NEW GRANTS

Development of an Agile Free-Electron-Laser-Powered Pulsed Electron Magnetic Resonance Spectrometer

Mark Sherwin (PHY), Raphaële Clément (MAT), Songi Han (ChemE, Chem) — NSF, $2.16 million, 3 years:

High-field electron magnetic resonance (EMR) is needed to achieve breakthroughs in disciplines ranging from biology to quantum information science. Magnetic resonance imaging (MRI) spectrometers deployed in hospitals use powerful pulses of electromagnetic radiation at frequencies well below 1 GHz to excite and detect the magnetic moments of protons in large magnetic fields. Because the magnetic moments of electrons are nearly 700 times larger than those of protons, high-field EMR spectrometers require powerful pulses of electromagnetic radiation having frequencies above 100 GHz. Generating such pulses is extremely difficult; as a result, the capabilities of high-field EMR spectrometers lag far behind those of MRI and other nuclear MR spectrometers. Researchers will build an agile free-electron-laser-powered EMR spectrometer designed to enable unprecedented studies of the basic properties of materials seen as candidates for new classes of quantum sensors; fast, energy-efficient alternatives to electronics; and exotic quantum mechanical states of matter.

During the 2020-'21 academic year, the College of Engineering had: **324** ***proposals awarded***

Rheology-enhanced Chemo-Catalytic Upcycling of Polyolefins

Rachel Segalman (ChemE), Mahdi Abu-Omar (ChemE, Chem), Songi Han (ChemE, Chem), Susannah Scott (ChemE, Chem) — Dept. of Energy, (up to) $2.5 million, 3 years

The world faces an enormous plastic-pollution problem, which recycling cannot solve. In this project, the researchers seek to use shear forces in novel ways to facilitate breaking carbon-carbon and carbon-hydrogen bonds in long, complex polymeric molecules, making it possible to upcycle the carbon-based molecules (rather than simply recycling the same polymers) which can be used as feedstock for new polymers. Developing a successful technique would be an important step in addressing the plastic-pollution problem.

Mitigation of Clogging in Drip-Irrigation Emitters: A Hydrodynamic Approach

Alban Sauret (ME) — US-Israel Binational Agricultural Research and Development Fund (BARD), $309,000, 3 years

Drip irrigation supports sustainable agriculture by reducing water consumption by up to 70 percent and reducing water scarcity, which is expected to affect nearly six billion people worldwide by 2050. Clogging, however, whether by contaminants such as grit or by biofilms growing within the emitter, reduces drip-irrigation efficiency, and clog mitigation adds complexity and cost to irrigation systems. Further, long-term use of herbicides to hinder biological clogging raises environmental concerns. Sauret and colleagues will use advanced in-situ imaging techniques to understand how clogging occurs in the emitter, and then take a hydrodynamic approach to developing and prototyping new geometries for clog-resistant drip emitters.

At any moment, hundreds of research projects are under way at UC Santa Barbara, while many dozens more are receiving funding or ramping up. Here are some of the many newly funded projects in the College of Engineering.

Integration Large: Democratizing Networking Research in the Era of AI/ML

Arpit Gupta (CS), Elizabeth Belding (CS), Trinabh Gupta (CS) — NSF, $1 million, 2 years

Emerging "self-driving networks" enable administrators of campus networks to automate most network-management tasks, ensuring reliable performance amid disruptions and requiring minimal interventions from network administrators. However, making significant contributions to a self-driving network requires developing tools based on artificial intelligence and machine learning and demonstrating that they work in practice. Unfortunately, in contrast to their counterparts in industry, most academic researchers have neither access to the proper data for developing learning-based tools nor properly instrumented testbeds for road-testing the resulting tools in realistic settings. Researchers in this project will investigate how to use campus networks to overcome barriers to self-driving network research. The project promises to be transformative not only for the network community as a whole but also for a range of campus-network stakeholders.

$91.7 M

awarded in total to the COE during the 2020-'21 academic year

Scalable and Quantitative Verification for Neural Network Analysis and Design

Tevfik Bultan (CS), Yufei Ding (CS) — NSF, $750,000, 4 years

Neural Networks (NNs) have been applied successfully in many areas, including computer vision, speech recognition, and natural language processing. However, the increasing adoption of NNs in safety-critical and socially sensitive domains, such as self-driving cars, robotics, computer security, criminal justice, and medical diagnosis, gives rise to a pressing need for verification techniques that can guarantee the dependability and safety of NN applications. The team intends to develop a holistic formal-verification framework that will provide a systematic and principled approach for developing dependable and safe NNs.

New End-to-End System for a Practical and Accessible Internet of Things (IoT)

Chandra Krintz (CS), Giovanni Vigna (CS), Rich Wolski (CS) — NSF, $1.2 million, 3 years

The project is aimed at determining how to securely program, deploy, and manage IoT systems and applications, making it possible to perform advanced data analysis in place and, therefore, to enhance human decision-making; detect, diagnose, and remediate problems without human intervention; and automate operations throughout our economy. The researchers will develop a portable, multi-tier (sensors, edge, cloud) platform, called Detroit, that supports "write-once-run-anywhere" programming for IoT devices and is aimed at democratizing key processes in order to realize the positive societal transformation and shared economic impact that the IoT promises.

Wicking in Gel-coated Tubes

Emilie Dressaire (ME) — NSF, $646,875, 3 years

Surfactant replacement therapies rely on plugs of liquid to carry drugs into the lungs to treat respiratory distress syndrome. The administered liquid plugs travel through airways lined with mucus, a gel that traps inhaled contaminants. The deposition of liquid in the airways is often held responsible for therapeutic failures, yet the influence of the mucus lining on drug delivery is not yet understood. Experiments will be conducted onboard the International Space Station and on Earth to establish the role of a gel lining in the transport of a liquid plug. The team will examine and explain how the gel's mechanical properties affect the liquid delivery in gravity and microgravity conditions. The aim of the project is to develop a comprehensive understanding of free and forced liquid imbibition through gel-coated tubes.

Largest sponsors of awards received by COE faculty in 2020-'21:

$20.7 M Department of Defense

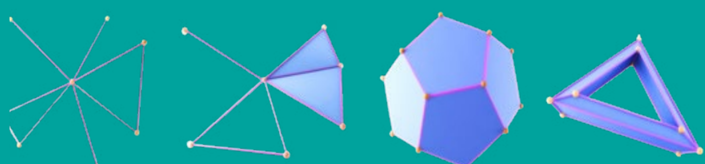
$18.5 M National Science Foundation

$11.3 M Department of Energy

Symmetry-Guided Machine Learning for the Discovery of Topological Phononic Materials

Susanne Stemmer (MAT), Bolin Liao (ME) — NSF, $1.04 million, 4 years

Fundamental understanding and control of heat-conduction processes in materials are important for energy infrastructure, electronic devices, and renewable-energy generation systems. The researchers will focus on a novel property of phonons — vibrations of atoms that carry heat in materials, in a process called *topology* — which may allow new phenomena, including more efficient transport of heat waves on material surfaces. The research team will search for materials hosting these special heat carriers, synthesize and characterize candidate materials, and use the results to refine the search algorithm. A public database of materials will be created. This research will not only advance the fundamental understanding of how topology affects heat conduction in real materials, but also provide new routes to realizing unusual functionalities, such as heat conductors that can be switched on and off.



Examples of cell complexes, courtesy of collaborator Mustafa Hajij, an assistant professor of mathematics and computer science at Santa Clara University.

A Unifying Deep Learning Framework Using Cell Complex Neural Networks

Nina Miolane (ECE) — NSF, $334,780, 3 years

Deep learning has fostered the development of many new transformative technologies that originated with rapid advancements in the fields of computer vision and natural language processing, that is, the processing of images and texts. Yet, a wide range of data is not best represented by a grid of pixels or a sequence of words. For example, (biomolecular) shapes and (social) networks are data types exhibiting local and global geometric properties that might not be efficiently leveraged by existing deep-learning architectures. Hence, there is a need to rigorously understand and expand the data types to which deep-learning methods can be applied. This research project considers the more abstract "cell complex" data type, and is aimed at quantifying the potential of "cell complex networks" in deep learning. Applications range from computational biology and medicine, social science, and art, to a better understanding of deep learning itself. Miolane will collaborate with Mustafa Hajij, an assistant professor of mathematics and computer science at Santa Clara University.

Development of an Ultrafast, Ultrasensitive, High-resolution Direct Electron Detector for Next-Generation Electron Back-scattered Diffraction of Metallic and Beam-sensitive Materials

Daniel Gionola (MAT), Michael Chabinyc (MAT), Tresa Pollock (MAT), B. S. Manjunath (ECE), Raphaële Clément (MAT) — NSF, $578,000, 2 years

Electron back-scattered diffraction (EBSD) is a powerful, widely used characterization technique for mapping and analyzing phases in materials. The advent of direct electron detection, which circumvents inefficient conversion between electrons and photons, has revolutionized the field of transmission electron microscopy, but its use in scanning electron microscopes (SEMs) is in its infancy. In this project, researchers will develop an ultrafast, ultrasensitive direct electron EBSD instrument for the widely accessible SEM platform, providing a rich opportunity for materials research currently hindered by electron beam damage and temporal limitations of detectors. The development project improves on the state-of-the-art EBSD acquisition speed and enhances sensitivity through a new sensor design, unlocking the most vexing challenges in the rapid 3D characterization of additively manufactured materials and emerging dose-sensitive materials.

The researchers plan to develop a new direct electron sensor design to address the key challenges faced when using present-day instruments, like the one shown here.

Direct-force Measurements and Analysis of Intrinsically Disordered Proteins

Omar Saleh (MAT) — NSF, $835,000, 4 years

A major goal of this project is to find the key molecular-scale features that control the behavior of disordered proteins, a class of proteins found in all living organisms and named for their unique trait of being both dynamic and floppy. Saleh and his collaborators in Israel will investigate the overall incidence of these anomalous effects across biologically occurring disordered proteins, and study the molecular determinants that cause the behavior. The research has the potential to broadly impact our basic understanding of the molecular processes of life, while also disseminating a specialized experimental technique that is expected to have wide utility in the quantitative study of biological molecules.

Living Biotic-Abiotic Materials with Temporally Programmable Actuation

Megan Valentine (ME) — NSF, $360,000, 4 years

A team of five comprising physicists, biologists, and engineers intends to design and create a new class of self-directed, programmable, reconfigurable materials inspired by cells and capable of producing force and motion. Their approach will capitalize on two important design principles of living organisms, to wit: 1) cells are composite in nature to meet numerous functional demands, and 2) decision-making and timing are achieved through biomolecular circuitry.

This effort will couple synthetic hydrogels to living layers of active polymer composites infused with cellular timing circuits to produce next-generation materials that self-actuate programmable cycles of work and motion. The proof-of-concept design will be a gap-closing micro-actuator that closes upon exposure to light and then autonomously re-opens at times and locations programmed into the embedded cell circuits. The goals in terms of material development, combined with customized high-throughput characterization and publicly shared property-formulation libraries, will empower the broader Materials Genome Initiative community to manufacture and deploy such disruptive materials of the future.