
Alameda, CA 94501

37. The Plasma Centrifuge (A Compact, Low Cost, Stable Isotope Separator)

Mahadevan Krishnan
510/521-8087

	Funding Profile
Date Started: September 15, 1991	FY 91 - $495,000
Anticipated Duration: 3 Years	FY 92 - $441,000
	FY 93 - $317,000

The objective of this project is to make practical a new type of isotope separator called the Plasma Centrifuge. The Plasma Centrifuge is based on the concept of a cylinder of ionized matter (plasma) contained by a magnetic field and set into rotation by application of an electromagnetic body force. The typical embodiment consists of a rotating column that is fed by a vacuum arc plasma source at one end. As the plasma streams towards the other end of the chamber, centrifugal forces cause the heavier isotopes of the plasma ions to move nearer the periphery of the rotating column, resulting in partial separation between the constituent isotopes. Collectors placed at the other end of the column can collect either the outer portion that is enriched in the heavier isotope, or the inner portion that is enriched in the lighter isotope, as desired. This Plasma Centrifuge apparatus fits into a small room and can enrich dozens of isotopes with a throughput of about 1-3 grams/hour of enriched product. Such a capability would make this centrifuge a useful new separator to supply the US demand for a variety of enriched isotopes that are badly needed in these quantities in the fields of basic research in physics/chemistry/geology/medicine and in medical diagnostics radiological practice. The cost, modularity and size of this approach makes the Plasma Centrifuge a potential replacement for CALUTRONS, which are today's primary source of supply of enriched isotopes.

Stanford University
Stanford, CA 94305

38. Growth of High T_c Superconducting Fibers Using a Miniaturized Laser-Heated Float Zone Process**

Robert S. Feigelson, Center for Materials Research
415/723-4007

Date Started: January 15, 1989

Anticipated Duration: 4 years*

Funding Profile

FY 89 - $478,000

FY 90 - $375,000

FY 91 - $355,000

The primary objective of this project is to thoroughly explore the potential of the laser-heated pedestal (float zone) growth method for the preparation of flexible wires (fibers) of the new copper-oxide ceramic superconductors, in particular, the Bi-containing compounds that are capable of carrying high currents at temperatures above 77 K. This method, which involves drawing wires directly from a melt, has many advantages over other methods, most important of which is that it allows precise control of the growth process through the control of melt composition. Critical issues that will be considered in this superconducting fiber program include: (a) determining the most suitable compositions to be grown; (b) the maximum allowable growth velocity that can be used to grow fibers with high T_c; and (c) the maximum length of fiber that can be produced. To address these issues, the program will involve an in-depth study of: (a) the thermodynamic and kinetic factors that affect growth rate and the properties of the fibers produced; (b) the development of an advanced fiber growth system that will permit better control of system parameters; and (c) the development of techniques to enhance fiber throughput via increased growth velocity, postgrowth heat treatments, and the possibility of growing many fibers simultaneously.

*Project Completed

**Includes 20 month no-cost extension

Stanford University
Stanford, CA 94305

39. Nonlinear Optics in Doped Fibers

Richard H. Pantell, Electrical Engineering Department
415/723-2564

Date Started: May 1, 1992	Funding Profile
Anticipated Duration: 3 years	FY 92 - $364,000
	FY 93 - $363,000
	FY 94 - $366,000

The objective of this project is to develop a novel and simple technology for optical, all-fiber switches based on the third order nonlinear effect in doped, single-mode fibers. The principle behind these devices is that, when exciting a transition near resonance, the electronic distribution changes and so does the contribution of this transition to the refractive index of the material. This effect exists in pure silica, but it is extremely weak, and in undoped, pure silica fibers. Tens of watts and tens of meters of fiber are required to induce the phase shift of π needed for switching. The novelty of this approach is to use a fiber doped with an appropriate impurity and excite it optically near an absorption resonance of this impurity to produce strongly enhanced nonlinear susceptibilities. Modeling shows that it is then possible to reduce the pump and length requirements by several orders of magnitude each, and to produce a π phase shift in centimeter lengths with milliwatts of pump power. The ultimate thrust of this project is to investigate this effect with a variety of impurities exhibiting high oscillator strength transitions to produce both high speed and very short devices. For picosecond response times, the reduction in the pump power-fiber length product is predicted to be 7 - 8 orders of magnitude over undoped silica. Slower but useful devices will also be investigated using well-understood erbium and neodymium-doped fibers that have been extensively studied as lasers and amplifiers but not as nonlinear switches. This investigation is anticipated to open the door to the first low-power, ultra-short switches and modulators made with single-mode optical fibers, operated with a low-power, long-lifetime laser diode. Such components are not currently available in a form compatible with fiber optic systems, either from fiber-based or integrated-optic based elements. There are a variety of energy applications for the proposed research, including oil exploration, control of power substations, and management of consumer distribution systems. Interactions with several companies are planned throughout this study for directivity, technology transfer, and manufacturing of some of the devices tested under the program.

Texas A&M University
College Station, TX 77843

40. Utilizing Laser Spectroscopy of Noble Gas Tracers for Mapping Oil and Gas Deposits

Hans A. Schuessler, Physics Department
409/845-5455

	Funding Profile
Date Started: December 15, 1992	FY 93 - $152,000
Anticipated Duration: 3 Years	FY 94 - $164,000
	FY 95 - $168,000

Radioactive nobel gases are being used as tracers to measure the structure of gas and oil deposits. Due to their chemical inertness, they offer the advantage that they do not react with the environment with which they are in contact. Usually a nobel gas tracer is injected at an injection well and gas or liquid samples are taken from a production well. When a long-lived tracer, such as ^{35}Kr ($T_{1/2}$ = 10.8 y), is used for extended deposits, the specific activities of the production well samples are low. The measurements are then difficult, since the sample must be analyzed in an ultralow counting facility to minimize the background counts. This problem exists even when large amounts of tracer gas with high radioactivity levels (several hundred curie) are injected for which extensive safeguarding of the personnel is necessary. The objective of this project is to improve the sensitivity of nobel gas detection in samples taken from production wells by more than three orders of magnitude by applying optical rather than nuclear detection. The novel technique will not only reduce the required radioactivity levels at the injection site, but work even with stable tracer isotopes thus abolishing most handling, transportation and storage problems. Collinear fast beam laser spectroscopy will be used for which a sensitivity at the few atoms level and also complete isotopic selectivity has already been demonstrated. The construction of a prototype analytical instrument is planned, that can routinely and quickly analyze samples for their noble gas content. Single nobel gas atoms can then be detected, even in the presence of other isotopes and atoms which are more abundant by a factor of about 10^{15}. Since sample enrichment might not be necessary and stable noble gas tracers are inexpensive, the method promises to be more cost effective and environmentally safe than present nuclear decay detection.

The University of Texas at Austin
Austin, TX 78712

41. Photoassisted Oxidation of Oil Films on Water*

Adam Heller, Department of Chemical Engineering
512/471-8874

Funding Profile

Date Started: January 1, 1990 — FY 90 - $333,000

Anticipated Duration: 39 Months** — FY 91 - $297,000

FY 92 - $297,000

The objective of this project is to develop a new environmentally safe technology for eliminating crude oil slicks from oil spills. To accomplish this, microbeads that float on oil slicks are used. Under solar illumination, the microbeads accelerate the oxidation of the oil. The low-cost, hollow glass microbeads will be partially coated with a layer of titanium dioxide, a known photocatalyst for oxidation of contacting organic compounds. The beads will harvest light from areas substantially larger than their own, because oil films between air and water trap and propagate light, waveguiding it to the beads that, in turn, waveguide it to the titanium dioxide photocatalyst particles. The waveguiding is associated with increasing indices of refraction. The required coverage of oil slicks with microbeads depends on their optical properties, increasing for heavier crudes. Coverage of 1% of the surface with microbeads is projected to be adequate for the photodissolution, under average solar illumination, in 1 month, even for the heavy crude spills.

*Project Completed
**Includes 3 month no-cost extension

The University of Texas at Austin
Austin, TX 78712

42. Synthesis of New High Performance Lubricants and Solid Lubricants

Richard J. Lagow, Department of Chemistry
512/471-1032

	Funding Profile
Date Started: June 1, 1991	FY 91 - $377,000
Anticipated Duration: 3 Years	FY 92 - $272,000
	FY 93 - $218,000

Work will be conducted on the synthesis and characterization of perfluoropolyethers, an extraordinary class of high performance lubricants, by a relatively new technique, direct fluorination, that is emerging as the best way to prepare perfluoropolyethers. Many new and important classes of perfluoropolyethers will be prepared with very significant potential as lubricants. Currently, the highest obtainable molecular weight perfluoropolyether synthesized using conventional polymerization processes is 50,000. This fluid with a molecular weight of 50,000 has a viscous syrup-like consistency. High molecular weight solids with a perfluoropolyether backbone have not been attained using methods other than direct fluorination technology. There exists now the capability to synthesize perfluoropolyethers with molecular weights over 1,000,000. Thus, solid perfluoropolyether lubricants are accessible for the first time. A feature of direct fluorination technology where hydrocarbon structures are converted to fluorocarbon structures is that the organic precursors are converted to fluorocarbon fluids and solids without substantial cross-linking and without increased or decreases in degree of polymerization. The synthesis of hydrocarbon polymers as starting materials has many other advantages and introduces great flexibility and capabilities not attainable using polymerization processes with various perfluorinated ethylene oxides. Work will be done on many generic classes of solid fluorocarbon lubricants. The capability to make perfluoropolyethers soluble (miscible) with less expensive hydrocarbon lubricants and poly alpha olefins has recently been developed. One of the most important and promising prospects of this research is the synthesis of chlorinated perfluoropolyether fluids that are very compatible and soluble in hydrocarbons offering potential as high performance lubrication additives.

The University of Texas at Austin
Austin, TX 78712-1063

43. The Railplug: Development of a New Ignitor For Internal Combustion Engines

Ronald D. Matthews, Department of Mechanical Engineering
512/471-3108

	Funding Profile
Date Started: January 15, 1991	FY 91 - $500,000
Anticipated Duration: 3 Years	FY 92 - $500,000
	FY 93 - $500,000

Although conventional spark plugs appear to be entirely suitable for spark ignition (SI) engines, the design of the SI engine is limited by the characteristics of the ignitors. That is, if superior ignitors were available, the SI engine could be designed in a manner that would yield reduced emissions and improved fuel economy. Similarly, the design of virtually all types of internal combustion engines is limited in one way or another by the characteristics of the available ignitors. In this project a new type of ignitor is being investigated that operates on a much different principle than either conventional ignitors or any of the other advanced ignitor concepts that have been studied recently. Technology is being transferred from "star wars" to the automotive industry--railguns (a kinetic energy defense weapon) are being miniaturized to generate a new ignitor for internal combustion engines. Two characteristics make the miniaturized railgun, or "railplug", highly attractive as a replacement for conventional ignitors: a relatively large mass of plasma is generated and the plasma leaving the muzzle of the railplug has a high velocity. The advantages of using a railplug ignition system in three different engine applications are being investigated: replacement of spark plugs in both conventional SI engines and in dilute homogeneous charge SI engines; and replacement of glow plugs in indirect injection diesels to improve cold start characteristics. The primary objectives of the research are to improve internal combustion engine performance and fuel economy and to reduce emissions.

University of Washington
Seattle, WA 98195

44. The Supersonic-Mixing, Shock-Wave Reactor: An Innovative Approach for Efficient Chemical Production

Arthur T. Mattick, Aerospace and Energetics Research Program
206/543-6181

	Funding Profile
Date Started: June 15, 1993	FY 93 - $272,000
Anticipated Duration: 3 Years	FY 94 - $418,000
	FY 95 - $309,000

The production of many commercially-important chemicals involves pyrolysis of hydrocarbon feedstocks, an energy-intensive process that is now carried out by heating components of oil or natural gas in a furnace. This research will examine the potential of a novel approach for pyrolysis, the supersonic-mixing, shock-wave reactor, for reducing the energy consumption and production cost of ethylene and other compounds. These benefits arise from the use of gasdynamic processes to precisely control the temperature history of a reactant and thereby maximize the yields of valuable products. Initial studies indicate that ethylene yields in the pyrolysis of ethane may be 20-40% higher by using this method in place of conventional technology, and energy consumption may be reduced by 15% or more. The research program entails: 1) experimental investigation of fundamental aspects of supersonic mixing and reacting gas streams, such as mixing shear layers, shock structure and uniformity, and reaction pathways, that are important in the reactor's operation; 2) measurement of product yields under conditions of pyrolysis expected in commercial applications of the reactor; and 3) examination of methods of implementing the reactor for chemical manufacture.

Washington State University
Pullman, WA 99164-2814

45. Tunable Femtosecond UV Light Source Using a Novel Frequency Upshift Technique

Henry C. Kapteyn, Department of Physics
509/335-4671

Date Started: April 19, 1993

Anticipated Duration: 3 Years

Funding Profile

FY 93 - $156,000

FY 94 - $158,000

FY 95 - $131,000

The goal of this project is to implement a new approach for producing ultrashort light pulses at ultraviolet to extreme-ultraviolet wavelengths. An intense light pulse can be used to create a moving ionization front; light can be reflected from this front and experience a relativistic Doppler upshift. Two recently-developed technologies now make it possible to create tunable light pulses of unprecedented short duration using this technique. First, the recent development of small-scale terawatt femtosecond laser systems makes it possible to create an extremely abrupt moving ionization front, using the process of multiphoton ionization. Second, recently-developed techniques have resulted in the generation of single-optical-cycle duration pulses in the far-infrared. It is shown herein that it is possible to upshift such pulses to optical and shorter wavelengths while still retaining nearly single-cycle duration. This way, pulses of 1-5 femtoseconds duration in the UV to XUV region of the spectrum can be created.

SMALL BUSINESS INNOVATION RESEARCH PROGRAM

The Small Business Innovation Research (SBIR) program was created in 1982 by Public Law 97-219 and reauthorized in 1992 until the year 2000 by Public Law 102-564. This program has the following objectives: to increase private sector commercialization of technology developed through Federal R&D; to increase small business participation in Federal R&D; and to improve the Federal Government's dissemination of information to women-owned-, and economically disadvantaged small business concerns.

Agencies with extramural R&D budgets of over $100 million are required to conduct an SBIR program using a set-aside of a stated percentage of that budget. The percentage increased from an initial 0.2% in 1983 to 1.25% in 1986 through 1992. Public Law 102-564 increased the set-aside further, starting with 1.5% in 1993 and reaching a maximum of 2.5% in 1997. The Department's SBIR budget for FY 1993 was about $50 million.

In the Department of Energy, SBIR funds are used to support an annual competition for Phase I awards of up to $75,000 for about 6 months to explore the feasibility of innovative concepts. Only Phase I winners are eligible to compete for Phase II awards, which are a continuation of the Phase I projects. Phase II is the principal research or R&D phase. The maximum funding for Phase II projects through FY 1993 has been $500,000 over a two-year period. The maximum funding level will be raised to $600,000 in FY 1994. Technical topics for DOE's annual SBIR Solicitation are compiled by program managers in the agency.

In Fiscal Year 1993, the Division of Advanced Energy Projects (AEP) managed six Phase II SBIR projects. These projects were selected from grant applications submitted to the Advanced Energy Projects topic, "Novel Sources of Electromagnetic Radiation", which was included in both the 1990 and 1991 DOE SBIR Program Solicitations. AEP is managing thirteen Phase I SBIR projects that were awarded under the topic, "Design and Applications of Novel Materials," included in the 1993 DOE SBIR Program Solicitation.

PHASE I SBIR PROJECTS

Advanced Fuel Research, Inc.
P.O Box 380379
East Hartford, CT 06138-0379

46. On-Chip Ferroelectric Energy Storage Capacitors for Silicon Solar Cells

Jing Luo
203/528-9806

Funding Profile

Date Started: September 8, 1993

FY 93 - $74,573

When a solar cell array is designed to power an electric motor car or is used for a space mission, a favorable power-to-weight ratio is important for its energy storage unit. Compared with batteries, the most frequently used energy storage technology, a thin film ferroelectric (FE) capacitor bank can be of lower cost and yield a higher power-to-weight ratio. In single crystal form, FE materials have superior dielectric properties, such as a large dielectric constant and a high breakdown voltage. Thick films of FE materials have already been used in metal-insulator-metal (MIM) capacitors and are well characterized. The technical challenge in this project will be to grow high quality ferroelectric thin films with large dielectric constant and low leakage current on a silicon (Si) substrate. In Phase I, a multilayer MIM capacitor energy storage unit for Si solar cells will be developed. This unit can be deposited at the back of a solar cell wafer to provide on-chip energy storage. This stacked capacitor unit offers ease of fabrication and avoids the various leakage mechanisms found in trench structures. Its structure is compact and should be suitable for wafer scale production (compatible with that for Si solar cells).

Advanced Refractory Technologies, Inc.
699 Hertel Avenue
Buffalo, NY 14207

47. Porous Aluminum Nitride Part Fabrication to Support Advanced Battery Development

Thomas J. Mroz, Jr.
716/875-4091

Funding Profile

Date Started: September 8, 1993

FY 93 - $74,878

Advanced batteries based on lithium-metal sulfide cell technology are under consideration for applications such as the electric vehicle, primarily because of their high energy density capabilities. However, current materials of construction limit the reliability of this battery technology for long-term use. In particular, the containment of the electrolyte by an inert separator material is a design-limiting issue. The typical separator fabrication method, involving pressed powder combinations, leads to fragile components that may shift during use, altering the electrical response of the cell. In extreme cases, the entire cell may be shorted. Development of a rigid, porous separator is planned in this project, in order to alleviate this reliability issue. Aluminum nitride (AlN), which is a current candidate for the separator component, will be fabricated into rigid, porous plates using an existing aqueous-based roll fabrication method and specialized sintering technology. Phase I will result in a suitably porous, strong tile that can be impregnated with electrolyte and inserted into the battery cell as an integral unit. Tiles with increased porosity will be developed, based on technology previously used to make tiles for refractory applications. The tile separator concept is expected to greatly improve the reliability of the entire cell, and is also expected to improve the commercial viability of the cell by facilitating a reduction in cell size and weight, as well as improving the ability to mass manufacture cells inexpensively.

American Superconductor Corporation
149 Grove Street
Watertown, MA 02172

48. Oxide Dispersion Strengthened Silver for Use in High-Temperature Superconductor Composite Wires

Gilbert N. Riley, Jr.
617/923-1122

Funding Profile

Date Started: September 8, 1993

FY 93 - $75,000

The strengthening of high-temperature superconducting (HTS) composite wires with oxide dispersion strengthened (ODS) silver is the subject of this project. State-of-the-art HTS composite wires consist of ceramic superconductor filaments encased in a silver sheath. For reasons of chemical compatibility and oxygen permeability, silver is the only material that can be used to sheath the HTS. However, the current method of manufacture weakens the silver sheath, resulting in reduced HTS composite strengths. The low strengths are a major obstacle in the development of HTS wires for applications requiring high strength such as power transmission cables, superconducting magnetic energy storage, current limiters, and motors. The only known method of increasing the strength of sheath, while maintaining the chemical compatibility and oxygen permeability of silver, is ODS. ODS is currently used to strengthen silver for relatively low-temperature applications. However, high temperatures are used in the manufacture of HTS composite wires, and little is known about the high temperature characteristics of ODS silver materials. Phase I will evaluate novel ODS silver materials, in the context of HTS composites processing. Two synthesis routes to form ODS silver will be evaluated in Phase I: internal oxidation of a metallic alloy precursor and powder metallurgy. An assessment of the formability and mechanical properties of the ODS silver materials produced by each route will be made. Materials produced using the two synthesis routes will be used in statistically designed experiments, based on process conditions similar to those used to fabricate HTS composites. A quantitative expression of the mechanical properties of the novel ODS silver materials as a function of the process parameters (temperature, oxygen activity, time, and strain) will be achieved. Phase II will be directed to the fabrication and testing of HTS composites using the optimum sheathing materials.

CHEMAT Technology, Inc.
19441 Business Center Drive, #139
Northridge, CA 91324

49. Capacitive Energy Storage Using High Surface Area Transition Metal Compounds

Haixing Zheng
818/727-9786

Funding Profile

Date Started: September 8, 1993 — FY 93 - $75,000

High surface area materials have diverse applications, such as for energy storage systems and for catalytic converters. In Phase I, high surface area materials will be prepared using the sol-gel process. Various electrically conductive transition metal oxides, nitrides, and borides will be prepared and studied by measurement of their double layer capacitance (which implies energy storage capability per unit area). The effect of the sol-gel processing conditions (such as precursors, concentration, viscosity and drawing speed) on the thickness of the porous coatings will also be determined, while making thick, porous coatings. These coatings would be used as electrodes. An energy storage device will be designed and its energy storage capability will be evaluated, based on the use of these new sol-gel derived electrodes. The experimental results will be used to optimize the process in order to achieve the best energy storage technology.

Colorado Engineering Research Laboratory (CERL), Inc.
1500 Teakwood Court
Fort Collins, CO 80525

50. Lubricious-Surface Silicon-Nitride Rings for High-Temperature Tribological Applications

Frank M. Kustas
303/484-5940

Funding Profile

Date Started: September 8, 1993

FY 93 - $74,898

Frictional losses account for a large percentage of the total mechanical power loss in engines. Therefore, sliding surfaces with low friction, high wear resistance, and long lifetimes, represent an enabling technology for future transportation systems. This project will investigate an entirely new class of ceramic-matrix-composite (CMC) rings and cylinders, with a graded distribution of ceramic compounds near the sliding-wear interface. The selective ceramic reinforcements will convert to low-friction and low-wear lubricious oxides during high-temperature air exposure. Long-wear-endurance lifetimes of the CMC surfaces will result, due to the self-lubricating, replenishable nature of the reinforcements that are incorporated in the matrix to large depths. Phase I will demonstrate innovative fabrication methods that include: (1) centrifugal spinning of a slurry of titanium nitride (TiN) reinforcements and silicon matrix powders that will be fired and nitrided to produce a TiN outer-surface-reinforced silicon nitride (Si_3N_4) ring, and (2) infiltration of a graded porosity Si_3N_4 cylinder liner with Ti molten metal that will be subsequently carburized to form a titanium carbide (TiC) inner-surface-reinforced Si_3N_4 cylinder liner. Test specimens will be subjected to microstructural examinations and microhardness measurements. Sliding wear tests will be performed on mating specimens from the rings (TiN/Si_3N_4) and cylinders (TiC/Si_3N_4) in 800°C air, to enhance piston ring-on-cylinder liner contact. Coefficients of friction, wear rates, and lubrication mechanisms will be established. In Phase II, near-net shape fabrication of rings and cylinders will be studied through the use of controlled geometric dies.

Giner, Inc.
14 Spring Street
Waltham, MA 02154-4497

51. Molded Titanium Carbide Bipolar Plates for High Voltage Battery and Fuel Power Sources

John A. Kosek
617/899-7270

Funding Profile

Date Started: September 8, 1993 — FY 93 - $74,978

A lack of inexpensive, corrosion-resistant materials for bipolar plates is a major hindrance to commercialization of many advanced acidic electrochemical systems, where one of the electrodes operates at a high oxidizing potential. Under these conditions, graphite, a relatively low cost material, is unstable. Some stability improvements can be made by resin impregnation and high-temperature heat treatment, but this significantly increases the cost of the graphite. In this project, bipolar plates made from corrosion-resistant titanium carbide will be developed. In preliminary testing, such plates showed significantly better corrosion resistance at oxidizing conditions than graphite. The titanium carbide plates will be molded, a low-cost process. They are expected to be less expensive than resin-impregnated graphite plates, and also to have higher electrical conductivity than graphite plates. Phase I will develop procedures for molding bipolar plates with desirable physical, chemical, and electrochemical properties for use in acid-containing applications under oxidizing conditions. The effect of molding conditions on bipolar plate properties and the use of the plate in fuel cells will be investigated.

Ibis Technology Corporation
32A Cherry Hill Drive
Danvers, MA 01923

52. Room Temperature Photoluminescence of Germanium (Ge) Nanostructures by High Energy Implantation of Ge into a Buried Oxide of Silicon

L. P. Allen
508/777-4247

Funding Profile

Date Started: September 8, 1993 FY 93 - $74,927

The optical properties of nanometer-sized indirect-bandgap semiconductors is an area of great fundamental and practical interest. Demonstrations of room temperature yellow-orange Ge photoluminescence have made such quantum confinement effects of interest to both the commercial and military markets. A significant issue related to the practical application of Ge nanostructures is the ability to fabricate a uniform distribution of nanocrystalline precipitates in a silicon (Si) fabrication-ready matrix. This project will investigate a method of fabrication that incorporates the implantation of Ge^+ ions into a silicon-on-insulator (SOI) structure. The peak distribution of the Ge^+ implant is designed to match the buried oxide center position of the SOI wafers. In Phase I, a matrix of implant and anneal parameters is planned in order to obtain a thermodynamically predicted uniform layer of angstrom-size Ge precipitates at a calculated depth. Characterization of precipitate presence and size will be performed, along with room temperature photoluminescence (PL) testing.

Interphases Research
722 Rushing Creek Place
Thousand Oaks, CA 91360

53. Nanoscale Processing for Ternary Semiconductors

Shalini Menezes
805/492-9814

Funding Profile

Date Started: September 8, 1993 — FY 93 - $75,000

This project will develop an electrochemical technique to synthesize composition modulated ternary semiconductor alloys. Phase I is directed toward defining optimal conditions for the synthesis of novel superlattice structures based on I-VI-VII materials, particularly copper selenium iodide ($CuSe_3I$), an important component of a low cost n-$CuInSe_2$- based photovoltaic cell. The technique will be demonstrated by investigating the deposition of continuous-epitaxial and abrupt layered Cu-Se-I based superlattices. The reaction mechanisms and deposition parameters will be investigated by synthesizing and characterizing a variety of Cu-Se-I based superlattices. The information derived from this project will help to devise a generic electrochemical method to fabricate nanostructured materials.

ISM Technologies, Inc.
9965 Carroll Canyon Road
San Diego, CA 92131

54. Low Temperature Deposition of Titanium Nitride

Anthony J. Perry
619/530-2332

Date Started: September 8, 1993

Funding Profile
FY 93 - $74,599

Titanium nitride (TiN) has been found to be an excellent coating for many wear applications. For example, a very high percentage of tool inserts are coated with titanium nitride. However, the temperature at which it is deposited, even for "low temperature" processes, such as cathodic arc deposition, is still too high for coatings on aluminum, polymers, many steels, and some other materials, without reducing the strength of the base materials or creating other problems. The temperature at which titanium nitride is deposited by conventional physical vapor deposition processes, such as electron beam evaporation, sputtering, and cathodic arc deposition, must be high in order to prevent excessive stress build-up in the coating and to a achieve the desired micro-structure. A process for cathodic arc deposition has been developed whereby a pulsed, high voltage bias applied to the work piece allows deposition at near room temperature without excessive stress build-up and with superior adhesion. This project will extend this technology to the deposition of titanium nitride on aluminum, steel, and other materials that are not able to withstand the higher temperatures associated with conventional deposition technologies. Phase I will establish that TiN can be deposited at low temperatures using a pulsed, high voltage bias along with the conventional bias. The coatings should have low residual stress and good adhesion without loss of mechanical properties.

Jet Process Corporation
25 Science Park
New Haven, CT 06511

55. Jet Vapor Deposition of Ultra-Thin Platinum Catalyst Loadings Directly on Polymer Ion-Exchange Membranes for Fuel Cell Applications

Bret L. Halpern
203/786-5130

<u>Funding Profile</u>

Date Started: September 8, 1993 — FY 93 - $75,000

Polymer Electrolyte Fuel Cell (PEFC) technology has great promise for the electric vehicle. However, state-of-the-art technology currently requires catalyst loadings of expensive noble metals such as platinum (Pt) at costs that hinder economic vehicular application of PEFCs. A novel Jet Vapor Deposition (JVD) process will be used to address this problem. JVD is capable of high rate, highly efficient deposition of metal particles. This project will deposit ultra-thin, nanometer-sized loadings of high surface area Pt electrocatalyst clusters directly on the surface of polymer electrolytes such as Nafion™ (DuPont). Phase I will test and evaluate samples to determine the catalytic effectiveness of these ultra-thin Pt deposits. It will also develop preliminary studies on process scale-up and production economics. Specialists in PEFC technology at Los Alamos National Laboratory and Ballard Power Systems will participate in Phase I.

New Material Concepts
15 Guile Avenue
Tewksbury, MA 01876

56. A Direct Thermal to Optical Energy Converter

R. G. Roy
508/851-2451

Funding Profile

Date Started: September 8, 1993 FY 93 - $74,918

This project will conduct crystal growth research on a single crystal rare earth oxide, that is expected to be a converter of thermal energy to a narrow wavelength emission in the near infrared. This crystal is expected to behave as a photonic band gap (PBG) material (a new class of materials). The concept of a PBG material was first explicitly described by Eli Yablonovitch (Phys. Rev. Lett. 58, (1987) 2059-2062). In Phase I, measurements will be made of the light emission from these crystals when they are heated to a temperature that can be achieved with a propane torch.

Spire Corporation
One Patriots Park
Bedford, MA 01730-2396

57. Quantum Confinement Effects in Heteroepitaxial Silicon/Zinc Sulfide (Si/ZnS) Nanostructures Produced by Organometallic Chemical Vapor Deposition

H. Paul Maruska
617/275-6000

Funding Profile

Date Started: September 8, 1993

FY 93 - $74,788

Silicon multiquantum wells with lattice-matched ZnS barriers will be grown on silicon substrates by organometallic chemical vapor deposition. Such silicon nanostructures are expected to exhibit the same quantum confinement effects that have already been reported for porous silicon, but now with a carefully controlled, planar crystal structure. Although silicon quantum wires produced by electrochemical etching show visible photoluminescence and electroluminescence, the fractal nature of those structures makes the preparation of reproducible devices unlikely. Because the Si/ZnS superlattices will be configured as waveguides, analogous to AlGaAs/GaAs quantum well structures, it is anticipated that silicon diode lasers operating at visible wavelengths may become possible. Visible photoluminescence has already been reported with Si/Si_3N_4 quantum well structures. Because ZnS can be made conducting, the capability to generate electroluminescence under relatively low electrical bias is expected. In Phase I, ZnS films will be prepared epitaxially by mixed oxide chemical vapor deposition (MOCVD) on perfectly cleaned silicon substrates, using a procedure recently developed at the University of Florida. Silicon films with thickness on order of 50 Å will be deposited, using a photo-assisted deposition process and several silicon-based precursors. The goal of Phase I is to demonstrate photoluminescence from a single silicon quantum well. Phase II will proceed to investigate multiquantum wells, and configure the devices as junction diodes, to search for visible electroluminescence.

Ultramet
12173 Montague Street
Pacoima, CA 91331

58. Coated Micrograin Carbides for Wear Resistance

Brian E. Williams
818/899-0236

Funding Profile

Date Started: September 8, 1993

FY 93 - $69,781

Micrograin carbides are small grain size (1-5 micron diameter) particles of tungsten carbide (WC) that have been "cemented" together with a predominantly cobalt matrix, using liquid phase sintering. They are an excellent material for carbide cutting tools and other wear- and/or corrosion-resistant parts, having better mechanical properties due to their finer grain size than typical carbide tools (20-50 microns). However, some of their potential advantage is lost because of the difficulty of handling such fine powders and mixing them with cobalt and nickel powders to form the blend that is then preformed and sintered. Problems that arise during handling and blending include increased impurity content, nonhomogeneous distribution of matrix powders, and WC-WC particle contact, all of which cause lowered mechanical properties in the finished part. The result is that higher cobalt contents must be incorporated to achieve the desired fracture toughness and transverse rupture strength, with a consequent decrease in tool hardness life. Phase I will demonstrate the feasibility of coating each individual WC grain with the proper thickness of cobalt matrix material so that, after consolidation, the problems resulting from powder blending (especially WC-WC particle contact and carbide formation) will be minimized or eliminated. This will not only improve mechanical properties and performance over conventional micrograin carbides, but also permit faster consolidation times with lower impurity contents and less deleterious interaction between the matrix and carbide. A large reduction in the amount of cobalt required is also expected.

PHASE II SBIR PROJECTS

Adelphi Technology, Inc.
2181 Park Boulevard
Palo Alto, CA 94306

59. Parametric Radiation as an Intense Monochromatic X-Ray Source

Melvin A. Piestrup
415/328-7337

	Funding Profile
Date Started: March 31, 1992	FY 92 - $292,000
Anticipated Duration: 2 Years	FY 93 - $208,000

The objective of the program is to investigate the use of parametric x-ray radiation (PXR) as a low-cost, pulsed, tuneable x-ray source. PXR generation is achieved by placing natural or synthetic crystals, or multilayer structures, into a relativistic electron beam. The virtual photons associated with the fields of the electrons are Bragg reflected by the periodic crystal lattice, and real x-rays appear at the Bragg angle. The production process is thus analogous to x-ray diffraction by crystals, except that the x-ray beam incident at the Bragg angle is replaced by a relativistic electron beam. This source is quasi-monochromatic, directional, tuneable, and polarizable. Bandwidths can be adjusted from about 0.1% to 50%. Parametric x-ray radiators can be designed to produce specified x-ray energies and bandwidths by careful selection of the crystal radiator, the Bragg angle, and electron-beam parameters. In contrast to synchrotron radiation, PXR requires only the moderate electron-beam energies of inexpensive linear accelerators. Under Phase I, the calculations and proof-of-principle experiments have demonstrated that PXR is a viable source from 5 to 30 keV. The x-ray spectrum from silicon and mosaic graphite crystal was measured using a 90 MeV electron beam. It was found that the intensity from graphite was roughly an order of magnitude higher than that produced by silicon radiators. Up to six harmonics could easily be observed. During Phase II, the range of the PXR source will be extended down to 1 keV and above 30 keV. High-intensity x-ray emission using high average electron-beam currents will also be demonstrated. Natural and synthetic crystal and multilayer structures will be used in these experiments. The angular distribution of the x-rays will be measured, using existing imaging systems. An improved theoretical model for the spectral distribution will be derived and a theory of PXR production by multilayer structures will be developed. Two applications will be studied: medical imaging of the arteries of the heart and the production of x-ray lithographs using soft x-ray emission.

Adelphi Technology, Inc.
2181 Park Boulevard
Palo Alto, CA 94306

60. A Pulsed X-Ray Source Using K-Edge Transition Radiation*

Melvin A. Piestrup
415/328-7337

	Funding Profile
Date Started: February 15, 1991	FY 91 - $292,000
Anticipated Duration: 2 Years	FY 92 - $208,000

The objective of this project is to investigate the use of a novel transition-radiation source to produce a low-cost, laboratory-scale, intense, pulsed x-ray source. By designing transition radiators to emit x-rays at the foil material K-shell photoabsorption edge, the x-ray spectrum is narrowed. The source is thus quasi-monochromatic (40 to 50% bandwidth), directional, intense, and uses an electron beam whose energy is considerably lower than that needed for synchrotron sources. By using a pulsed electron source, foil heating is minimized and high peak currents can be obtained. The radiation produced can be in the soft (0.1 to 5 keV), warm (5 to 15 keV) and hard (> 15 keV) x-ray regions of the spectrum depending upon the foil material used, the foil thicknesses, and the electron-beam energy. Under Phase I the spectral and spatial photon densities from a titanium radiator, whose bandwidth is between 2 and 5 keV, were measured. Using a high current beam, the total power from this radiator, along with a copper radiator whose bandwidth was between 5 and 9 keV, was also measured. Cylindrical and ellipsoidal optics were used to focus the 2 to 5 keV photons to a 1-mm diameter spot 3 m from the radiator. In Phase II, a permanent x-ray beamline will be constructed at an existing accelerator. This beamline will then be used to test five radiators at high average and pulsed currents. These radiators will generate x-rays from 5 to 25 keV. Focusing optics will be designed, fabricated, and used to focus the x-rays in the 5 to 10 keV range. Three applications will be studied: (1) Laue diffraction in the study of the static and kinetic structures of protein molecules, (2) the production of x-ray lithographs using soft x-ray emission, and (3) flash soft x-ray emission from pulsed electron sources.

*Project Completed

Deacon Research

2440 Embarcadero Way
Palo Alto, CA 94303

61. Solid State UV Light Source

David Deacon
415/493-6100

	Funding Profile
Date Started: July 6, 1992	FY 92 - $333,000
Anticipated Duration: 2 Years	FY 93 - $167,000

Deacon Research is developing inexpensive, diode laser based sources of coherent radiation in the blue and ultraviolet regions of the spectrum. In the first phase of this program, we have achieved high efficiency doubling of a diode laser, and anchored these results to the theoretical structure needed to scale to other configurations. We intend to develop a system that produces high conversion efficiency into the ultraviolet. If we succeed, we will have created a revolutionary new tool for use by the biological analytical and scientific communities. The combined advantages of long laser lifetime and rugged components will enable this product to rapidly penetrate existing UV laser markets, and will open up new applications due to its small volume and low power consumption.

Deacon Research
2440 Embarcadero Way
Palo Alto, CA 94303

62. A Precision Undulator Adjustment Tool*

David Deacon
415/493-6100

Funding Profile

Date Started: May 20, 1991 — FY 91 - $236,000

Anticipated Duration: 2 Years — FY 92 - $264,000

The available means for trimming up undulator magnetic fields are inadequate both for free electron lasers (FELs) and advanced synchrotron radiation sources. This problem prevents the generation of short wavelengths with FELs, and limits the beam brightness in synchrotron light sources. This program will produce a measurement tool that measures directly the quantity of interest in undulators, the particle trajectory, rather than calculating it from other quantities. The result will be an improvement in the brightness and coherence of the beam produced by the undulator, and a reduction in the manpower required to achieve it. This technology enables the production of essentially perfect undulators with a length ten times longer than possible now. Such undulators in turn will make possible the production of coherent light in the extreme ultraviolet (XUV) and the x-ray regions of the spectrum. In the Phase I program, the accuracy of the experimental detection system was measured, and the system was shown to perform better than expected. In Phase II, an innovative particle beam/detector system will be built and used to measure one of the high quality undulators being produced at the Lawrence Berkeley Laboratory for the Advanced Light Source. A comparison with the measurements made by conventional means will establish the value of the device.

*Project Completed

SFA, Inc.
1401 McCormick Drive
Landover, MD 20785

63. Physical Applications of Channeling Radiation as a Novel, Intense X-Ray Source*

Paul Marshall
301/925-9400

	Funding Profile
Date Started: May 20, 1991	FY 91 - $230,000
Anticipated Duration: 2 Years	FY 92 - $257,000

The Phase I investigation has shown that in the x-ray region, channeling radiation (CR) can be highly competitive in intensity to contemplated applications with a synchrotron radiation (SR) source or with the proposed transition radiation (TR) source, while from the economic standpoint it is clearly superior: the required 5-20 MeV electron linacs are available for about $1 million, but corresponding 0.5-1 GeV synchrotrons or storage rings are priced from $60 million up. Corresponding electron linacs for TR must have 200 MeV or more, also at much higher cost. Concentrating thus on CR in the x-ray region, a number of prototype experiments will be carried out in Phase II for applications of commercial or medical importance in order to verify the predicted intensity and the effectiveness of CR sources of several keV (perhaps tens of keV) for such applications. Foremost will be x-ray microlithography, where exposure times of only several minutes are expected for 4" x 4" wafers. In addition, angiography experiments on phantoms will be performed, for which a new approach based on calcium deposits will be tested. Further experiments will demonstrate the superiority of CR over conventional sources for applications on the detection of trace elements via fluorescence or on the structural analysis of macromolecules.

*Project Completed

X-Ray Optical Systems, Inc.
1400 Washington Avenue
Albany, NY 12222

64. Kumakhov Lens with Rotating Anode to Obtain an X-Ray Source Which is an Advantageous Alternative to Synchrotron

Alexandre I. Kolomitsev
518/442-5250

	Funding Profile
Date Started: July 6, 1992	FY 92 - $331,000
Anticipated Duration: 2 Years	FY 93 - $165,000

Material analysis studies that require well-collimated x-ray beams typically have long measurement times or require use of a synchrotron. The ability to substantially shorten data collection time for measurements such as diffraction would make these techniques more widely available and improve our national capacity to perform new materials research. Use of capillary based x-ray optics to collect and collimate a divergent beam laboratory x-ray source appears to be feasible, based on experimental and modeling data. The proposed project will include design, fabrication, and characterization of x-ray optics. These optics would be used in diffraction experiments to investigate the benefits from inclusion of the optic in the experimental setup. X-Ray Optical Systems, Inc. and its consultants from the Institute for Roentgen Optical Systems, Moscow, and the Center for X-Ray Optics, Albany, the groups most qualified with optics, will work with diffraction experts to evaluate the opportunity.

SAMPLE STATEMENT OF WORK

1) Project Objective

The proposer shall investigate the electrocatalytic oxidative dehydrogenation of ethylbenzene and butane in solid electrolyte fuel cells. The effort is directed toward defining optimal operating conditions for achieving high yields of styrene and butadiene with simultaneous electric energy generation.

2) The work to be performed consists of the following tasks:

2.1. Construction of tubular stabilized zirconia fuel cells with a platinum cathode and an iron oxide or platinum anode. Both anode materials are quite promising and a decision between the two will be made after preliminary runs.

2.2. Measurement of the styrene cell activity and yield as a function of temperature, inlet ethylbenzene concentration and external resistive load.

2.3. Measurement of the cell electric power output and overpotential as a function of the operating parameters described in 2.2.

2.4. Determination of the nature of the overpotential according to the results of 2.3. If ohmic overpotential dominates, a small well mixed cell with thin (150 microns) electrolyte discs will be constructed to increase power density.

2.5. Development of correlation for styrene yield and electrical power output in terms of operating and design parameters for use in future scale up.

2.6. Repeat tasks 2.2. through 2.5. using butane and/or butene as the fuel.

2.7. Preliminary engineering and economic analysis according to the results of 2.2. through 2.6.

3) Deliverables

The proposer shall provide the data of experiments performed according to paragraphs 2.2., 2.3., 2.4., 2.5. and 2.6. along with analyses and conclusions based on this data.

4) Performance Schedule

4.1. Complete construction of cells 3 months after start of work.

4.2. Complete ethylbenzene experiments within 12 months after start of work.

4.3. Complete butane and butene experiments and data analysis 20 months after start of work.

4.4. Complete data correlation, economic analysis and final report 24 months after start of work.

FY 1993 PROGRAM DATA

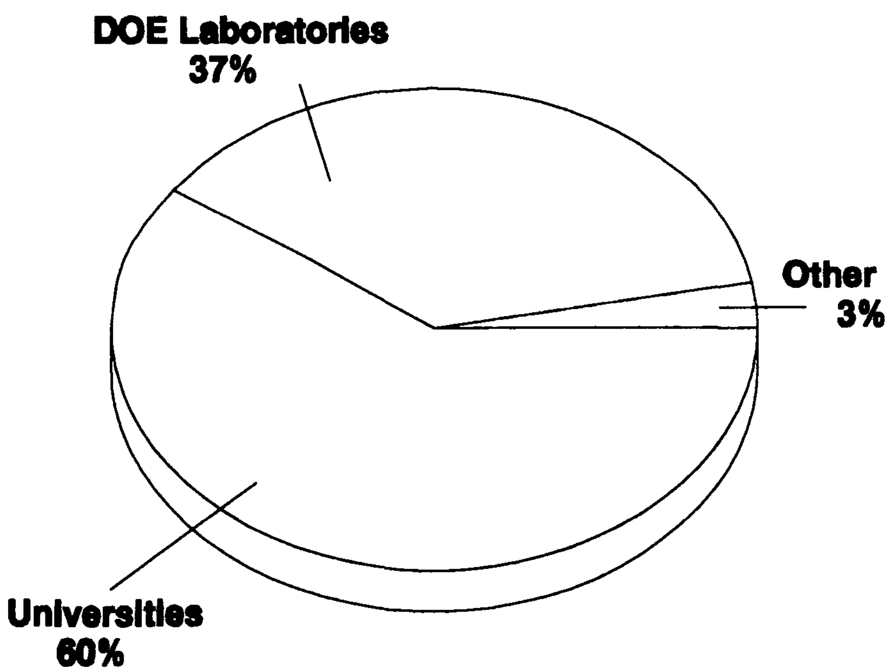
OFFICE OF BASIC ENERGY SCIENCES

DIVISION OF ADVANCED ENERGY PROJECTS

BUDGET

	FY 1992	FY 1993	FY 1994 (REQUEST)
OPERATING	$10,800,000	$10,900,000	$11,400,000
EQUIPMENT	310,000	300,000	310,000

DISTRIBUTION OF FY 1993 PROJECTS



INVESTIGATOR INDEX
(Project Numbers)

INSTITUTIONAL INDEX
(Project Numbers)

INSTITUTIONAL INDEX, Cont.d
(Project Numbers)

APPENDIX E

FACSIMILE COVER SHEET

DATE: ____________

TO: Division of Advanced Energy Projects, ER-16
U.S. Department of Energy
Washington, D.C. 20585

FROM: ______________________________
(Inc. tel #)
____

SIGNATURE: ______________________________

☐ D. L. Barney ☐ G. C. Carter ☐ W. M. Polansky

☐ S. E. Stottlemyer

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