

**AWARDS ADMINISTERED**  
**July 2005 – June 2006**

NOTE: Dates in green are the projected end dates and dollar value in green is the projected total award value.

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**Guenter Ahlers**

**National Aeronautics and Space Administration, NAG3-2872**

**Boundary Effects on Transport Properties and Dynamic Finite-Size Scaling Near the Superfluid-Transition Line of  $^4\text{He}$**

**03/26/03-09/30/07**

**\$614,000**

We extended the analysis of the thermal conductivity measurements of helium confined in cylindrical channels of glass capillary arrays to the case of rectangular channels. Measurements were made on plates with channels of 1x10 micro-m cross section, and simultaneously on bulk helium. To our great surprise the results show that the finite-size scaling-function for this geometry does not differ measurably from the scaling function for cylindrical confinement. This differs qualitatively from what had been found for thermodynamic properties in one-dimensional and two-dimensional confinement. We have now started the measurements of the heat capacity in the same micro-channel plates. Knowledge of this is necessary for the complete theoretical interpretation of the conductivity data. Results have been obtained for cylindrical channels of diameter 1 micro-m.

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**Guenter Ahlers**

**National Aeronautics and Space Administration, NAG3-2903**

**The Superfluid Transition of  $^4\text{He}$  Under Unusual Conditions**

**05/01/03-04/30/07**

**\$386,020**

This award continued the work on the superfluid transition in a heat current. With previous support from NASA, we have begun to extend the studies to pressures greater than saturated vapor pressure. We now propose to study the properties of this system in the immediate vicinity of the phase transition in greater detail, and to extend the pressure range of our measurements. This work has a direct bearing on the proposed flight experiment DYNAMX, which will probe similar phenomenon in smaller heat currents. We expect this work to yield new fundamental scientific results and to be relevant to the detailed choice of parameter values for the DYNAMX flight experiment.

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**Guenter Ahlers**  
**National Science Foundation, DMR-0243336**  
**Stochastic Effects in Systems Far From Equilibrium**  
**05/01/03-04/30/07**  
**\$620,000**

This work focuses on quantitative studies of fluctuations caused by thermal noise below and near bifurcations in systems far from equilibrium. Well below the bifurcation it is expected that the measurements will test recent predictions about the structure factor of a fluid in a thermal gradient. Near the bifurcation the nonlinear interactions between the fluctuations should lead to critical phenomena in the sense that the various measurable quantities will deviate non-trivially from mean-field (or linear) predictions. The experiments will focus on Rayleigh-Bernard convection (RBC) in a horizontal layer of a fluid heated from below, and on electro convection (EC) of a nematic liquid crystal in an electric field. It has been predicted that RBC belongs to a universality class first studied theoretically by Brazovskii for which fluctuations change the bifurcation from a second-order to a first-order transition. For electro convection there is at present no theory of the critical behavior, but on general grounds one expects several different universality classes that depend on the relationship between the nematic director and the convection-roll wave director. The experiments will open a new research field of critical phenomena in non-equilibrium systems, and will prepare graduate students and postgraduate researchers for academic or industrial careers. Within an outreach program they will offer opportunities for participation by high school students. Many properties of equilibrium systems exhibit large thermally driven fluctuations near critical points. An example is the density of a fluid near a liquid-gas critical point. Nonlinear interactions between the fluctuations then cause the critical behavior to be different from that which is expected when fluctuations are small. The same phenomena should occur in a very different context, namely near transitions in non-equilibrium systems. For example, the transition from pure conduction to convection in a thin horizontal layer of a fluid heated from below was predicted to be of second order when fluctuations were neglected, but to become a first-order transition when they were considered. This work will determine the critical behavior near transitions in several non-equilibrium systems, including convection in a fluid heated from below and convection in a liquid crystal exposed to an electric voltage. This research will use advanced experimental techniques and sophisticated numerical image analysis, which will provide excellent training of graduate students for careers in academic and industrial positions. It also lends itself well to the participation of undergraduate students. Within an outreach program it is expected that high school students will also participate in some of the experiments.

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**Guenter Ahlers**  
**Department of Energy, DE-FG02-03ER46080**  
**Heat Transport by Turbulent Rayleigh-Bernard Convection**  
**09/15/03-3/15/07**  
**\$574,226**

This award focuses on the study of turbulent Rayleigh-Bernard convection. Turbulent convection is of fundamental interest in nonlinear science, relevant to practical problems involving energy transport in fluid flow, and a significant ingredient of natural phenomena in the Earth's atmosphere and oceans as

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well as in the stars. In addition to providing data needed to verify recently developed theoretical models of turbulent convection, our results will contribute to the elucidation of seemingly conflicting results obtained in experiments by others at very large Rayleigh numbers.

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**S. James Allen**

**Kevin Plaxco**

**ARMY, W911NF-05-1-0034**

**Submillimeter-Wave Circular Dichroism Spectroscopy of Biomaterial in Water**

**02/01/05-01/31/06**

**\$125,000**

The objective is to establish the feasibility of submillimeter-wave or terahertz circular dichroism spectroscopy as a rapid, species-specific, technology for the detection of biological agents under realistic, water borne, conditions. Terahertz circular dichroism spectroscopy offers the possibility of detection of biological agents unobscured by the ubiquitous presence of strongly absorbing contaminants such as water. The project is centered on a polarization articulated Michelson interferometer recently developed by the principal investigators. Based on the measured performance of the spectrometer, a terahertz circular dichroism detection and identification system will be designed using solid-state submillimeter wave sources and detectors.

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**S. James Allen**

**UC Lawrence Livermore National Laboratory, B553615**

**Characterization of Solid Materials for Terahertz Standoff Detection**

**08/23/05-04/30/06**

**\$63,314**

The objective is to obtain preliminary data that will help make an early identification of opportunities, obstacles, and critical issues that need attention for standoff detection of high explosives by terahertz spectroscopic imaging. This project is organized into two phases:

Phase I: Initial feasibility testing of materials of high LLNL interest relative to their spectroscopic response in the terahertz frequency regime.

Phase II: Based on the anticipated success in Phase I, continue to investigate materials of high LLNL interest in specified parameter regimes that will indicate potential success for a terahertz standoff system.

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**S. James Allen**

**Kevin Plaxco**

**ARMY, W9119NF-06-1-0241**

**Terahertz/Optical Two Color Non-Linear Sensing of Liquid Biochemical Agents (II.B.1.e)**

**06/15/06-06/14/07 (06/14/09)**

**\$259,746 (\$681,665)**

The species-specific sensor of biochemical agents in water is based on terahertz/optical sum and difference frequency generation that appears only in chiral liquids. Terahertz sidebands on an optical probe, at the sum or difference frequency, are allowed in a liquid only in the presence of chiral symmetry and are free of signals from non-biological material. The process is doubly resonant – the terahertz radiation resonantly drives the macromolecular vibrations while the optical probe resonates with an electronic transition in a chromophore. At the same time the appearance of a sideband requires a spatial overlap of the driven macromolecular vibration and the chromophore. The terahertz frequency dependent appearance of the sideband on the optical probe signals the presence of the biomaterial of interest. While chiral allowed sum and difference frequency generation has been documented in the near-IR/optical, the phenomenon has not been exploited in the terahertz part of the spectrum. Spectrometer development uses the UCSB terahertz free-electron lasers to explore and develop this phenomenon in this part of the spectrum. The terahertz sideband spectrometer as biochemical sensor uses terahertz harmonic generators in conjunction with narrow line width semiconductor diode lasers.

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**David Awschalom**

**Cornell University, 39508-6587**

**Spin Interactions and Spin Dynamics in Electronic Nanostructures**

**05/01/01-08/31/06**

**\$700,000**

This award proposes a multidisciplinary, multi-university research program that draws on leading experts and unique research facilities from across the nation, and which has as its organizing theme the study, understanding and control, at the nanoscale, of the spin properties of electronic systems of very substantial technological potential. This aggressive research program examines nanostructures fabricated by both bottom-up and top-down techniques. In the former case, spin systems are assembled spin-by-spin by both atomic manipulation and advanced materials processing techniques, and studied by innovative scanned probe measurement technologies. In the latter, the most advanced methods of nanofabrication are employed to produce functional, nanostructured spin devices that can be electronically addressed and studied by highly sensitive tunneling and direct electrical transport spectroscopies, and investigated in detail by advanced scanned electrical, optical and mechanical resonance probe instrumentation. The program objectives are to substantially advance our understanding and control of spin phenomena at the nanoscale, to develop new and improved experimental approaches for the measurement and characterization of spin systems with sensitivity approaching the detection of an

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individual spin, and to explore and develop new approaches that will enable the study, manipulation and reversible modification of spin-interactions and dynamic spin phenomena in nanoscale systems.

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**David Awschalom**

**University of Pittsburgh, 400882-3**

**Quantum Information Processing with Ferroelectrically Coupled Si/Ge Quantum Dots**

**06/01/01-02/28/06**

**\$252,448**

This award focuses primarily on probing the magneto-optical properties of Ge/Si quantum dots and semiconductor/ferroelectric heterostructures using time-resolved optical probes. This includes low temperature femtosecond-resolved spectroscopies such as Faraday rotation, spin-resolved absorption, and photoluminescence. In addition, we will conduct spatiotemporal studies of the energy-dependent spin landscape using our variable-temperature near-field optical microscopes to provide a high degree of spatial information.

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**Jeffrey Bode**

**Camille & Henry Dreyfus Foundation, SB#040029**

**Design, Synthesis and Applications of Adaptive Organic Molecules**

**10/01/03-09/30/08**

**\$40,000**

This award supports the design and synthesis of a new class of organic molecules that can spontaneously adjust their shape and properties to adapt to their environment. Potential applications of these materials include drug discovery, chemical sensing, and drug delivery. We have completed the chemical synthesis of a functionalized core and demonstrated the dynamic nature of these model compounds. This represents the first rational synthesis of a designed, adaptive organic molecule. Currently we are developing technologies for the specific modification of the dynamic core to prepare molecules with wide-ranging applications and to utilizing these unique structures for fundamental chemical studies.

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**Jeffrey Bode**

**National Science Foundation, CHE-0449587**

**CAREER: Development and Applications of Catalytic Generated Activated Carboxylates**

**01/15/05-12/31/06 (12/31/09)**

**\$252,045 (\$579,045)**

Intramolecular redox reactions of  $\alpha$ -functionalized aldehydes mediated by N-heterocyclic carbenes (or heterocyclic ylides) lead to the catalytic generation of activated carboxylates, suitable for the synthesis of esters, amides, and other carboxylic acid derivatives under economical and environmentally friendly

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reaction conditions. The discovery of this novel reactivity, mediated by an organic catalyst, of  $\alpha$ -heteroatomic and  $\alpha,\beta$ -unsaturated aldehydes opens a broad range of mechanistically unique pathways for the synthesis of chiral carboxylic acid derivatives, including anti- $\beta$ -hydroxyesters and  $\beta$ -amino peptides. The design and application of chiral heterocyclic salts for catalyzing this novel process will provide an enantioselective method for directly controlling the absolute stereochemistry concomitant with esterifications and peptide couplings, and has the potential to supplant traditional multi-step chiral auxiliary based methodologies. By developing means of effecting the direct, enantioselective synthesis of amides from  $\alpha,\beta$ -didehydroamino aldehydes, a waste-free, atom-economical approach to the synthesis of poly- $\alpha$ -amino-peptides from achiral precursors will emerge. The unique reactivities of unsaturated aldehydes under these catalytic conditions will enable novel carbon-carbon bond forming processes, including new annulation reactions affording lactones, lactams, and cyclopentanones, thereby providing a long-sought method for the direct, intermolecular synthesis of hetero- and carbocycles from stable, readily available starting materials. Applications of these new reactions include the synthesis of (1) short, biologically active  $\alpha$ - and  $\beta$ -peptides, (2) the kalafungin class of naturally occurring antibiotics, and (3) the antibiotic moiramide B, which is active against drug resistant bacterial strains. With the support of this CAREER award from the Organic and Macromolecular Chemistry Program, Professor Jeffrey W. Bode, of the Department of Chemistry and Biochemistry at the University of California, Santa Barbara, is developing new reactions catalyzed by simple organic molecules rather than by metals. This reaction chemistry not only offers promise of great chemical selectivity, but also represents an economical, environmentally friendly ("green") approach to organic synthesis, eliminating the use of potentially hazardous metals and greatly reducing waste generation. Professor Bode will exploit the newly discovered reaction chemistry for the synthesis of a variety of products, including biologically active polypeptides and antibiotics, demonstrating the potentially broad applicability of this chemistry in the synthesis of important products. He will also engage undergraduate students, both at UCSB and from local community colleges, in an alternative sophomore level organic laboratory course aimed at exposing them to hands-on training in the realities of inquiry and research based organic chemistry.

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## **Jeffrey Bode**

**American Chemical Society, PRF 43246-G1**

**Development and Applications of New Reactions for Chemoselective Amidations**

**09/01/05-08/31/07**

**\$35,000**

Detailed studies and applications of a new approach to direct, chemoselective amidation by decarboxylative condensations of hydroxylamines and  $\alpha$ -ketoacids are proposed. This novel process proceeds in polar solvents (DMF, DMSO, H<sub>2</sub>O) under mild reaction conditions and displays remarkable functional group tolerance. On the basis of our preliminary findings we will pursue the development and mechanistic understanding of this unique process. These studies will lead to innovations in substrate scope, including the use of cyclic hydroxylamines amines as substrates for an iterative, waste-free approach to the iterative synthesis of poly- $\beta$ -peptides. In addition, we will utilize these new reactions for preliminary studies towards the facile polymerization of hydroxylamine amine monomers.

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**Jeffrey Bode**

**UC Cancer Research Coordinating Committee, SB060005**

**New Approaches to the Synthesis of Anti-Cancer Gamma-Lactam Proteasome Inhibitors**

**06/01/05-06/30/06**

**\$50,000**

Small molecule inhibitors of the 26S proteasome are emerging anticancer therapeutics. While the  $\gamma$ -lactam natural product lactacystin has been instrumental in elucidating the role of the proteasome in cancer progression, its pronounced metabolic instability has rendered it a poor candidate for the development of novel anticancer drugs. In contrast, the structurally related natural product salinosporamide shows greater stability and increased potency, thereby providing inspiration for the synthesis of a new generation of anticancer proteasome inhibitors based on a  $\gamma$ -lactam core. Despite the promise of this discovery, current efforts to take advantage of it have been hampered by limitations in the supply of salinosporamide and the lack of a concise synthetic route to its densely functionalized core. To address this challenge, we are developing catalytic methods for the direct synthesis of functionalized  $\gamma$ -lactams from readily available imines and enals. Importantly, this novel, organocatalytic process proceeds under mild conditions and opens the pathway for the single step synthesis of enantiomerically enriched  $\gamma$ -lactams suitable for the synthesis of a new generation of proteasome inhibitors.

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**Jeffrey Bode**

**Pfizer, Inc., SB050115**

**AIR Minority Research Fellowship in Organic Chemistry**

**07/01/05-09/30/05**

**\$5,000**

This project involves new methodology for the synthesis of  $\beta$ -peptides. This truly remarkable approach to the synthesis of  $\beta$ -peptides works by direct coupling and is optimal in an aqueous solution. Furthermore, the only by-products produced from this reaction are methanol and carbon dioxide. Clearly, the mild conditions and relative ease of this method give this project the potential to profoundly alter the way chemists approach  $\beta$ -peptide synthesis.

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**Jeffrey Bode**

**Government of Japan, 101**

**Design and Synthesis of AFM-Probe-Modifying Nanoscaffolds for Screening of Drug Safety against Acquired Long QT Syndrome**

**12/01/05-03/31/06**

**\$20,956**

Long QT syndrome (LQTS) is a serious abnormality of the heart's electrical system. Recent studies and awareness of this condition have led to the recognition that LQTS may be a major cause of otherwise

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preventable deaths, particularly among children. LQTS was once thought to be an inherited genetic disease arising from mutations on one of 6 or 7 genes coding for membrane bound proteins. Recent studies, however, have raised the possibility that a number of medications can lead to *acquired long QT syndrome* in otherwise healthy individuals. This has led to speculation that these individuals contain subtle genetic defects, which sensitizes them to negative interactions with these drugs, resulting in the sudden onset of LQTS. We propose to develop special organic reactions and linkers that will allow us to attach drug candidates to the scaffold under dilute, aqueous conditions. These protocols will be used to attach a variety of drug molecules to the atomic force microscopy (AFM) probes modified by the nanoscaffold.

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**Jeffrey Bode**

**NIH Center for Scientific Review, R01 GM076320**

**New Reactions for Direct, Native Peptide Ligations**

**(Note: Pre-Award Date 06/02/06) 09/01/06-08/31/07 (08/31/11)**

**\$221,553 (\$1,155,461)**

The goal of the proposed research is to develop a comprehensive method for the direct coupling of unprotected molecules via a new chemoselective amidation reaction. The basis for this project is the reagent-less reaction of  $\alpha$ -ketoacids and *N*-alkylhydroxylamines to give amides via decarboxylation and dehydration. These studies will provide new methods for the synthesis of biomolecule targets including proteins, glycopeptides, and peptidomimetics. The proposed research will provide a new chemical tool for the direct synthesis of amides under physiologically compatible reaction conditions. It will significantly impact the synthesis of complex biomolecules including proteins, glycoproteins, peptidomimetics, and biocompatible materials.

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**Dirk Bouwmeester**

**Lawrence Coldren**

**Pierre Petroff**

**National Science Foundation, PHY-0304678**

**NIRT: Quantum State Transfer Between Photons and Nanostructures**

**08/15/03-07/31/06 (07/31/07)**

**\$1,510,000 (\$1,560,000)**

Photons have proven to be most useful for encoding special quantum states and for transmitting them through free space or optical fibers. For local quantum-state operations photons are less favorable and well-localized quantum systems are desirable. In this respect quantum dots, often referred to as artificial atoms, are particularly attractive. This research aims at combining the advantages of photons with those of artificial atoms. The main objective is to transfer the polarization quantum state of a single photon onto excitons in quantum dots and visa versa. The anticipated results are: a novel positioning technique for a quantum dot in the center of an optical waveguide, the demonstration of a single-photon absorption and reemission by a single quantum dot inside a micro-pillar with intrinsic lensing, the demonstration of the polarization quantum-state transfer between single photons and single quantum dots, and creating

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entanglement between a quantum dot and a photon and between two quantum dots. The first requirement to achieve the objectives is that the coupling between photons and quantum dots has to be resonant in order to preserve the quantum-phase coherences. For this optical-cavities resonant both with the incoming photon and the quantum dot inside the cavity will be used. Two novel ways of achieving a strong optical mode overlap with the quantum dots will be explored. The first is to use quantum dots inside micro pillars that containing optical lensing through the use of tapered oxidation layer. The second is to develop a technique to position a single quantum dot in the center of an optical micro cavity. The second requirement is that the quantum dots have to be effectively symmetric in order to obtain exciton spin degeneracy. For this magnetic fields and/or strain-induced effects on the micro-pillars will be explored. The third requirement is that the reemitted photon from the quantum dot should be distinguishable from photons reflected from the sample surface. For this a Michelson interferometer will be used where the two end mirrors are replaced by one micro-cavity containing a quantum dot on resonance and one micro-pillar containing no quantum dots on resonance. Reaching the objectives will be a major step forwards in quantum-state control and harnessing and understanding quantum decoherence in nano-structures. The research is based on a close collaboration between the Materials, Engineering and Physics Departments at the University of California Santa Barbara. This collaboration provides an excellent opportunity for young researchers to perform interdisciplinary research on important topics in quantum (and classical) communication and information processing and in nano-structure fabrication. Reaching the objectives will initiate future research in storage of quantum information and in implementing the quantum repeater scheme (enabling long-distance quantum cryptography), quantum error correction and quantum networks.

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**Dirk Bouwmeester**

**Deborah Fygenon**

**National Science Foundation, CCF-0404440**

**NER: Energy Transport in Microtubules**

**07/01/04-06/30/06**

**\$99,999**

Microtubules are very important biological polymers that support the structure and function of cells. They are about 25 nm in diameter and often grow to many microns in length. However, microtubule length is rarely constant. During growth a chemical reaction takes place that releases energy. This energy is stored within the microtubule and contributes to the sudden change to a disassembling state. Little is known about the energy storage and possible energy transport along microtubules. The very regular structure of the microtubule together with the fact that the small segments of microtubules have an electric dipole moment suggest that energy transport through dipole-dipole interactions is possible. We aim to investigate the possibility of energy transfer by chemically attaching artificial atoms (colloidal quantum dots) to bundles of microtubules. Using light, dipoles can be induced inside the artificial atoms, thus providing a way to initiate and read-out energy transport. Evidence of this type of energy transport could have a major impact on the understanding of cell dynamics.

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**Dirk Bouwmeester**  
**National Science Foundation, PHY-0504825**  
**Quantum Superposition States of a Mirror**  
**08/01/05-07/31/06 (07/31/08)**  
**\$120,000 (\$360,000)**

Quantum Mechanics is based on a wave-mechanical description of a system and on the von Neumann postulate (1920s) that a quantum measurement results in an indeterministic outcome. The wave-mechanical description allows for superposition states of a system (e.g. an object being in two places at the same time), and the von Neumann postulate implies that one cannot directly detect such a superposition. Models of environmental induced decoherence do give an explanation of why quantum superpositions are not observed in everyday life, however the indeterministic nature of the measurement outcome is still the topic of many debates. The aim of this research proposal is to create a quantum superposition states involving of order  $10^{14}$  atoms. Such quantum superposition states will be ten orders of magnitude more massive than any quantum superposition observed to date and will therefore provide a fundamental test of quantum mechanics in a new regime. The experiment contains a tiny mirror (smaller in diameter than the thickness of a human hair) that is part of an optical cavity, which forms one arm of an interferometer. The mirror is mounted on a tiny Silicon rod and can be displaced by the multiple reflections of a photon. A single photon is sent into the interferometer and will evolve into a superposition of being inside the optical cavity with the tiny mirror, thereby slightly displacing it, and being in the other arm of the interferometer, leaving the mirror at rest. The superposition of a single photon is therefore transferred to a superposition of the mirror, or more precise, the mirror becomes entangled with the photon. By observing the interference of the photon leaving the interferometer one can study the creation and decoherence of superpositions involving the mirror. Preliminary experiments have been supported by a one-year NSF exploratory-research grant and led to remarkable initial progress; a high-quality Bragg mirror of diameter 20 microns has been fabricated using a focussed ion beam and has been positioned onto a Silicon cantilever [tip of an atomic force microscope (AFM)]. The cantilever/mirror system has been piezo-positioned to be the end mirror of an optical cavity. Measurements in air showed an initial cavity finesse of 1000. The individual components of the precision measurement system will be of interest for applications in many other fields with direct benefits to society. Anticipated spin-off projects are ultra-fast switchable mirrors (for optical communication), ultra-high resolution AFM readout, and optical cooling of micro-mechanical oscillators (for position measurements). The project will provide excellent training since it combines fundamental research interests with cutting-edge technologies. Since the project involves different subprojects, it is the intention to have several undergraduate researchers assisting the project each summer, as well a high-school students participating in the UCSB summer science education program.

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**Michael Bowers**

**National Science Foundation, CHE-0140215**

**Gas Phase Ion Chemistry: Confirmation and Energetics of Biopolymers and Solvated Salt Crystals**

**04/15/02-03/31/06**

**\$830,470**

In this project funded by the Experimental Physical Chemistry Program of the Chemistry Division, Bowers will conduct research on the ion mobilities of molecules, clusters, metal ions, peptides, oligonucleotides, and other biomolecules. Specifically, work will be done on the energetics and mechanism of solvation of salt crystals, as well as on the conformations of polypeptides/proteins and DNA/RNA oligonucleotides. The energetics associated with their folding, hydration and interaction with metal ions will be investigated. These systems will be studied in the gas phase in order to avoid complications due to a solvent effect. This research attacks fundamental problems on the mobilities of ions and biomolecules in the gas phase. The results of these studies will be correlated with theoretical modeling. Graduate and undergraduate students as well as postdoctoral research associates will participate in this research. They will receive training in one of the forefront areas of contemporary physical chemistry and be thus prepared for advanced studies, or employment in industry, academia, or government laboratories.

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**Michael Bowers**

**Air Force, F49620-03-1-0046**

**Structures and Energetics of Macromolecular Systems: POSS, Metal Clusters and Other Oligometric Molecules**

**01/01/03-12/31/05**

**\$519,000**

There are three objectives of this research:

1. Structures and Characterization of Polyhedral Oligomeric Silsesquioxanes (POSS): The POSS family of molecules are of great interest due to their inherent thermal stability and their ability to improve the thermal, physical and chemical properties of host polymer systems. We have developed mass spectrometric based methods to both identify and structurally characterize POSS and POSS containing materials. Examples of ongoing and new projects include building block development, POSS lubricants, POSS-polymer adduction and POSS based resins.
  2. Luminescent Organic Oligomers: We have developed a collaborative program with UCSB professors Guillermo Bazan (synthesis) and Steve Buratto (single molecule photo physics) to structurally and optically characterize a number of families of organic oligomeric materials.
  3. Metal Cluster-Ligand Energetics and Structure: We are designing and building a source capable of depositing high fluxes of size selected metal clusters onto metal oxide surfaces under UHV conditions. We will then measure both substrate to cluster charge transfer and binding energies of catalytically important molecules to the clusters. These results will help interpret the cluster-surface work and provide important quantitative data to test theoretical calculations.
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**Michael Bowers**  
**ERC, Inc., RP040814**  
**POSS Research (Equipment Grant)**  
**09/30/04-09/30/05**  
**\$20,629**

Funds are requested to upgrade our computer capability in order to study polymers constructed of monomer units.

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**Michael Bowers**  
**University of Warwick, HR/DD/13 12763**  
**Toward an Antermortem Test for Bovine Spongiform Encephalopathy: An Ion Mobility/Mass Spectrometry Approach**  
**01/01/05-12/30/06**  
**\$160,000 (\$480,000)**

The need for an antemortem test for TSE diseases is apparent and urgent, but the difficulties are formidable. Small fractions of PrP<sup>Sc</sup> must be detected in the presence of large excess of native PrP<sup>c</sup> in accessible body fluids that contain only minute amounts of total PrP. Since PrP<sup>Sc</sup> and PrP<sup>c</sup> have the same primary structure any method must detect differences only in folding (shape) using methods that do not induce isomerization between the isoforms. In this proposal the ultra sensitive techniques of Ion Mobility Spectrometry and Mass Spectrometry (IMS/MS) will be combined and provide unambiguous differentiation of the isoforms.

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**Michael Bowers**  
**Air Force, FA9550-05-1-0280**  
**Ultra High Resolution Ion Mobility Instrument**  
**04/01/05-03/31/06**  
**\$352,235**

A request is made for an ultra high resolution ion mobility machine that will greatly increase our ability to resolve both conformers and geometric isomers of complex systems. In recent years we have frequently encountered systems where we have been unable to resolve structural isomers and thus could not provide accurate feedback to synthetic groups we are collaborating with. We are convinced that this will become a much more serious issue as we intensify our collaborations with the POSS synthesis group at Edwards AFB. A second application for the new machine involves size-elected metal clusters where structural isomers are common but cross sectional differences are often small. Being able to accurately determine structural identities of these clusters and obtain structurally resolved energetic and reaction information will greatly assist the ongoing effort in catalysis research funded under a DURINT grant. The instrument will take advantage of known technology but with improvements we hope will increase sensitivity by up to a factor of 10. Current instrumentation is limited to a resolving power of

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$\Delta t/t \approx 20$  at room temperature while the new machine will routinely provide a resolving power of at least 180. When cooled to liquid nitrogen temperatures, resolutions of  $\sim 300$  are expected.

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**Michael Bowers**

**National Science Foundation, CHE-0503728**

**Conformation, Hydration, Metal Ion Interactions and Aggregation States of Peptides, Proteins and Oligonucleotides**

**07/01/05-04/30/07 (04/30/08)**

**\$442,877 (\$632,877)**

This research is supported by the Experimental Physical Chemistry Program to examine molecules and systems of biological importance, using mass spectrometric methods. Work will focus on the following specific areas: (1) duplex formation in oligonucleotides, (2) solvation energies, entropies, and diagnostics, and (3) structure and energetics of metal ion binding to nucleotides, peptides, and proteins. Ion-mobility-based mass spectrometry will be used for structural (cross-section) measurements and ion-neutral equilibrium methods for hydration studies. High-level electronic structure calculations and/or molecular dynamics calculations will accompany experiment in all cases. This project presents the opportunity to make significant inroads toward developing new ways to solve biological problems using mass spectrometry. For example, outcomes could help unravel fundamental and practical issues such as water molecule binding to biomolecules. Students and postdoctoral associates will have valuable research education opportunities in both experiments and theory, and they will participate in designing new forefront technical methodologies.

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**Michael Bowers**

**Air Force, FA9550-06-1-0069**

**POSS and Metal Clusters: Structures and Energetics**

**01/01/06-11/30/06 (11/30/08)**

**\$183,000 (\$558,000)**

There are several objectives for this proposal:

1. Structure and Characterization of Polyhedral Oligomeric Silsesquioxane (POSS) attached to Polymer Backbones: The POSS family of molecules has recently generated great interest due to their inherent thermal and chemical stability and their ability to improve the thermal, physical and chemical properties of host polymer systems. We have developed ion-mobility-based mass spectrometric methods suitable for characterizing a wide variety of POSS cages. In the coming three years, these methods, coupled with extensive molecular modeling will be applied to POSS cages covalently bound to oligomers of a variety of organic polymers. We will collaborate with a number of synthetic research groups in the development of rational synthetic strategies to produce these materials.

2. Size-Selected Structures and Ligand Binding Energies of Metal Clusters: In recent years there has been a major renaissance in the study of small metal clusters as catalytic agents for select, important industrial processes. Of special importance are the clusters of coinage metals: gold, silver and (possibly) copper. At UCSB we have constructed a unique instrument for the deposition and characterization of size-selected coinage metal clusters on metal oxide surfaces, funded by a multi-investigator DURINT

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grant. There are several aspects of this work that are strongly complemented by gas phase studies, Careful STM measurements have established that clusters of four or more gold atoms have specific structures on the surface and that the onset of the transition from 2-dimensional to 3-dimensional surface clusters occurs below  $n=8$ . It will be very important to know the actual structures of the species that are deposited at low energies onto the surfaces to see if they correlate with observed surface structures. Theory also plays a large role in interpreting the structure and reactivity of surface-deposited systems. Careful measurement of structures and ligand binding energies of size- and charge-selected gas-phase clusters is crucial for providing experimental benchmarks for testing theoretical models. Finally, shape and ligand binding energy studies over large cluster size ranges allows direct observation of atomic to bulk transitions, an area where much is speculated but little is known.

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**Frank Brown**

**National Science Foundation, MCB-0203221**

**Starter Grant Dynamic Elasticity Modeling of Protein Diffusion on the Surface of Red Blood Cells**

**02/01/02-07/31/05**

**\$50,000**

The research builds upon previous work in the area of protein diffusion on the surface of erythrocytes. The investigator will develop numerical algorithms to efficiently evolve the shape of the cell membrane as a function of time. Thermal fluctuations insure that the membrane's dynamics will be stochastic and it is anticipated, on the basis of preliminary results, that these fluctuations will be sufficiently large in amplitude and sufficiently long in duration to account for the escape of band 3 protein from the cytoskeletal "corrals" on the surface of the red blood cell. The simulations may provide a microscopic justification for the choice of empirical parameters in earlier studies, or, it may prove necessary to include the dynamics of the cytoskeleton to achieve agreement with experiments. In either eventuality, the investigation will quantify the relative importance of membrane fluctuations and cytoskeletal dynamics on protein mobility. The algorithms developed will be of use in future studies of cell motility and other biological behavior that is dependent upon dynamic membrane fluctuations.

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**Frank Brown**

**Research Corporation, R10966**

**Methods for Interpreting Single Molecule Spectroscopy: Generating Functions, Stochastic Simulation and e-Machine Reconstruction**

**11/18/02-11/17/07**

**\$35,000**

**This research aims to develop theoretical tools and computational strategies for the analysis of time-dependent single molecule spectroscopy (SMS) signals. Emphasis is placed on interpreting experiments that monitor the dynamics of single molecules in condensed phases through the spectroscopy of chromophores coupled to the individual molecules.**

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**Frank Brown**  
**National Science Foundation, CHE-0349196**  
**CAREER: Stochastic Methods in Chemistry and Biophysics**  
**04/01/04-03/31/09**  
**\$505,000**

This CAREER award develops a dynamic elastic model for lipid bilayers which is used in simulating complex biochemical and biophysical phenomena. The research involves the development of Fourier Space Brownian Dynamics, or FSBD, for stochastically evolving these surfaces. This method will allow the modeling of cellular motility and membrane protein diffusion. A second project supported by this award is the development of theoretical and computational approaches to single molecule spectroscopy. The results of these simulations are used to interpret photon counting experiments. This research has a broad impact on the field of biology, particularly the biophysics of membranes. Professor Brown is involved with the Computational Science and Engineering program on the UCSB campus and is working to incorporate computational chemistry into the program. Courses in atomic and mesoscale simulation techniques are being developed by Professor Brown as part of this project. This project is supported by the Theoretical and Computational Chemistry Program in a co-funding arrangement with both Molecular Biophysics of Molecular and Cellular Biology and the Materials Theory Program of the Division of Materials Research.

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**Frank Brown**  
**American Chemical Society/PRF, 42447-G7**  
**A Coarse Grained Model for Studying Inhomogeneous Membrane Interfaces**  
**01/01/05-08/31/07**  
**\$35,000**

This research focuses on the refinement and application of a novel mesoscale model for biological membranes. Individual lipids are treated as semi-flexible “rods” formed from a chain of beads with unique interaction potentials. This model distinguishes itself from prior coarse grained lipid models by capturing the hydrophobic effect implicitly via effective lipid-lipid interactions; there is no need for explicit simulation of solvent. Preliminary studies show that this model behaves in accord with many of the expected properties of lipid bilayers including: fluid behavior of the lipids, realistic magnitudes of elastic moduli (bending and compression) and self assembly of the bilayer structure. Previously developed solvent-free models have been unsuccessful in reproducing all such behaviors.

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**Frank Brown**  
**Alfred P. Sloan Foundation, BR-4469**  
**Nomination for Alfred P. Sloane Foundation**  
**09/16/05-09/15/07**  
**\$45,000**

The research carried out with the aid of the Sloane Research Fellowship will build on previous work with emphasis in the area of biochemistry/biophysics:

1. Polymerization of cytoskeletal filaments at membrane surfaces.
2. Modeling inhomogeneous lipid bilayers
3. Interpreting complex single molecule experiments.

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**Thomas C. Bruice**  
**Public Health Service/National Institutes for Health, R37 DK09171**  
**Biomechanical Mechanisms-Enzymes, Cancer and Models**  
**09/01/02-08/31/06 (08/31/07)**  
**\$2,177,501 (\$2,655,286)**

The major goals of this project fall into three categories: (i) blocking of the binding of certain protein transcription factors (TF) to their consensus DNA binding sites, (ii) specific inhibition of DNA and RNA function (antisense and antigene agents), and (iii) understanding the structural basis for RNA self splicing.

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**Steven Buratto**  
**National Science Foundation, CHE-0316231**  
**Probing and Manipulating the Luminescence Properties of Porous Semiconductor Nanoparticles**  
**07/15/03-06/30/07**  
**\$346,000**

This award is supported by the Experimental Physical Chemistry Program for research that aims to probe and manipulate luminescence properties of porous silicon nanoparticles. To avoid deleterious averaging effects, optical properties will be probed on isolated nanoparticles derived from bulk porous silicon, using single molecule spectroscopic techniques. Project goals include obtaining a detailed understanding of the luminescence properties of these nanoparticles and how such properties depend on the surface functionality, the size of the emitting silicon quantum dot (i.e. porosity of the bulk porous silicon) and the dopant concentration of the silicon starting material. Another goal is to correlate more accurately the size of the emitting species with the luminescence wavelength, in order to determine the degree of quantum confinement. Finally, experiments will determine if the single nanoparticles under study consist of a single two-level system by measuring antibunching in the sample emission. Outcomes are expected to enable new understandings of nanoparticle luminescence properties, aid in the development of porous silicon as an optical material, and suggest new directions to maximize the optical

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properties of porous silicon. The observation of visible light emission from porous silicon has stimulated tremendous interest over the past several years due to its applications in optoelectronic devices and lasers, and the potential for integration with current silicon processing technologies. Luminescence from porous silicon was first observed over a decade ago, and since that time scientists have struggled to develop a mechanism to describe the photophysical properties of this material. Although a consistent physical description is still lacking, a host of test devices has been produced making use of the tunable luminescence and high surface area of porous silicon. These devices include molecular sensors, light emitting diodes, optical switches, and photovoltaic cells. Successful outcomes for this research are expected to impact the development of further useful devices using porous silicon.

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**Alison Butler**

**Public Health Service/National Institutes for Health, GM38130**

**The Bioinorganic Chemistry of Iron**

**02/01/01-12/14/05**

**\$935,081**

The objectives of this research are to improve our understanding of the mechanisms of metal acquisition by microorganisms in the marine environment. We are interested in the mechanisms of acquisition of iron (and other metal ions) by open ocean marine bacteria, because the discrepancy between iron availability and requirements ranges between 2-5 orders of magnitude and because the transition metal composition of the oceans is extreme and unique. Molybdenum and vanadium are the two most abundant transition metal ions in surface seawater. All microorganisms, with the possible exception of lactobacilli, require iron for growth. It is surprising that so little is known about mechanism(s) of iron acquisition by marine microorganisms. Given the discrepancy between iron availability and requirements, oceanic bacteria may have developed very efficient means to sequester iron, tailored to the chemical and physical constraints of the ocean. We are focusing first on the structures of siderophores produced by oceanic marine bacteria. These studies are the first part of an investigation into whether the mechanisms of metal acquisition (eg., siderophore-mediated sequestration of the metal, outer membrane receptor protein recognition of the metal siderophore complex, transport, and metal regulation of these processes, etc) by marine bacteria differ from terrestrial bacteria.

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**Alison Butler**

**National Science Foundation, CHE-0213523**

**Investigations of the Mechanisms of Vanadium Haloperoxidases**

**09/01/02-08/31/06**

**\$415,000**

This award by the Inorganic, Bioinorganic and Organometallic Chemistry program supports research to study haloperoxidase enzymes, more specifically the vanadium bromoperoxidases found in several types of marine algae. The mechanisms of these enzymes and the biogenesis of halogenated terpene and acetogenin marine natural products will be explored. Using site-directed mutagenesis, Butler will determine the functional role of selected amino acid residues in the enzymes and prepare mutants suitable for in vitro reactivity. These mutants may eventually be used for the industrial synthesis of

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halogenated compounds suitable for medical applications. In addition to the fundamental bioinorganic chemistry and enzymology proposed, the work has broad implications for marine biology and pharmaceutical chemistry. Butler also trains a diverse group of students in an emerging interdisciplinary field

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**Alison Butler**  
**Princeton University/CEBIC, 00000781**  
**CEBIC: Subcontract**  
**10/01/03-09/30/06**  
**\$322,000**

The objectives of this research are to **1)** test the hypothesis that the photoreactivity of Fe(III)- $\alpha$ -hydroxy acid siderophores enhances the Fe acquisition by marine microorganisms; **2)** investigate the hypothesis that the amphiphilic marine siderophores confer a special advantage to Fe acquisition; **3)** characterize siderophores produced by other important species of marine bacteria; **4)** investigate the receptor-mediated iron uptake process in marine bacteria; **5)** investigate the regulation of siderophore and outer membrane protein production; and **6)** characterize the ligand(s) complexing the dissolved Fe(III) in the ocean.

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**Alison Butler**  
**Public Health Service/National Institutes for Health, GM38130**  
**Investigations of the Bioinorganic Chemistry of Iron: New Siderophores**  
**12/15/05-11/30/06 (11/30/09)**  
**\$275,698 (\$1,038,254)**

The objectives of this research are to improve our understanding of the mechanisms of metal acquisition by microorganisms in the marine environment. The specific aims of the proposed research are to i) investigate the photoreactivity of the marine ferric siderophores with alpha-hydroxy acid groups, ii) investigate the amphiphilic properties of the suites of marine amphiphilic siderophores, iii) investigate the photoreactivity and amphiphilic effects on iron acquisition by the source bacteria, and iv) isolate and characterize new siderophores produced by selected other marine bacteria.

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**David Cannell**  
**National Aeronautics and Space Administration, NNCO4GA**  
**Gradient Driven Fluctuations**  
**12/04/03-11/30/07**  
**\$346,000 (\$479,000)**

We will work with our collaborators at the University of Milan (Professor Marzio Giglio and his group-supported by ASI) to define the science required to measure gradient driven fluctuations in the microgravity environment. Such a study would provide an accurate test of the extent to which the

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theory of fluctuating hydrodynamics can be used to predict the properties of fluids maintained in a stressed, non-equilibrium state. As mentioned above, the results should also provide direct visual insight into the behavior of a variety of fluid systems containing gradients or interfaces, when placed in the microgravity environment.

During the past year, we have used the UCSB prototype to demonstrate that the overall design is functional. In doing this we have obtained data for the fluctuations in a single-component fluid heated from above, extending to wavelengths that have not been accessible in the past. The companies responsible for constructing flight hardware have been placed under contract by the European Space Agency. We met with them once shortly after they were selected, and again in early August for what ESA calls the "Preliminary Design Review". PDR went well, and both ESA and the science teams (UCSB and U. of Milano) are relatively confident that the companies will be able to perform.

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**Andrew Cleland**

**Philip Lubin**

**Peter Meinhold**

**National Aeronautics and Space Administration, NAG5-11426**

**Nanobolometers and Single-Electron Readout Amplification**

**02/01/02-01/31/07**

**\$759,998**

Made the world's smallest electron calorimeter/bolometer, including thermometer and heater for changing and measuring temperature, with a total volume of about 1.5 cubic micrometers. Demonstrated the world's fastest thermometer, with a time resolution of about 10 nanoseconds. Directly measured the thermal relaxation of electrons via phonons using this device, limited by fundamental coupling parameters at the lowest measurement temperatures. Demonstrated the largest frequency range single electron transistor, with a range of 1.5 GHz. Demonstrated simultaneous detectability of ten millionths of an electron charge with a time resolution of 100 nanoseconds using this device.

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**Frederick Dahlquist**

**Public Health Service/National Institutes for Health, RO1 GM059544**

**Mechanistic Studies of Bacterial Chemotaxis**

**03/01/04-06/30/06 (06/30/07)**

**\$790,919 (\$1,102,134)**

The original goal of this research was to define the molecular mechanisms that underlie bacterial chemotaxis. It has become clear that bacterial chemotaxis employs "two component" regulation in its basic biochemistry. This mechanism is common to many bacterial signaling pathways (at least 30 in *Escherichia coli*). These feature a specific histidine auto-kinase that phosphorylates a specific response regulator domain on an aspartate residue that is conserved in the family of response regulators. The phosphorylation event modulates the interaction of the response regulator domain, resulting in enhanced or diminished interactions with other domains or proteins. Thus our long-term has expanded to include

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a more general understanding of the consequences of phosphorylation of response regulator domains while we continue our focus on bacterial chemotaxis.

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**Frederick Dahlquist**

**Public Health Service/National Institutes for Health, RO1 GM057766**

**Protein Energy Landscapes by NMR and Single Molecules**

**03/01/04-07/31/07**

**\$641,597**

This research is concerned with probing the energy landscape in order to define its shape both near the true minimum and far from it. We previously developed a new nuclear magnetic resonance approach, based on relaxation dispersion measurements. This will allow us to gain access to new information about the energetics and structural location of higher energy conformations whose equilibrium populations may be present in only a few percent of the dominant conformation(s). In addition, we have used single molecule, mechanical unfolding experiments to probe the landscape more widely.

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**Frederick Dahlquist**

**Public Health Service/National Institutes for Health, RRO20900**

**NCRR Shared Instrumentation Grant Program**

**02/15/05-02/14/06**

**\$285,538**

Purchase of an 800 MHz NMR Spectrometer.

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**Mattanjah DeVries**

**National Science Foundation, CHE-0244341**

**Microsolvation of Individual DNA Bases**

**05/15/03-04/30/06**

**\$450,000**

In this project, funded by the Experimental Physical Chemistry Program of the Chemistry Division, the PI will conduct research on the properties and behaviors of individual nucleobases, nucleosides and nucleotides, with controlled numbers of water molecules. Experiments will be done by laser spectroscopy of water clusters, formed with laser desorbed, jet cooled bases. Molecular dynamics simulations and state-of-the-art nonempirical chemical ab initio calculations will complement the experimental work. Graduate and undergraduate students as well as postdoctoral associates will participate in the research. In addition, an outreach program is focused on minority students and high schools, and the development of a web based interface to facilitate access to science museum resources by grade school science teachers.

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**Mattanjah DeVries**

**American Chemical Society, 40642-AC6**

**Spectroscopy of Individual Small Model Peptides and Clusters with Water**

**01/01/04-08/31/07**

**\$120,000**

This research aims to study small molecule peptides as individual molecules and as clusters with water in the gas phase. We will employ laser desorption jet-cooling combined with REMPI Spectroscopy and with UV-UV and IR-UV spectral hole burning. The objective is to investigate to what extent the structural properties are intrinsic to the individual molecules as opposed to being a result of the biological environment, such as the solvent. We will study model sequences of two to six amino acids, designed to allow for following the effects of systematic sequence variation. We will also study a family of enkephalin peptides that will provide a comparison with well characterized bulk and solution structures. The study of their clusters with H<sub>2</sub>O will provide insight in the role of individual solvent molecules.

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**Mattanjah DeVries**

**Luann Becker**

**National Aeronautics and Space Administration, NNG04GK27G**

**Search for Molecular Building Blocks of Life in Meteorites**

**05/15/04-05/14/06**

**\$117,724**

Biomolecular building blocks of life, as we know it, are amino acids, purines and pyrimidines. The latter two form the bases of DNA and RNA. A dedicated search for these compounds in meteorites can shed light on the origins of life in two ways: (1) Results can help assess the plausibility of extraterrestrial formation of prebiotic molecules followed by their meteoritic delivery to the early earth. (2) Such studies can also provide insights into possible prebiotic synthetic routes. We will search for these compounds in selected meteorites and IDPs by resonant ionization mass spectrometry. In this technique a dye laser is tuned to a resonant transition of the molecule that we search for. This selectivity excites those molecules and puts them in the S<sub>1</sub> electronic state. A second photon subsequently ionizes the selectively excited molecules in the source of a mass spectrometer. Very high selectivity and sensitivity are made possible by a unique laser-desorption jet-cooling source. By this technique we can identify molecules not only by mass but also by their resonant excitation wavelength. We have developed and optimized this resonant two photon ionization, R2PI, detection for RNA bases and certain amino acids, as well as for their derivatives and precursors.

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**Peter Ford**  
**Civilian Research & Development Foundation, AC2-2520TB-03**  
**Spectral and Kinetic Study of NO<sub>x</sub> Reactions with Metalloporphyrins**  
**10/08/03-10/07/05**  
**\$13,000**

The CRDF is a partnership created to facilitate scientific and technological cooperation between the United States and the countries of the Former Soviet Union. This research is a collaboration between scientists in Armenia and UCSB. The combined efforts directed toward spectroscopic characterization of solid phase reactive intermediates in Armenia and solution phase kinetics explorations in the USA will give opportunity to elucidate the mechanisms of reactions of high importance both to the fundamental biochemistry of the nitrogen oxides, and to the biomedical implications of such research.

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**Peter Ford**  
**Department of Energy, DE-FG02-04ER15506**  
**Studies Relevant to Catalytic Activation of Small Molecules**  
**12/01/03-11/30/06**  
**\$390,000**

This research is concerned with the applications of quantitative kinetics techniques to probe fundamental mechanisms relevant to the catalytic activation of small molecule. Three projects are described. One is concerned with using time-resolved optical and infrared spectroscopy to probe the metal-based radicals proposed as key intermediates in a catalyst for ethylene hydrocarboxylation based on molybdenum hexacarbonyl with ethyl iodide as a promoter. The goal is to characterize the spectroscopy and dynamics of organometallic radicals that may play key roles in such catalytic sequences. The second applies similar techniques to evaluating the quantitative behavior of nitrogen oxides NO<sub>x</sub> and metal-NO<sub>x</sub> complexes as possible mediators in controlled catalytic oxidations of organic substrates by dioxygen. The third is an exploratory foray to probe mechanisms of reactions between metal oxide complexes and haloalkanes with the goal of modeling a key component of a newly patented system for alkane partial oxidations. The principal goals of our research are fundamental in nature, namely to elucidate quantitatively details reaction mechanisms relevant to the activity and selectivity of molecular catalysts for efficient use and applications of chemical feedstocks and energy resources.

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**Peter Ford**  
**National Science Foundation, CHE-0352650**  
**Thermal and Photochemical Reactions of Transition Metal Complexes of the Nitrogen Oxides**  
**03/01/04-02/28/07 (02/28/08)**  
**\$573,157 (\$738,157)**

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This award supports research to pursue investigations of the photochemical and thermal reactions of transition metal complexes of nitric oxide (NO) and other nitrogen oxide ligands (NO<sub>x</sub>). One goal is to develop precursors that can be photochemically activated for NO delivery to biological targets. Another goal is to characterize interactions of NO and other NO<sub>x</sub> such as nitrite ion, NO<sub>2</sub>, N<sub>2</sub>O<sub>3</sub>, the nitroxyl anion NO<sup>-</sup> and HNO, with metal centers and the influence of such interactions on the reactivities of these species. Modern kinetics instrumentation will be used to elucidate the pathways by which these compounds react, either spontaneously or under photochemical stimulation. These methods include time-resolved optical and infrared spectroscopy of reactive intermediates generated by laser flash photolysis or by rapid mixing. Computational techniques will be employed to investigate the relative energies and spectra of known and unknown compounds (using density functional theory) and to simulate the kinetics behavior observed or expected for complex reaction systems. Studies will explore the reaction mechanisms for the basic chemical transformations such as the formation and breaking of metal-ligand bonds and the atom and electron transfer reactions that constitute the chemistry of these "simple" species. Although fundamental in nature, the proposed studies have potential relevance to the design of materials displaying desirable photochemical properties for biomedical applications and for the reinterpretation of the mechanism(s) by which a prospective vasodilator is formed in the hemoglobin of red blood cells. The research also serves as a platform for the education and training of members of underrepresented groups at the graduate, undergraduate and postdoctoral levels.

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**Peter Ford**

**Susannah Scott**

**University of Washington, 919941**

**Time-Resolved Spectroscopy on Dehydrogenation Systems**

**09/01/04-08/31/06**

**\$77,150**

This research is concerned with utilizing flash photolysis techniques to generate reactive intermediates from various iridium pincer complexes prepared at the University of Washington. Time resolved optical (UV/vis) and infrared detection will be used to accumulate the TRO and TRIR spectra of these intermediates and to identify the products subsequently formed. The quantitative effects of variations of the media and other reaction conditions on the decay dynamics of these intermediates and upon their eventual products will allow one to define what roles these species might play in alkane dehydrogenation and other catalytic pathways of these iridium complexes.

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**Thomas Gerig**

**American Chemical Society, ACS-PRF#36776-AC4**

**Solvation and Aggregation in Fluorous Phases**

**04/01/01-08/31/05**

**\$60,000**

This work has been intended to explore the interactions between solute and solvents in so-called "fluorous" reaction mixtures. We have recently completed and published a study of the interactions of a

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fluorine-containing camphor derivative with a solvent mixture composed of perfluoromethylcyclohexane and chloroform. The solvent mixture exists as two phases at low temperature but a single phase at temperatures above 51 degrees. Solvent interactions are particularly strong in the chloroform-rich low temperature phase and appear to be regio-specific. It is hoped that these results along with those from similar systems can be summarized in a linear free energy relationship that will permit reliable prediction of the "fluorophilicity" of a given molecule.

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**Thomas Gerig**

**National Science Foundation, CHE-0408415**

**Conformation-Stabilizing Small Molecule-Protein Interactions**

**08/15/04-07/31/07**

**\$360,000**

Building on the experimental and computational capabilities that have been developed in the lab over the past few years, we are carrying out the following projects. (1) Interaction of the osmolyte trimethylamine N-oxide (TMAO) with a model dipeptide has been examined by intermolecular NOE and ROE experiments. Interpretation of the observations available turns out to be complicated by exchange processes involving water protons and the rather strong binding of water to TMAO. A series of computer programs has been written to simulate these experiments and are now being used in an attempt to disentangle these factors. Submission of a manuscript to J. Phys. Chem. is planned. (2) Solvent interactions of the designed peptide "tc5b", a 20-residue peptide that takes up a defined conformation with helical, bend and beta features by the same experimental approaches is underway. We have previously found indications that water and fluoroalcohol interactions with peptides appear to depend on local conformation. This system, in a single molecule, should provide validation of this. Preliminary work on other designed peptides and the hormone angiotensin is also underway.

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**Song-i Han**

**Camille & Henry Dreyfus Foundation, SB050022**

**Dynamic Nuclear Polarization of Small Biomolecules for High-Resolution Solutions**

**State NMR Spectroscopy of Biochemical and Biophysical Processes**

**10/01/04-09/30/06**

**\$50,000**

The setup of my equipment lab and wet lab has been completed. The equipment lab contains a fully functioning 7Tesla wide bore NMR system and CW (X- and Q-band) EPR system. An old, dysfunctional (for more than 5 years) X-band EPR equipment, partly inherited has been repaired and upgraded to a Q-band EPR spectrometer. Also, full NMR imaging capabilities have been programmed to a high-resolution NMR spectrometer and probe with triple (xyz) gradients. EPR spectra of organic stable radicals for optimum Dynamic Nuclear Polarization (DNP) performance were obtained and the microwave power consumption for saturation of the electron Zeeman level found. The first device for DNP enhancement utilizing both the EPR and NMR equipment has been built.

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**Yadong Huang**

**UC Tobacco-Related Disease Research Program-TRDRP, 14DT-0130**

**A Novel Total Synthesis of Brazilin and Brazilide A**

**07/01/05-06/30/07**

**\$59,500**

It is estimated that 90% of lung cancer deaths are caused by cigarette smoking, and lung cancer remains the leading cause of cancer-related deaths in the USA with a less than 5% overall survival rate. It is known that there are two major lung cancer, small-cell lung cancer (SCLC) and non-small-cell lung cancer (NSCLC). Recently, it has been discovered that unlike normal lung tissues, upregulation of telomerase, an enzyme that restores the length of the telomere, occurs in 98% of SCLC. AS for NSCLC, telomerase activity is regarded as an important prognostic factor for NSCLC patients after surgical resection. There are very few molecule inhibitors of telomerase known. Brazilin (**1**) is reported to inhibit telomerase at concentration of less than 100 micromolar and to kill cancer cells *in vitro*. We speculate that brazilin (**1**) is processed to brazilide A (**5**) in cells and this metabolite is responsible for the noted biological activity. Brazilide (**5**) possesses a unique propeller structure, where two blades are comprised by a remarkable bis-lactone. Through synthesis, refinement, and testing, we aim to discover the mechanism by which this class of compounds interacts with telomerase. For this purpose, we propose an efficient and novel strategy for the synthesis of **1** and **5** that is amenable to construction of the brazilin family and their analogs. Our proposed synthesis makes use of our exclusive phenol hydroxylation chemistry and an unknown method for asymmetric induction, a desymmetrizing tautomerization of a *meso* intermediate. Both the strategy and target are very appealing.

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**Luc Jaeger**

**National Science Foundation, CHE-0317154**

**RNA Tectonics and Self-Assembling RNA Nano-Devices**

**07/15/03-08/31/06**

**\$376,000**

With the support of the Organic and Macromolecular Chemistry Program in the Chemistry Division and the Molecular Biochemistry Program in the Division of Molecular and Cellular Biosciences, Professor Luc Jaeger will work to further the science and technology of fabricating novel nano- devices using ribonucleic acids (RNA) as a material. This project relates to RNA tectonics, a concept that refers to the fabrication of RNA self-assembling architectures and nano-devices with novel properties by taking advantage of the knowledge of motifs, folding and assembly rules governing the three-dimensional shape of complex natural RNA molecules. Like organic chemistry that allows an infinite number of molecules to be build with the same subset of synthons, RNA tectonics open the way to the design of an infinite number of RNA supra and macromolecules by judiciously using known RNA motifs and modules. General principles of RNA tectonics will be explored and applied to the design of smart, programmable 2D RNA arrays for generating templates with desirable topography for bottom-up fabrication of nano-electronic devices. It is anticipated that RNA is a suitable material for building electronic systems over large areas on the sub-10 nm scale. The Organic and Macromolecular Chemistry Program in the Chemistry Division and the Molecular Biochemistry Program in the Division of Molecular and Cellular Biosciences supports Professor Luc Jaeger who will collaborate with scientists

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in leading European laboratories to pursue various strategies for immobilization of RNA arrays on a surface, and investigate electronic properties of the decorated materials. Besides establishing RNA tectonics as a new field for the supra-molecular chemist, Professor Jaeger will investigate a new route to device RNA based technology with strong potential in micro and nano-electronics, a key economic sector of significance to all leading world economies. This multidisciplinary project will offer the possibility of fruitful exchange between US and European laboratories and will contribute to training graduate students and postdoctoral fellows at the interfaces between supra-molecular chemistry, biochemistry, nano-engineering, material and physical sciences.

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## **Bruce Lipshutz**

**Public Health Service, National Institutes of Health, R01 GM040287**

### **Metal-Mediated Routs to Biaryls**

**04/01/04-03/31/07 (03/31/08)**

**\$908,433 (\$1,237,360)**

Biaryls represent a major area of natural and unnatural products chemistry. Given the widespread occurrence of physiologically active compounds in nature that contain a biaryl axis, many of which due to hindered rotation possess an element of axial chirality, methodology is needed to respond to these special synthetic challenges. Representative targets which highlight existing limitations yet which provide opportunities for significant advances in this area include the clinically essential antibiotic vancomycin, and the potent *anti*-AIDS biaryls, the michellamines. Using a judiciously placed internal phosphine ligand in an aryl halide coupling partner, the directionality associated with our key Suzuki-biaryl coupling-based approach to the vancomycin biaryl and the subunits of the michellamines will be controlled. Alternatively, a conceptually new entry to stereocontrolled biaryls, as applied to vancomycin, will be pursued using a Bergman cyclization of a substituted nonracemic endiyne.

The chemistry of biaryl constructions, which is usually effected in solution using Pd(0) catalysis, is to be pursued *via* an alternative metal system: nickel. Proposed herein are new methods for heterogeneous catalysis based on Ni/C, to be examined under microwave conditions, and the next generation species nickel-on-graphite (“Ni/C<sub>g</sub>”), which appears to offer a different reactivity profile.

Finally, a new series of nonracemic ligands based on the binaphthyl core, in particular of NOBIN, will be constructed. The approach presented will provide entry to unprecedented substitution patterns on this ligand system, as well as opportunities for their mounting on a solid support for use, and re-use, under heterogeneous conditions. A particular, albeit representative, application of a novel substituted *cyclo*-NOBIN will be studied for selected asymmetric aldol reactions.

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Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.

**Bruce Lipshutz****National Science Foundation, CHE-0550232****Asymmetric Catalysis with Ligated Copper Hydride****02/01/06-01/31/07 (01/31/10)****\$148,000 (\$592,000)**

This project is focused on the theme of catalysis, specifically involving copper(I) hydrido complexes that are mainly ligated by nonracemic bis-phosphines ((L\*)CuH). The action of catalytic (L\*)CuH on aryl ketone intermediates will form products useful for the synthesis of known pharmaceuticals. Catalytic (L\*)CuH will be used in new contexts that will afford valued nonracemic intermediates for synthesis, extending the limits of this CuH chemistry. A newly designed ligand will be synthesized to test the factors that may control both reaction rates and enantioselectivities. Experiments aimed at investigating the nature of the species (L\*)CuH are planned, supporting the goal of providing a practical source of (L\*)CuH; i.e., effectively CuH in a Bottle. Using boranes as the stoichiometric source of hydride, new inroads to boron enolates will be developed and used to synthetic advantage based on transmetalations. Finally, copper-in-charcoal (Cu/C) will be explored as a potential new approach to asymmetric (heterogeneous) organocopper chemistry. Catalysis represents a powerful tool in the development of more economical and environmentally friendly technologies. Professor Lipshutz and his students are exploring new ways to catalyze organic chemical transformations using copper compounds. These copper compounds are significantly less expensive than the more commonly used precious metal catalysts and offer unique chemical reactivity as well. By developing these new catalysts, Professor Lipshutz is developing methodologies that may be generally and broadly applicable in the synthesis of complex organic molecules and pharmaceuticals.

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**R. Daniel Little****Proctor & Gamble Company, SB020139****Materials Synthesis****07/01/02-09/15/05****\$262,693**

This research focuses upon the synthesis of a variety of substances, the nature of which will be mutually agreeable to the parties concerned. The work will be of a nature that will serve an important role in the further education of a postdoctoral scholar.

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**R. Daniel Little****National Science Foundation, CHE-0200855****New Avenues of TMM Diradical Chemistry****08/15/02-07/31/05****\$404,402**

With the support of the Organic and Macromolecular Chemistry Program, we are studying the reaction chemistry of trimethylenemethane diradicals and 1,3-diyl radical cations. Using diazenes as diradical

Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.

precursors, Professor Little is exploring the factors responsible for selective formation of 8-membered ring carbocyclic compounds or their 6-membered ring isomers, as well as oxygen- and nitrogen-containing heterocyclic analogs. Symmetrical and unsymmetrical 1,3-diy radical cations are the subjects of studies relating to the assembly of 7- and 8-membered ring compounds as well as mechanistic analyses of cation radical equilibration and recoil accompanying loss of nitrogen from diazenes. Many organic compounds which display interesting chemical or biological activity contain 7- or 8-membered rings of atoms. The development of efficient techniques for the synthesis of such cyclic compounds remains of great interest, particularly in light of the generally greater stability of smaller-ring (5- and 6-membered) compounds. We are developing new reactions allowing the selective synthesis of 7- and 8-membered ring compounds and studying the factors responsible for the selectivity of these reactions.

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**R. Daniel Little**

**American Chemical Society, PRF#43443-AC1**

**Catalytic, and Potentially Enantioselective ERC and EHC Reactions**

**07/01/05-08/31/07**

**\$80,000**

In this award we describe the use of nickel (II) salen as a catalyst/mediator in the ERC and EHC reactions. To the best of our knowledge, the ability to affect either reaction in this manner is a first of its kind. Preliminary evidence is provided to suggest that the first electron transfer occurs *via* a ligand-centered process. It is upon this topic/process that we will focus our attention. Through additional detailed investigations involving voltammetric inquiries, semi-empirical quantum calculations, and ESR probes, as well as through structural variations of the substrate, the metal, and the ligand, we intend to optimize the chemistry, expand the scope of the transformations, and gain additional levels of understanding mechanistically. We hope to be able to perform the reactions enantioselectively, and plan to use what we learn to synthesize cinnamolide, a simple, yet interesting natural product that is effective in halting bleeding.

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**R. Daniel Little**

**Robert Jacobs**

**Army, W81XWH-06-1-0089**

**The Role of the Pseudopterosins and their Analogs in Wound Healing**

**11/20/06-10/19/09**

**\$991,582**

Severe injury from chemical or physical sources continues to be a serious and challenging medical problem from the perspective of successful treatment, survival, and recovery. A physical surface injury to the skin of most animals initiates a complex series of immune and physiological responses involving pain, inflammation, wound repair and scar formation. The total process of wound repair or wound healing is not homogenous among species but many components of the response are phylogenetically conserved and are observed in very primitive unicellular algae and ciliates.

Note: Dates in **green** are the projected end dates and dollar value in **green** is the projected total award value.

In vertebrates including man certain forms of injury are followed by a major initial infiltration and concentration of neutrophils at the sight of injury. During the early stages of phagocytosis, these cell degranulate and release stored enzymes such as myeloperoxidase, proteases, lipases, and pro-inflammatory eicosanoids and chemotactic factors that attract additional immune cells. They also produce reactive oxygen species, alter vascular permeability, and induce swelling. Most cells also contribute to this early stage by releasing histamine and other autocooids.

We hypothesize that donor sites in patients undergoing repeated reconstructive surgery may represent a clinical condition that can be simulated experimentally by topical treatment of mouse ears with the irritant phorbol myristate acetate (PMA). We base our hypothesis on the fact that Pseudopterisin A and its analogs block infiltration of neutrophils in the PMA treated mouse ear and also block phagocytosis and degranulation in cell culture models. Recent phase 2 clinical trials have shown that topical application of pseudopterisin A methyl ether significantly increased healing rate of donor sites in burn patients. WE believe this may be in part the result of diminished pro-inflammatory mediators at the wound site. We wish to exploit these results and propose to optimize the potency and efficacy of the pseudopterisin pharmacophore, increase its bioavailability and provide a new molecule that can be readily synthesized.

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**Maurice Marsini**

**Thomas Pettus**

**ARMY, DAMD17-02-1-0334**

**A Synthetic Route to the Novel Telomerase Inhibitor Diazaphilonic Acid:  
Applications of a Assymetric Dearomatization Protocol**

**07/08/02-07/07/05**

**\$66,000**

Predoctoral Traineeship Award: Natural products, bioactive compounds isolated from natural sources, have proven invaluable as both lead compounds for drug development as well as tools for the elucidation of biological mechanisms. One such compound, diazaphilonic acid, has recently been isolated and shown to be a telomerase inhibitor. In this research, a route for the total synthesis of diazaphilonic acid is described. The total synthesis diazaphilonic acid is anticipated to resolve issues concerning its structure as as provide access to analogogues which mau posses increased anti-telomerase activity.

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Note: Dates in **green** are the projected end dates and dollar value in **green** is the projected total award value.

**Horia Metiu**

**Michael Bowers**

**Steven Buratto**

**Martin Moskovitz**

**Eric McFarland**

**Air Force, F49620-01-1-0459**

**Catalysis by Nanostructures: Methane, Ethylene Oxide, and propylene oxide  
Synthesis on Ag, Cu or Au Nanoclusters**

**07/01/01-12/31/06**

**\$4,519,452**

**UC Participation: \$120,012**

We study, theoretically and experimentally, catalysis by small supported metallic clusters. Our calculations have determined the binding of Au, Ag, H<sub>2</sub> and O<sub>2</sub> to Au clusters, TiO<sub>2</sub> and Au/TiO<sub>2</sub>. We have built an instrument that prepares mass-selected clusters, deposits them on a surface and examines their properties by STM and surface science methods. We have discovered that K salts promote CO oxidation by Au/TiO<sub>2</sub>. We demonstrated that electric fields applied across the surface of an oxide catalyst can modify its catalytic properties.

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**Horia Metiu**

**Air Force, F49620-02-1-0394**

**Theoretical Studies of Catalysis on Supported Metal Clusters: Propylene Oxidation  
on Gold**

**08/01/02-07/31/05**

**\$240,000**

One of the most recent discoveries in “nano-science” is that catalytic chemistry taking place on nano-sized metal clusters is radically different from that taking place on large clusters. A dramatic and useful example of this size dependence is provided by the partial oxidation of propylene, by a mixture of O<sub>2</sub> and H<sub>2</sub> on Au clusters supported on TiO<sub>2</sub>. If the diameter of the cluster is less than 2nm, the reaction product is almost exclusively propane. For sizes between 2 nm and 4 nm, the same system produces propylene oxide with excellent selectivity. Larger clusters are inert. One of our objectives in this research is to use the methods of quantum chemistry to find the mechanism of the reaction and to provide a complete understanding of its unique features.

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**Horia Metiu**

**Air Force, FA9550-06-1-0167**

**Catalysis by Single Atoms: Water Gas Shift and Ethylene Hydrogenation**

**03/01/06-11/30/06 (11/30/08)**

**\$70,000 (\$270,000)**

Recent experimental work has shown that in several catalytic systems, consisting of metal supported by an oxide, the active centers are the metal ions. These systems are ideally suited for reliable theoretical studies because they involve a relatively small number of atoms. The funds requested here are for the pursuit of such investigations. We plan to use density functional theory to determine the location of the ions in the oxide, the adsorption properties of the “doped” oxides, the spectroscopic properties of the molecules adsorbed on such systems, and the reaction mechanism for the water gas shift reaction and for ethylene hydrogenation. Our overall purpose is to find out what makes these systems active and how this activity depends on the metal-oxide interaction. We hope to generate qualitative rules that will help experimentalists find better metal ion-oxide catalytic systems.

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**John Perona**

**David Low**

**Public Health Service, National Institutes of Health, GM62630**

**Stereochemical Basis for Transcriptional Control of the E. Coli Pap Operon**

**01/01/02-12/31/05**

**\$1,048,752**

After many years of effort we have determined the X-ray structure of *E. coli* Lrp protein. The DNA sequence which is cocrystallized is: 5'-T GTG GGT TAA AAG ATC GTT. These crystals were previously indexed in the orthorhombic space group C222<sub>1</sub> with unit cell parameters a = 100.1 Å, b=237.0 Å, c=75.6 Å. Extensive heavy-metal searches were conducted by conventional procedures, to determine the structure by MIR, after it was determined that selenomethionine-substituted protein could not yield suitable crystals. Data collection in Summer 2004 partially resolved previous bottlenecks in the phasing of the complex. We were able to improve the resolution of the ethyl mercury thiosulfonate (EMTS) derivative to 3.2 Å, which is equal to the resolution of the native data. In addition, we identified sodium iodide as a second derivative with a short soaking time of 5 min in a solution of mother liquor containing 1.0 M NaI, which assisted in the phasing. For the 2-derivative solution in SOLVE, the Z-score (a measure of phasing quality that combines traditional criteria) is 26.4, normally sufficient to allow interpretation of maps. The electron density maps indeed reveal a discrete solvent boundary. Backbone chain traces of most of the Lrp monomer have been constructed, and assignment of side-chains is in progress. The C-terminal portion of *E. coli* Lrp is similar to that of the archaeal LrpA homolog, despite the low sequence identity between the two proteins. The N-terminal portion of Lrp, which was expected to bind the DNA, is partly disordered and may not adopt the helix-turn-helix motif of LrpA. Further, no electron density for the DNA is observed. Interestingly, the maps show a distinct “hole” some 20 Å in diameter which can accommodate duplex DNA, and which is surrounded by the C-terminal portion of Lrp. This indicates that an unexpected, possibly nonspecific, DNA binding mode is adopted in the crystal. The arrangement of Lrp dimers is similar to the octamer unliganded state

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seen in the archaeal LrpA homolog, but the symmetry of the octamer is apparently broken to allow entry of the DNA duplex. Further analysis is in progress. Although we have not solved a specific complex, this structure will have important implications for understanding the transition to the DNA-bound state, and for appreciating the role of Lrp as a packaging protein.

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**John Perona**

**Public Health Service, National Institutes of Health, 2R01GM063713**

**Specificity in the Synthesis of Aminoacyl tRNA**

**06/04/05-05/31/07 (05/31/09)**

**\$533,881 (\$1,071,244)**

Mechanisms underlying the specificity of aminoacyl-tRNA synthesis will be studied in a variety of experimental systems. First, recently determined structures of *E. coli* cysteinyl-tRNA synthetase will be used as a basis for exploring unique mechanisms underlying the selectivities for amino acid and tRNA in that system. A zinc-mediated conformational switch controlling placement of the tRNA 3'-end in the active site will be studied and the origins of shape-selective tRNA recognition will be explored in complementary studies of human and *E. coli* CysRS. Next, the mechanistic basis for the coupling of amino acid and tRNA specificities will be studied in *E. coli* glutamyl-tRNA synthetase. In this case the primary approach will be the application of newly-developed transient kinetic methods. Results of these experiments will inform the design of amino acid specificity switches by rational mutagenesis, with a view towards introduction of activity towards noncognate and nonstandard amino acids. Finally, the mechanisms by which the *H. pylori* tRNA-dependent amidotransferase converts misacylated tRNA into suitable substrates for protein synthesis will be studied. Experiments here will focus on establishing the identities of the tRNA recognition elements and some aspects of the reaction pathway. The elucidation of how induced fit and indirect readout mechanisms control tRNA and amino acid specificities in model tRNA synthetases will be relevant to understanding such processes in more complex particles such as the ribosome.

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**John Perona**

**Norbert Reich**

**Public Health Service, R01 GM 53763**

**Selectivity Determinants in DNA Restriction and Modification Enzymes**

**12/15/05-11/30/06 (11/30/09)**

**\$275,665 (\$1,131,829)**

The detailed structural and energetic origins of sequence-specificity in the recognition and modification of DNA will be investigated using prokaryotic restriction endonucleases and modification methylases as experimental systems. Elucidation of how DNA sequence recognition is manifested through induced-fit conformational rearrangements in the restriction endonuclease and methylase families will be relevant to understanding this phenomenon in a variety of nucleic-acid modifying enzymes including recombinases, topoisomerases, and enzymes of DNA repair and RNA modification pathways. Further, a clearer appreciation of the detailed structural and energetic basis for specificity and rate enhancement

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forms an essential basis for the rational engineering of enzymes with new specificities. Since restriction endonucleases and DNA methylases are an essential part of the recombinant DNA technology that underlies all areas of biological research, this is a prospect of substantial importance to the development of therapies for many human diseases.

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**Thomas Pettus**

**Public Health Service, National Institutes of Health, GM64831**

**The Synthesis and Application of Chiral Cyclohexadienones**

**01/01/02-12/31/06**

**\$1,295,154**

Small cell-permeable natural products and their analogs play a crucial role in the treatment of disease. This grant addresses the syntheses of several biologically active molecules relevant to the treatment of cancer, HIV, stroke and heart disease through optically enriched chiral cyclohexadienones that until now have been relatively inaccessible chemical entities. Their fragile nature coupled with the lack of enantioselective access has hampered their widespread synthetic applications. The Pettus group has shown that robust enantiopure cyclohexadienones can be constructed to undergo a myriad of diastereoselective reactions including 1,2-, 1,4- and 1,6-additions, along with various rearrangements and cycloadditions. Telomerase, an enzyme responsible for telomere elongation, has been recently linked to the immortalization of cells and cancer. Most somatic cells, with the exception of rapidly regenerating tissue such as bone marrow, show little to no telomerase activity. However, 85%-90% of human breast cancer cell lines demonstrate upregulated telomerase activity. It has been suggested that telomerase holds the key to cancer cell immortality. Therefore, by inhibiting telomerase, it should be possible to prevent cancer cells from dividing indefinitely, leading to eventual tumor death with minimal side effects. One such telomerase inhibitor of unknown stereochemistry, diazaphilonic acid, was recently discovered. The Pettus group is pursuing a synthesis of diazaphilonic acid.

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**Thomas Pettus**

**National Science Foundation, CHE-0135031**

**CAREER: New Applications for Ortho-Quinone Methides in Organic Synthesis**

**02/01/02-01/31/07**

**\$463,416**

The objective is to investigate the use of ortho-quinone methides (o-QMs) as larger than usual building blocks for organic synthesis. The synthetic methods developed in this project is being used in the syntheses of natural products such as robustadiol A, heliquinomycin and diinsinanol. These natural products display a wide range of biological activities. Students trained during the course of this research work will gain skills needed by the pharmaceutical and specialty chemicals industries.

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Note: Dates in green are the projected end dates and dollar value in green is the projected total award value.

**Thomas Pettus**

**UC Cancer Research Coordinating Committee, SB060002**

**Synthesis of the Unique Telomerase Inhibitors Using Novel Chemical Methods and Strategy**

**07/01/05-06/30/06**

**\$50,000**

Each time a cell divides, its telomeres located at the end of its chromosomes shortens until cell division halts and the cell enters a feeble state known as senescence. Telomerase, an enzyme that restores the length of the telomere, is not present in most normal cells and tissues. However, during tumor progression telomerase is abnormally reactivated in most cancer types. There are very few molecule inhibitors of telomerase known. Brazilin (**1**) is reported to inhibit telomerase at concentration of less than 100 micromolar and to kill cancer cells *in vitro*. We speculate that brazilin (**1**) is processed to brazilide A (**5**) in cells and this metabolite is responsible for the noted biological activity. Brazilide (**5**) possesses a unique propeller structure, where two blades are comprised by a remarkable bis-lactone. Through synthesis, refinement, and testing, we aim to discover the mechanism by which this class of compounds interacts with telomerase. For this purpose, we propose an efficient and novel strategy for the synthesis of **1** and **5** that is amenable to construction of the brazilin family and their analogs. Our proposed synthesis makes use of our exclusive phenol hydroxylation chemistry and an unknown method for asymmetric induction, a desymmetrizing tautomerization of a *meso* intermediate. Both the strategy and target are very appealing.

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**Kevin Plaxco**

**Stanford University, PY-2093**

**Nucleation and the Topological Search: Relativer Contributions to the Folding Barrier**

**07/01/02-06/30/06**

**\$516,709**

We have been exploring the unfolded states of proteins using both small angle x-ray scattering and spectroscopic methods. We find that, while the chemically-denatured state adopts a fully random coil conformation, the unfolded state populated under physiological conditions is extremely compact. This compaction, however, does not require sequence specific interactions and thus probably reflects simple heteropolymer collapse rather than the formation of a specific, partially folded state.

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**Norbert Reich**

**UC Los Alamos National Laboratory, SB050104**

**Collaborative Project between Los Alamos National Laboratory and UCSB**

**05/14/05-08/31/05**

**\$10,000**

The purpose of this research is to provide the Los Alamos National Laboratory with the expertise and samples for the ongoing work on the DNA based nanoelectronics and sensor development. This work is a part of T-11, CNLS and Center for Integrated Nanotechnologies research on the theory and experiment on the organic molecule based nanoelectronics. Specifically, this work will focus on design, experimental characterization and simulation of the local electronic and optical properties of DNA macromolecules decorated with Au nanoparticles.

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**Norbert Reich**

**UC Discovery Grant-Biotechnology, bio05-10524**

**Tamarisc Diagnostics, SB060120**

**Rapid Detection of HPV in Clinical Samples**

**04/25/06-04/24/07**

**\$62,165 (\$64,788)**

Human Papillomavirus (HPV) infection in the human population can lead to cancer and there is an immediate need for robust, inexpensive, and rapid diagnostics to detect HPV, both in and out of the clinic. We will develop a technology to be incorporated into a point of care diagnostic which enables the rapid and accurate detection of HPV. Our goal is to carry out viral typing to further facilitate treatment of the high risk HPV types associated with cancer. The detection is based on a simple and robust optical principle involving fluorescently labeled molecules, which only emit light in the presence of the viral genome. Currently, we are able to detect as little as 100 fmoles of a target DNA sequence with high precision, at a cost of under \$3 per assay. Our goal is to optimize an assay that will be accurate, economic, efficient, and can be performed by non-specialists for broad application.

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**Martin Sagermann**

**UC Cancer Research Coordinating Committee, SB060004**

**Characterization of Regulation of the Vacuolar ATPase**

**07/01/05-06/30/06**

**\$40,000**

Recently, plasma membrane V-ATPases have been identified to be involved in the regulation of extracellular acidity of tumor cells, essential for cellular invasiveness and proliferation in metastasis. The goal of this proposal is to elucidate the interactions of the regulatory subunit H of the V-ATPase. This subunit has been suggested to communicate with other cellular processes as it is known to be important for activity but not for the assembly of the enzyme. Subunit specific protein interaction

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assays in combination with proteomics-scale mass spectroscopy will provide an unprecedented view on the interactions of this subunit to other factors and improve current understanding of V-ATPase regulation and its enhanced activity in malignant cells. A better understanding may therefore provide an advantageous basis for the development of potent and specific cancer drugs in the future.

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**Joan-Emma Shea**

**National Science Foundation, MCB-0133504**

**CAREER: Bridging “In Vitro” and “In Vivo” Protein Folding: An Integrated Interdisciplinary Research and Teaching Plan**

**04/01/02-03/31/07**

**\$605,000**

The current understanding of the mechanism by which a protein folds and adopts its biologically active three dimensional structure stems from experimental and theoretical investigations in idealized dilute environments. Under biologically relevant conditions, however, proteins fold in the much more complex cellular environment, where folding is plagued by a number of obstacles. For example, the crowded cytoplasmic environment, sequence mutations and changes in pH or temperature, can all lead to the formation of misfolded or intermediate structures. While recent experimental advances are permitting an exploration of folding in the cell, a theoretical framework and understanding of protein folding in the cellular environment is lacking. This project seeks to bridge the gap in our theoretical knowledge between in vitro and in vivo protein folding. Methods of statistical physics will be used to develop new methods and models to further our understanding of protein folding and to develop a microscopic picture of the kinetics and thermodynamics of protein aggregation. New algorithms based on parallel tempering Molecular Dynamics, Stationary Phase Monte Carlo and Field Theoretic methods will be developed to efficiently sample relevant aggregate conformations. The effect of crowding on folding and the competition between folding, misfolding and aggregation will be addressed. The educational goals of this project relate to the interdisciplinary nature of this research. A reform of the chemistry curriculum, to reflect the growing interdisciplinary nature of biochemical research and the impact of computers in modern research, will be achieved through the development of a new computational biophysics and chemistry course as well as through the creation of an interdisciplinary undergraduate research program. Outreach activities will be pursued through introductory computer classes aimed at middle school girls.

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**Joan-Emma Shea**

**David and Lucille Packard Foundation, 2003-25907**

**Theory and Simulation of Protein Folding in the Cell**

**10/02/03-10/01/08**

**\$625,000**

Computational studies of the aggregation process involved in Alzheimer's disease.

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**Joan-Emma Shea**  
**Alfred P. Sloane Foundation, BR-4359**  
**Nomination for Alfred P. Sloane Research Fellowship**  
**09/16/04-09/15/06**  
**\$40,000**

Development of computational models for chaperonin-mediated protein folding; Investigation of the role of the environment on protein folding.

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**Mark Sherwin**  
**National Science Foundation, DMR-0244390**  
**Terahertz Electro-Optics in Semiconductor Nanostructures**  
**06/01/03-05/31/06**  
**\$397,000**

The research conducted under this grant explores the basic physics, fabrication, and materials science of semiconductor devices which can modulate light at THz frequencies. In addition to their desirability in the field of optical communications, semiconducting Thz electro-optic devices operate in a regime where the effects of quantum mechanics, strong driving, many-body physics, and dissipation are all important. This regime is one of the frontiers of condensed matter physics.

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**Mark Sherwin**  
**S. James Allen**  
**David Awschalom**  
**Daniel Blumenthal**  
**Pierre Petroff**  
**Kevin Plaxco**  
**Jerry Ramian**  
**National Science Foundation, DMR-0321365**  
**Development of a Stable, User-Friendly, High-Power Terahertz Source:**  
**Enhancements to the UCSB Free-Electron Laser**  
**08/15/03-07/31/06**  
**\$425,000**  
**UC Participation: \$96,000**

The UCSB Free-Electron Lasers and newly-renovated User's Lab stand out as unique facilities which enable measurements that can be done nowhere else. The FELs work as follows. An electrostatic accelerator generates a beam of electrons with energies ranging from 2 to 6 MeV. The electrons are injected into one of two fully operational free-electron lasers before being recirculated. Narrow-band light emitted by the relativistic free-electron beam as it moves through the undulators in these lasers is

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amplified and trapped in a resonator. The small fraction which is coupled out is typically 1kW, tunable from 140 GHz to 5 THz, with pulse durations of a few  $\mu$ s.

The three enhancements undertaken are: 1. Modernize control system 2. Stabilize frequency 3. Build a FEL spectrometer.

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**Mark Sherwin**

**National Science Foundation, DMR-0244390**

**Collaborative Research: Terahertz Dynamics of Polymer Crystallization**

**05/01/05-04/30/06**

**\$58,117**

The crystallization of synthetic polymers, in spite of its significant industrial importance, continues to represent a primary challenge of polymer science and condensed matter physics. Although kinetic theories on polymer crystallization enjoyed widespread acceptance, the underlying dynamics of polymer crystallization is still unknown. Consequently, man's ability to control polymer structure via crystallization is limited, particularly during its early stages and at the nanoscale. In this SGER proposal, we propose to initiate research on the Terahertz (THz) dynamics of polymer crystallization. THz dynamics originates from the collective modes of inter- and intra-chain motions and is expected to be active during both stages of nucleation and growth. The spectral fingerprints of the collective modes lie in the far-IR region, from a few wavenumbers to some 300  $\text{cm}^{-1}$ . Energetically, they reside in the THz regime (1 THz = 1012 Hz). It is the objective of this proposal to establish the role of THz dynamics in structural formation during crystallization. Efforts will be focused on the stage of primary nucleation. The specific aim is to establish concrete microscopy evidence that THz energy input is capable of controlling nucleation behavior. Experimentally, brilliant monochromatic THz free-electron laser (FEL), whose energy is characteristic of nucleation activation, will be used. In-situ microscopy is employed to follow changes in nucleation behavior upon FEL illumination on metastable polymer melts. The goal is not only to establish the role of THz dynamics in polymer crystallization, but also to introduce the concept of THz dynamics to study structural phase transformations in polymer systems. The experimental strategy adopted in this proposal also opens the door for the development of a groundbreaking nanotechnology for molecular engineering.

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**Mark Sherwin**

**Pierre Petroff**

**Craig Pryor**

**Jelena Vuckovic**

**National Science Foundation, CCF-0507295**

**NIRT: Semiconductor Nanostructures and Photonic Crystal Microcavities for Quantum Information Processing at Terahertz Frequencies**

**08/01/05-07/31/09**

**\$1,500,000**

Note: Dates in **green** are the projected end dates and dollar value in **green** is the projected total award value.

NIRT: Semiconductor nanostructures and photonic crystal microcavities for quantum information processing at Terahertz frequencies Abstract This grant will explore the fundamental physics of elements in a proposed semiconducting quantum information processor (QIP) which is potentially scalable to ~1000 quantum bits (qubits). The qubits in the envisioned QIP are the two lowest orbital states of electrons bound to shallow donors (D0) in GaAs or bound in elongated self-assembled quantum dots called quantum dashes (QDAs). QDAs will be grown by molecular beam epitaxy on patterned substrates. The resonance frequency of D0 and QDA-based qubits will be between 1 and 4 Terahertz (THz). The energy relaxation and decoherence rates of these qubits will be measured, and are predicted to be slow because the resonant frequencies are well below that of an optical phonon. GaAs and Si Photonic crystal resonators for THz frequencies will also be fabricated and characterized. Finally, qubits will be incorporated into resonators and reversible coupling of energy between the resonator and qubits will be investigated. This research program works at two scientific and technological frontiers: harnessing quantum mechanics for information processing, and developing the portion of the electromagnetic spectrum between 1 and 10 THz (THz-1 THz=one trillion cycles/s). The research will explore a new approach to quantum information processing in semiconductors, enhance our fundamental understanding of the transfer of information and energy between simple quantum systems and their semiconducting hosts, and create new materials and structures in which to store THz light and control its interaction with matter.

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**Mark Sherwin**

**Florida State University, R00501**

**Instrumentation for Materials Research, Major Instrumentation Project: Free-Electron Laser Facility for Spectroscopy in the Terahertz to Near-Infrared Range Under Very High Magnetic Fields**

**11/01/05-08/31/07**

**\$373,292**

This award from the IMR\_MIP program and the Office of Multidisciplinary Activity in to Florida State University supports a conceptual engineering design (CED) of a Free Electron Laser Light Source for High Magnetic Field Research. This project brings together the expertise of three world-leading US institutions; the National High Magnetic Field Laboratory, Tallahassee, home to the world's highest steady magnetic field, the Jefferson Laboratory, site of the most powerful free-electron laser, and the renowned University of California at Santa Barbara Center for Terahertz Science and Technology. In the first phase, experts from these laboratories will design a versatile and powerful free-electron laser facility plus the infrastructure to couple it to the Tallahassee high-field magnets. The free-electron laser system will provide unprecedented coverage of the electromagnetic spectrum in a single facility, producing radiation ranging from millimeter wavelengths to the near infrared. In spite of this great versatility, the new laser system will be based on tried and tested US technology, with reliability a key design factor. This high-magnetic-field plus free-electron-laser facility is being developed in response to emerging needs and desires of the scientific community, identified at a series of workshops and conferences in the past two years. It will be dedicated to new types of experiment in physics, chemistry and biophysics that utilize a magnetic field's ability to manipulate the electrons within matter, plus the free-electron laser's ability to probe the resulting changes as a function of time, laser power and wavelength. Such techniques promise to provide important information about materials ranging from

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semiconductors to DNA, and from superconductors to nanoparticles, and processes from quantum computation to photosynthesis. The provision of this unique facility will help to maintain the US's competitiveness in fundamental science and its spin-off emergent technologies. Students, and postdocs from a diverse demographic and institutional backgrounds will be participate in this CED project.

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**Vojislav Srdanov**

**National Science Foundation, CHE-0098240**

**Photochemistry of Conjugated Polymer/Lanthanide Blends**

**07/01/01-09/30/05**

**\$248,275**

The Advanced Materials Program in the Chemistry Division supports this award. The focus of the research is the synthesis and characterization of conjugated polymer-lanthanide blends and to determine mechanisms for electronic couplings and charge transfer reactions in these systems. Under this award, ultra fast femto-second and time-resolved spectroscopic studies will be carried out by Vojislav Srdanov and Guillermo Bazan to determine the optical and electronic coupling between the conjugated polymers and lanthanides such as terbium neodymium and erbium in the prepared blends. Specifically, photoluminescence and electroluminescence properties of rare earth centered conjugated polymers will be studied with this award. Orbital energy levels of the polymer, the singlet and triplet levels of the ligand, and those of the lanthanides will be matched for the efficient combination of the polymer and the lanthanide. An understanding of the mechanism for the energy transfer reactions in conjugated polymers doped with different lanthanides may provide impetus for the development of monochromatic light-emitting diodes, flat panel displays and other related electro-optic devices. An understanding of the mechanism for the charge transfer reactions in conjugated polymers with lanthanide rare-earth metals may provide impetus for the development of monochromatic light-emitting diodes, flat-panel display and other related electro-optic devices. The educational plan will integrate interdisciplinary research and education in the area of macromolecular chemistry and photochemistry.

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**Vojislav Srdanov**

**American Chemical Society, ACSPRF#38613-AC5**

**F-Center Spin Glasses**

**07/01/02-08/31/05**

**\$80,000**

F-centers are point defects in an ionic lattice, consisting of an unpaired electron localized in the cavity of a missing anion. In certain types of sodalities, however, F-centers can be formed in every sodalite cage, thus giving rise to an ordered lattice of magnetically interacting F-centers known as electro-sodalite. We have found recently that alkali-electro-sodalites are Mott insulators with antiferromagnetic ground state, whose Neel temperature depends on the size of the alkali cation. We plan to introduce disorder in such a perfectly ordered bcc lattice of F-centers by filling sodalite cages with a desired percentage of randomly distributed, yet magnetically coupled, F-centers. The exchange interaction among such centers leads to spin frustration and thus offers studies of previously unknown F-center spin glasses.

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**Galen Stucky**

**Peter Ford**

**GRT, Inc., SB020016**

**Integrated Process for Synthesizing Higher Value Products from Natural Gas Components**

**08/01/01-07/31/05**

**\$1,834,847 (\$2,010,301)**

This research will focus directly on the advancement of the halogenation process for activating alkanes that was jointly developed by UCSB and GRT. The research will entail the exploratory synthesis of catalysts, studies of the catalytic mechanisms, and bench top testing of various catalytic and non-catalytic schemes for the developed process. Such a process is often referred to as a Gas to liquids (GTL) process. GTL conversion represents a new and exciting industry that is currently in transition from research and development to commercialization. Driving development of the GTL industry is the world's desire for cleaner air through cleaner burning fuels, more efficient use of energy resources and addressing the increasing world demand for energy. These factors suggest the need for an energy source that is ultra-clean and in abundant supply. Natural gas is the obvious solution. Proven reserves of natural gas in the world total in excess of 5,200 trillion cubic feet ("tcf") with more than 2,500 tcf of reserves categorized as "stranded": that is, found in remote locations without economical means of bringing the gas to market. Much of this gas is flared, which in addition to wasting a valuable resource, contributes additional greenhouse gases to the environment.

The focus of the chemistry research at UCSB will be the examination of catalytic and non-catalytic routes for the conversion of natural gas hydrocarbons to higher value fuels and chemicals. This examination will center on a mechanistic understanding of the reactions, with particular emphasis on the identification of process byproducts and their elimination.

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**Galen Stucky**

**Bradley Chmelka**

**National Science Foundation, DMR-0233728**

**Molecular Design and 3-D Assembly for Integrated Optical Functionality**

**02/15/03-01/31/07 (01/31/08)**

**\$720,000 (\$900,000)**

This project targets nanoscale control of molecular assembly to create integrated, functional systems such that "every atom counts", i.e. the active volume and function is maximized relative to the atomic density. The approach makes use of organized interfaces with high surface areas and amplification of response. The research is synthesis and processing focused to determine the molecular synthesis and 3 dimensional organization needed to structurally integrate hierarchical assembly with interacting electro-optic functionalities. Because of the ease of simultaneous synthesis and processing and the huge chemical diversity that is accessible through composition, inorganic modification, organic incorporation, and multidomain assembly, the potential significant technological applications are great. In order to

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realize these possibilities, it is essential to be able to predictively design and control the multivariable kinetic and thermodynamic parameters that lead to the desired multiscale structure and functional properties. The educational emphasis for undergraduate, graduate and postdoctoral researchers working on this project will include 1) the promotion of professional careers for female students and postdoctoral associates, 2) providing cutting edge collaborative interdisciplinary interactions and resources within the University of California scientific community, 3) personal exposure to leading research and educational programs in world-wide institutions, and 4) provision of summer "hands-on" training opportunities for K-12 and community college students. The goal of this project is to enable, by controlled molecular assembly, the creation of multi-functional devices made up of thin films, coatings or fibers that have thickness' which are the diameter of a human hair or smaller. The thin films, coatings and fibers will contain self-assembled, 3-d patterned and interfaced functional components that are dimensioned on the molecular and nanoscale. Synthesis and processing are carried out simultaneously to greatly reduce the expense and time normally associated with multi-step assembly. Commercial interest includes low-dielectric coatings, optical limiters, photovoltaics, photocatalysts, chemical and bio sensors, displays, microcavity lasers and laser arrays, battery electrolytes, and optical data storage. The educational emphasis for undergraduate, graduate and postdoctoral researchers working on this project includes the promotion of professional careers for female students and postdoctoral associates, providing cutting edge collaborative interdisciplinary interactions and resources within the University of California scientific community, personal exposure to leading research and educational programs in world-wide institutions, and provision of summer "hands-on" training opportunities for K-12 and community college students.

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**Galen Stucky**

**NAVY, N00014-04-1-0654**

**Zeolite and Molecular Sieve Hemostatic Agents**

**06/07/04-12/31/05**

**\$245,802**

Traumatic injuries, especially those sustained on the battlefield, often lead to death unnecessarily because of rapid and severe blood loss from the inflicted individual. The implementation of high-surface-area sorbents to initiate blood coagulation through rapid dehydration of a wound has proven successful in combat and emergency scenarios. Zeolites and molecular sieves are high-surface-area alumina-silicates and alumino-phosphates which are ideal materials for sequestering large amount of water. The energetics involved in water sorption to many of these materials, however, presents a heat dissipation issue with regard to the safety of the patient and the caregiver. With this research, we intend to identify both synthetic and natural zeolites and molecular sieves which are ideal sorbents but which have minimal heats associated with hydration. Zeolites and molecular sieves that are demonstrated to be promising hemostatic agents will be further modified to optimize the enthalpy of hydration. Finally, zeolites and molecular sieves will be functionalized to act as therapeutic and/or delivery agents. In this regard, the first task will be to prepare host/guest configurations of zeolites and molecular sieves with silver ions, to afford added antibiotic and therapeutic activity and promote the growth of healthy tissue.

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**Galen Stucky**

**J. Herbert Waite**

**UC Discovery Grant, 2005-240**

**The Clinical and Mechanical Properties of the Bio-Halogenated Coating of the Nereis Jaws**

**07/01/05-06/30/06 (06/30/07)**

**\$50,000 (\$100,000)**

Nature has elegant and sophisticated ways of making tough, durable and lightweight materials. The hypothesis of the proposed research is that the inorganic component's (zinc, iodine, bromine and chlorine) interaction with proteins, contributes hard and wear-resistant properties to the lightweight jaws of a polychaete worm, *Nereis* (commonly known as a clamworm). Toward this end, the specific aims of this interdisciplinary project are:

- (1) To identify the structural, inorganic, biochemical and molecular characteristics of jaws.
- (2) To correlate these jaw characteristics with mechanical investigations.
- (3) To use biomimetic rules derived from the analyses of the jaws to prepare synthetic mimics of jaw proteins.

The long-term goal of this work is to gain fundamental understanding of the engineering principles governing the adaptive design of polychaete jaws, and, particularly, to explore and mimic the relationships that couple their chemical, ultrastructural and mechanical properties.

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**Galen Stucky**

**Environmental Protection Agency, SB060043**

**US EPA Fellowship**

**08/03/05-08/02/08**

**\$17,000 (\$51,000)**

The objective of this proposal is the understanding and development of inorganic materials with compositions and nanostructures optimized for the coupling of energy from sunlight to oxidation/reduction chemistry for the photoelectrochemical degradation of environmental pollutants.

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**Galen Stucky**

**Navy, N00014-06-1-0145**

**Rationally Designing Functional Hemostatic Agents for Traumatic Injuries and Wound Healing**

**10/01/05-09/30/07**

**\$50,000 (\$387,892)**

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The successful treatment of traumatic injuries requires the intervention of rapid-acting and biocompatible hemostatic agents. We describe in this proposal a new approach for designing rapid-acting hemostatic materials for the treatment of traumatic injuries and wound healing. This proposal outlines the next generation of hemostatic technology by addressing the following needs of the Casualty Care and Management Program:

1. Improve the speed and integrity of induced blood clot formation and wound healing in traumatic injuries
2. Optimize heat release to promote healing while avoiding tissue-burning side effects.
3. Induce rapid formation of a continuous hemostatic interface that protects the wound.
4. Defend against opportunistic pathogens common to the battlefield.
5. Deliver blood-clotting metabolites to accelerate wound healing.

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**Petra Van Koppen**

**Camille & Henry Dreyfus Foundation, SG-05-081**

**Outreach Program to Improve Educational Opportunities for K-12 Students: A Hands-on Inquiry-Based Approach to Teaching Physical Science in the Fifth Grade**  
**01/01/05-12/31/06**

**\$24,661**

**UC Participation: \$9,974**

Outreach Program Goals:

- **Physical science summer workshop for elementary school teachers**
  - Provide standards-based content and activities for fourth and fifth grade teachers
  - Give teachers the opportunity to design and present activities
  - Provide ready to use classroom lessons
  - Provide hands-on activities and applications to real world problems and everyday experiences
  - Enable teachers to apply learned skills in their classroom: prepare their students to participate in a chemistry outreach workshop at UCSB
- **Chemistry outreach program for fifth grade students, parents and teachers**
  - Enable students from diverse backgrounds to work with UCSB students who are also from diverse backgrounds
  - Spark new interests in sciences and fuel current interests
  - Show students the relevance of chemistry
  - Engage students, parents and teachers in exciting hands-on activities
  - Enable volunteers to share their enthusiasm for science with young students
  - Inspire students to pursue a higher education in science
  - Show elementary school students the excitement of working in a college setting

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**Alec Wodtke**

**Department of Energy, DE-FG02-03ER15441**

**Electronically Non-Adiabatic Interactions in Molecule Metal-Surface Scattering:  
Can We Trust the Born-Oppenheimer Approximation in Surface Chemistry?**

**08/15/03-12/14/06**

**\$487,510**

**UC Participation: \$15,000**

When molecules with low levels of vibrational excitation collide with metal surfaces, vibrational coupling to electron-hole pairs is not found to be strong unless incidence energies are high. However, there is accumulating evidence that coupling of large amplitude molecular vibration to metallic-electron degrees of freedom can be much stronger even at the lowest accessible incidence energies. As reaching a chemical transition state also involves large amplitude vibrational motion, we pose the basic question: are electronically non-adiabatic couplings important at transition-states of reactions at metal surfaces? We have direct evidence in at least one example that the dynamics and rates of chemical reactions at metal surfaces may be strongly influenced by electronically non-adiabatic coupling. This implies that theoretical approaches relying on the Born-Oppenheimer approximation may not accurately reflect the nature of transition-state traversal in reactions of catalytic importance. Developing a predictive understanding of surface reactivity beyond the Born-Oppenheimer approximation represents one of the most important challenges to current research in chemical dynamics. This research reviews this topic and presents a progress report on our research in this area before describing proposed experiments that will be carried out in collaboration with a theoretical group, Horia Metiu's, on a model system for electronic non-adiabaticity in reactions at metal surfaces. Specifically, we will investigate the interactions of vibrationally excited HCl(v) on Gold. Overtone excitation may be used to populate states up to  $v=4$ , where at the outer turning point electron-transfer from the metal is more energetically favorable than near the molecule's equilibrium bond-length. Electron mediated vibrational energy transfer as well as dissociative adsorption will be studied with state-to state molecular beam methods. With this grant we will work to produce a comprehensive set of data characterizing: vibrational-state-specific survival probabilities, state-to-state vibrational promotion of dissociative adsorption for HCl(v) on Gold. We will compare our data to results of theoretical approaches within as well as beyond the Born-Oppenheimer approximation, allowing us to evaluate the importance of electronically non-adiabatic coupling in this model system. This work promises to be perhaps the best characterized example of electronic non-adiabaticity in surface reactivity.

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**Alec Wodtke**

**Air Force, FA9550-04-1-0057**

**The Chemistry of Cyclic All-Nitrogen Molecules**

**02/15/04-12/31/06**

**\$583,312**

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We report results from the last funding cycle of an AFOSR grant, the most significant of which is the detection of the formation process for the cyclic-N<sub>3</sub> molecule in the UV photodissociation of CIN<sub>3</sub>. This represents an opportunity to pursue fundamental new chemistry for a class of molecules that has been vigorously sought for applications in high energy and density materials. We propose several experiments designed to provide knowledge about the primary photochemical pathways to form this interesting molecule. Specifically, two-color velocity map imaging experiments will reveal the wavelength of the cyclic-N<sub>3</sub> production in CIN<sub>3</sub> and BrN<sub>3</sub> photochemistry. Continuation of an ongoing theoretical collaboration will help to provide a deeper understanding of the molecular dynamics of cyclic-N<sub>3</sub> production. We propose additional experiments to help show how cyclic-N<sub>3</sub> might be detected directly. One approach employs a multiphoton ionization scheme that should be workable even if the lifetime of cyclic-N<sub>3</sub> is as short as 10<sup>-9</sup> seconds. Additional experiments at End-station-1 of Berkeley's Advanced Light Source may provide the first information on the energy dependence of the stability of cyclic-N<sub>3</sub> as well as provide wavelength dependent information on the photoionization of cyclic N<sub>3</sub>. Finally, we will attempt to produce molecular beams of cyclic-N<sub>3</sub>, developing sample preparation protocols of general utility to other researchers using molecular beams technology.

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**Alec Wodtke**

**National Science Foundation, CHE-0454806**

**Hexapole Focusing of Optically-Pumped Molecules: Vibrational Promotion of Electron Emission**

**09/01/05-08/31/06 (08/31/08)**

**\$180,000 (\$420,000)**

In this award, funded by the Experimental Physical Chemistry Program of the Chemistry Division, Prof. Alec M. Wodtke and his post-doctoral and graduate research students will investigate electron ejection from metal surfaces when they are bombarded with vibrationally excited molecules. The goal of these experiments is to develop a better understanding of the ways in which molecules and surfaces interact. The work may help scientists to develop better models for heterogeneous catalysis - an industrially and economically important process. Besides the broader scientific impacts of the proposed studies, the young scientists working on this project will gain expertise in a number of sophisticated scientific techniques, including laser spectroscopy, ultrahigh vacuum and molecular beam methods.

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**Alec Wodtke**

**Steven Buratto**

**Horia Metiu**

**Martin Moskovits**

**Susannah Scott**

**National Science Foundation, OISE-0530268**

**PIRE: Partnership for International Research and Education for Electron  
Chemistry and Catalysis at Interfaces**

**10/01/05-09/30/06 (09/30/10)**

**\$499,257 (\$2,499,257)**

This award establishes a long-term Partnership for International Research and Education for Electron Chemistry and Catalysis at Interfaces (PIRE-ECCI) between the University of California Santa Barbara (UCSB) and the Dalian Institute for Chemical Physics (DICP) in Dalian, China. The focus area for research is modern heterogeneous catalysis with a multidisciplinary approach that seeks to increase contacts between the fields of surface science, catalysis and chemical dynamics at interfaces, thus striving for a "first principles understanding" of technologically important catalytic systems. Members of the team represent diverse scientific viewpoints, from surface chemical dynamics, to theoretical simulations of surface chemistry, to engineering applications of catalysis. A major part of the research and education plan involves support for graduate students and postdocs at UCSB and DICP to pursue collaborative research in chemistry. Extended research visits will include Chinese language and cultural sensitivity training for UCSB participants, with similar reciprocal support given to the Chinese participants coming to UCSB. Two summer schools on catalysis will be held at UCSB and a biannual scientific workshop will be held in Dalian. Special educational opportunities concerning the issues of technology transfer in international high-tech business will be organized and provided by the UCSB Technology Management Program. The Partnerships for International Research and Education Program seeks to create new international collaborations through long-term, large-scale projects that contribute to the development of a diverse, globally-educated U.S. science and engineering workforce. The program is a major initiative in the NSF Office of International Science and Engineering.

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