UC SANTA BARBARA

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New Frontiers

With energy demand growing rapidly and fossil-fuel combustion driving climate change, it is increasingly critical that we transform how we generate, supply, transmit, store and use energy. Water is generally required to produce energy, yet purifying water requires energy, making it still more urgent that we find energy-efficient ways to purify water and water-efficient ways to produce energy.

Radical new technologies are needed. Enter the U.S. Department of Energy's (DOE), Energy Frontier Research Center (EFRC) program. Established in 2009, its goal is to establish the scientific foundation for a new U.S. energy economy, one that will decisively enhance U.S. energy security and protect the global environment.

The DOE to date has established 36 EFRCs nationwide, partnerships among universities, national laboratories, nonprofit organizations and for-profit firms, each conducting fundamental research focused on "grand challenges" related to our energy future.

Several scientists affiliated with UC Santa Barbara's California NanoSystems Institute (CNSI) have now joined that effort. Four renewable, four-year UCSB projects are among 42 just approved EFRC proposals that altogether will receive $100 million in funding.

On the water front

The $10.75 million Materials for Water and Energy Systems (M-WET) project is a joint effort between UCSB ($3.9 million) and the project home, the University of Texas, Austin. Rachel Segalman, chair of chemical engineering, is the project associate director and principal investigator on the 10-scientist UCSB team, which brings to the effort deep and broad expertise in polymer research.

Working at the atomic level, the M-WET group will take a materials approach to “design and perfect” revolutionary new forms that can be used as membranes for filtering chemically contaminated water for re-use. The researchers will seek to “master energy and information on the nanoscale to create new technologies having capabilities rivaling those of living things.”

Powering up

The project Synthetic Control Across Length-scales for Advancing Rechargeables (SCALAR) is a collaboration with UCLA. Four researchers from UCSB, including principal investigator Ram Seshadri, a professor of materials and of chemistry, will take a materials approach to discovering the science to enable batteries that are more powerful and energy efficient, and also last longer and charge faster. Total funding for the project is $9.75 million, with UCSB researchers receiving just under $2 million.

Recognizing the limitations of current lithium-ion battery technology and the challenges they present, the SCALAR team will undertake an integrated program to create the enabling science and technology for next-generation electrochemical energy storage.

“Energy storage in batteries has become an increasing concern that can enable numerous future technologies, including those associated with renewable and clean-energy technologies,” said Seshadri, who is also director of the NSF-funded Materials Research Science and Engineering Center (aka, the Materials Research Laboratory) at UCSB. “UCSB has great depth of expertise in this area, and the EFRC is an opportunity to bring together a number of experts to address these important challenges. The UCSB team is particularly happy to combine expertise in soft (polymer) and hard (oxide) materials to improve the performance of lithium ion batteries.”

Controlling quantum coherence

Physicist Ania Bleszynski Jayich is the sole UCSB researcher on the EFRC project Novel Pathways to Quantum Coherence in Materials (CNPQCM), which is based at the Lawrence Berkeley National Laboratory.

A key goal of her part in the $11.75 million endeavor — $540,000 is directed toward her research — is to “dramatically expand our understanding of quantum coherence in solids by building on fundamental materials discoveries,” Jayich said.

Quantum systems, such as atoms, electrons and photons, are unique in their ability to exist in a superposition state — that is, they can be in two places at once. Quantum coherence refers to this fleeting phenomenon, which has no limit to how briefly it may last before dissipating into a classical state in a process called quantum decoherence. Quantum computing, quantum communication and other quantum applications take advantage of the superposition state.

For quantum technologies to be functional, quantum coherence has to exist for at least a few nanoseconds — long enough to perform a logic operation or store information in memory. Enter the “novel pathways” part of this project, which aims to develop new methods for maintaining quantum coherence, addressing the fact that coherence is highly susceptible to environmental factors.

Great minds

Back in the 1970s, Moore’s Law posited a doubling of the number of transistors on an integrated circuit every two years, and a corresponding increase in processing speed. And that has held true for several decades. Now though, experts agree that in the next 15 to 25 years, the cycle will end. With more data available all the time, a new computing paradigm is needed.

Associate Professor Jon Schuller is the sole UCSB researcher on Quantum Materials for Energy-Efficient Neuromorphic Computing (Q-MEEN-C), a project to identify, develop and characterize quantum materials to enable energy-efficient “neuromorphic” computing. A neuromorphic computing architecture would make it possible to solve problems in a way that replicates how the human brain functions. Total funding for the four-year project is $9.75 million, with $200,000 directed at Schuller’s work.

Based at UC San Diego, Q-MEEN-C is meant to establish fundamental research to drive the next information revolution. The grand challenge is to develop a highly energy-efficient and fault-tolerant computational machine “that works like the brain.” The researchers will explore and seek to understand and control the novel physical mechanisms of quantum materials that can enable functionalities necessary to develop a neuromorphic machine.

“By mimicking aspects of the brain and using them in your computer architecture, you can unlock the ability to process energy efficiently, and new materials are the key to that,” said Schuller, an expert in conducting optical spectroscopy of quantum materials and demonstrating their use in reconfigurable devices.

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.