

RESEARCH PROGRAM

Science and Engineering Abstracts for Grants Awarded in June 2020

Kansas State University

Manhattan, KS

Bret Flanders, Chris Orme, Paul Smith

\$1,000,000

June 2020

There is a general need to control and increase reaction rates in biology and chemistry. Instead of using catalysts or applying heat to a reaction vessel, the goal of this project is to demonstrate that stochastic electric fields accelerate the kinetics of chemical and biochemical reactions, particularly those in vesicles. The proposed mechanism for this rate-enhancement is that the fields elevate the kinetic energies of charged species in solution and, thus, amplify their effective temperature relative to the surrounding neutral solvent; consequently, they exhibit faster kinetics. To test the validity of this mechanism, a team from Kansas State University and Lawrence Livermore National Laboratory combine experimental and computational methods to pursue the following objectives: Objective 1 measures and models the temperature and temperature gradients near stochastically driven interfaces, establishing the basic principle of stochastic heating; Objective 2 measures and models the resultant reaction rates, establishing the benefit of this approach; Objective 3 tests whether reaction rates are enhanced at polarized but unwired interfaces; and, Objective 4 combines these concepts to investigate reactions in electrolyte filled spheres where the field is enhanced due to the geometry. The significance of this work is that, if successful, it will provide a means of accelerating reaction kinetics that does not require catalysts, enzymes, or elevated temperatures. Thus, this project broadens the classical Arrhenius picture of barrier crossing processes. Because stochastic heating can work in conjunction with catalysts or hydrothermal reactors, this concept has the potential to be broadly adopted in fundamental interfacial science, biochemistry, synthesis, and catalysis.

Oregon State University

Corvallis, OR

Jonathan Nash, Erin Pettit, Eric Skillingstad, Meagan Wengrove

\$1,000,000

June 2020

Much uncertainty in predicting future sea-level stems from challenges in understanding the physics that controls melt-rates and stability of ice sheets, ice shelves, and tidewater glaciers. One particular area of interest is the melting of the dangerously unstable ice cliffs that form the boundary where marine-terminating glaciers meet the relatively warm ocean. Recent remotely-sensed observations highlight the importance of the problem by uncovering a hundredfold discrepancy between measured and predicted total ice melt at an Alaskan glacier. Importantly, the reasons for this mismatch are unknown: the physics is not well enough understood because measurements at ice-ocean interfaces have never been made.

In this project, Nash, Pettit, Wengrove, and Skillingstad hypothesize that details of the millimeter-scale turbulent dynamics that connect the warm open ocean to the ice face are directly responsible for the increased ice melt through exploding air bubbles; flow-interface feedback; and, sudden, small-scale fracturing. The goal here is to transform our understanding of ice-melt dynamics by making the first direct observations of small-scale turbulence and ice-melt morphology at a real ice-ocean interface. To achieve this, a diverse team of ocean- and glacier-scientists, skilled technical and engineering support staff, and students at Oregon State University will develop an advanced robotic system – the Glacier Ice Lander. This underwater vehicle will be the first ever to land on the face of an actively-calving glacier to make detailed observations of the millimeter-scale processes that control ice melt and glacier stability. Observations will be integrated using high-resolution modeling. By linking the energetics of the small-scale physics to the large-scale glacier melt dynamics, parameterizations of glacier melt will become dynamically consistent and produce more accurate projections of global sea level rise.

University of Texas at Austin

Austin, TX

Eric Anslyn, Ananth Dodabalapur, Praveen Pasupathy

\$1,000,000

June 2020

Sequence-defined polymers (SDPs) for information storage and retrieval are pursued primarily using DNA. While DNA has advantages for these purposes, its foremost disadvantage is the inability to conveniently interface with devices and integrated circuits (ICs). This is challenging for all SDPs, as it requires electronic states that can be both controlled and read by ICs. This multidisciplinary team of researchers believes that such an interface can be developed with their proposed innovation of using electrochemically active polymer side chains. The team is uniquely positioned to design, fabricate, and exploit SDPs with electronics. They will pursue sequence-defined oligourethanes (OUs) embedded in a hybrid synaptic device that functions as a Hebbian synapse enabling neuromorphic networks based on a non-von Neumann computing architecture. The device also enables electronic readout of OUs providing a new method of molecular encoding. Beyond directly interfacing with electronics, the OUs have been designed to be chemically responsive (to artificial neurotransmitters) and emulate favorable features of nucleic acids: 1) a high-yielding synthesis (writing), 2) replication (copying) due to incorporation of tunable orthogonal reversible covalent bonds, 3) sequencing (reading) due to a thermally induced self-immolation process, and 4) information dense due to a base-8 system. The team aims to create the scientific framework and tools for realizing this electronic-molecular information encoding and exchange. If successful, this work will demonstrate that chemically responsive, electrochemically active SDPs can exchange information with ICs, and lay the foundation for the use of SDPs far beyond information storage, i.e. neuromorphic computing, molecular steganography, and possibly cryptography.