

RESEARCH PROGRAM
Science and Engineering Abstracts
for Grants Awarded in June 2018

Arizona State University

Tempe, AZ

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\$1,000,000

June 2018

The focus of the research project is the creation, characterization, and application of molecules and materials consisting of charge-stabilized carbon chains. There has been lively disagreement for over a century as to whether the simplest carbon allotrope, carbyne, a linear chain of *sp*-hybridized carbon, occurs in the condensed state. Based on recent experimental and theoretical reports, we hypothesized that a new class of molecules and materials related to carbyne, called pseudocarbynes, exists. They consist of carbon chains stabilized by small metal clusters along and adjacent to the length of the chain. They are expected to have important chemical, optical, and magnetic properties that arise from synergistic interactions between the carbon chain and metal clusters. The project consists of integrated experimental and theoretical research to: 1) define the variety of pseudocarbynes that can be produced; 2) determine their formation mechanisms; and 3) characterize the synergistic metal-carbon interactions of pseudocarbynes and define their connections to chemical, electrical, optical, and physical properties. The last goal will include evaluating pseudocarbynes as reagents and catalysts for driving chemical reactions. The new class of carbon-rich molecules and materials represented by pseudocarbynes has the potential of opening an unexplored realm of chemistry, with all its interesting applications and implications.

Colorado State University

Fort Collins, CO

Kristen Buchanan, Mario Marconi, Carmen Menoni, Jorge Rocca

\$1,000,000

June 2018

Today's electronic devices still rely primarily on electrical charges to transmit signals. As device sizes continue to shrink further into the nanoscale we are approaching the limits of what can be done using conventional approaches. The spin of an electron offers a potential way past this scientific and design barrier. Spin can be exploited simply by using it as an additional degree of freedom in a flowing electrical current. But, even more revolutionary ideas are possible if we broaden the idea of spin transmission to include the transmission of signals using waves in a magnetic material that are known as spin waves or magnons. Spin waves can travel through metals and insulators, and because there are many different ways to manipulate spin waves – local magnetic fields, spin orbit torques, anisotropies, spin textures, exchange bias, heat, and more – truly new paradigms for information transmission and processing are possible. Magnon-based devices can also provide information transfer with no Joule heating and hence will enable breakthroughs in energy-efficiency. To achieve this potential, new experiments are needed to test and refine ideas at nanometer length scales. The Colorado State University team will investigate vital scientific questions surrounding the generation and channeling of spin waves at nanoscale wavelengths, and they will construct novel imaging instrumentation using a soft X-ray laser. If successful, these advances will create a new paradigm for computing at the nanoscale and take the field of magnetics research in a promising new direction.

University of Hawai'i at Mānoa

Honolulu, HI

Margaret McFall-Ngai, Anthony Amend, Nicole Hynson, Camilo Mora, Craig Nelson, Joanne Yew

\$1,000,000

June 2018

The discovery of the vast impact of the microbial world represents the greatest change in our view of the form and function of the biosphere since Darwin developed his theory of evolution. This technology-enabled revolution has thus far focused principally upon defining circumscribed microbiomes, such as those of the human body. However, all microbiomes are nested within a broader environmental context and rely on the interactions among the components for health of the whole. These abundant and diverse microbes represent a nearly untapped natural resource whose potential contributions to health, food production, and habitat restoration constitute the next great opportunity for biological sciences. This project will address fundamental gaps in our basic understanding of environmental microbial communities with the goal of defining the compositions and functions that support healthy hosts and environments. Taking advantage of the highly diverse, yet compact landscape of Hawai'i's habitats, this program will explore the

microbiome dynamics of an entire mountain-to-sea watershed. The team of researchers from the University of Hawai'i at Mānoa will use a multidisciplinary strategy that integrates field observation, laboratory experimentation, and mathematical modeling, which will ultimately lead to future work in defining and engineering critical biotic and abiotic features that foster ecosystem microbiomes contributing to human and environmental health. The efforts of the team will focus on establishing the Keck Environmental Microbiome Observatory (KEMO), the first comprehensive view of natural interdependent microbiomes to be developed by the biology community. The long-term goal is to use tractable Hawaiian environments as models for large-scale ecosystems worldwide.

University of San Diego

San Diego, CA

Rae M. Robertson-Anderson, Moumita Das, Jennifer L. Ross, Michael J. Rust

\$1,000,000

June 2018

An interdisciplinary team of researchers from the University of San Diego, the University of Massachusetts-Amherst, the University of Chicago, and the Rochester Institute of Technology proposes to create a revolutionary class of autonomous materials that can harness energy-driven, biological ratchets to perform user-defined motion and work. The frontier of materials research is to engineer “intelligent” materials that can sense, decide, and move to create active work. While biology has already engineered such autonomous systems by using cascading chemical reactions and energy-utilizing molecular components, humans currently have no capability to build similar non-equilibrium, multi-component systems. The team will take a unique route to addressing this need: the programmed coupling of biopolymer networks derived from the cytoskeleton with the robust timekeeping of circadian oscillator proteins to create biomaterials that can rhythmically alter their mechanical properties. Guided by predictive mathematical modeling, the team will engineer a suite of tunable materials that can autonomously stiffen and soften through rhythmic crosslinking. Beyond the practical goal of creating a new platform of smart biomaterials, this work will elucidate the fundamental principles underlying dynamically self-regulating biomolecular networks. By fusing the information processing and signaling capabilities of circadian clocks with the mechanical tunability and versatility of the cytoskeleton, this revolutionary approach to materials engineering has the potential to create an entirely new class of autonomously active materials that can not only intelligently respond to external signals, but also anticipate future demands.

Washington State University
Pullman, WA
David Y. Lee
\$700,000
June 2018

A young investigator at Washington State University will develop a novel experimental approach to isolate and identify short-lived intermediate species in fundamental chemical reactions. The game-changing idea is to directly transpose the reaction environment from gas phase to an inert and cold surface while preserving the free-molecule chemical structures and unperturbed energy states of all the reactants, intermediates, and products. This is, in principle, made possible via precise alignment of a scanning tunneling microscope with a molecular beam and a tunable laser beam, so that the reactants can be excited to dissociate into selective product channels on surface while the entire reaction process is being monitored by the STM. The cold and inert surface will effectively absorb all the translational, vibrational, and rotational energies of the intermediates and extend their lifetimes for high-resolution imaging. As a proof-of-concept study, the roaming CH_3 radicals from UV photodissociation of acetaldehyde (CH_3CHO) will be experimentally isolated and observed using this new method. The foundational knowledge gained here, including the necessary instrumentation and detailed operation procedures, will allow future scientists to provide solid experimental evidence about reaction mechanisms and, in turn, to better shape modern theoretical models.

Woods Hole Oceanographic Institution
Tempe, AZ
Ying-Tsong Lin, Daniel P. Zitterbart, Paul Matthias, John N. Kemp
\$1,000,000
June 2018

Sound is one of the most efficient tools available for exploring the ocean's opaque interior, and many oceanographic advances have been made possible with underwater acoustic technologies. The team will develop a new scientific instrument which will push the frontiers of ocean science. It is a real-time 3D "acoustic telescope" formed by six phased hydrophone arrays capable of directionally isolating acoustic sources and equipped with a satellite communication system for real-time data transmission. This instrument will enable a variety of remote deep-water explorations by listening to ambient sound generated by biological, geophysical, and meteorological events, as well as oceanographic and anthropogenic processes and activities. The scientific goal is to provide a more complete, even holistic understanding of oceanic environmental processes by integrating underwater soundscape parameters with other oceanographic and meteorological measurements. This first-of-its-kind instrument will lead to an unprecedented integrated acoustic view of the ocean by resolving sound source 3D positions

to increase the breadth of data rather than only detecting their presence. The potential transformative impacts include enabling (1) the imaging of diversified soundscape observations (basin-scale ocean acoustic holography), (2) inference of marine life environments and interactions (soundscape ecology), and (3) remote acoustic sensing of oceanographic, geological, and seismological processes. Technical challenges include the development of: (1) acoustic data and information processing for high-volume and high-speed data telemetry; (2) acoustic feature recognition; and, (3) robust mooring engineering design and operations for minimal mechanical vibration noise.