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Investigator: Ravi Saraf

Position Title: Professor

Department: Chemical and Biomolecular Engineering

Email: rsaraf2@unl.edu

Phone: (402) 472-8284

Webpage: http://engineering.unl.edu/chme/ravi-saraf/

Artificial Photosynthesis: Mimicking Nature's Electronics in a Physical System for CO2 Fixation by Light

Abstract.

Mimicking photosynthesis is an attractive proposition where generation and (chemical) storage are integrated. The general approach to artificial photosynthesis is to couple one or two light-sensitive electrodes to make a (chemical storage) product. The coupling and the redox reactions on the two electrodes are limited by diffusion of the species between the two electrodes and at the electrode, respectively. As a result, the redox reaction cannot be sustained continuously at high throughput. In nature, the coupling is electronic; and the redox is kinetically controlled to allow continuous reaction. *The goal of this study is to develop a disruptive technology that mimics nature by creating a photosynthesis process in a physical system where the coupling between the electrodes is electronic and the redox reactions are kinetically controlled.*

The central concept of the proposed study is based on an analogy between the network of embedded protein electrodes in the biomembrane for photosynthesis and a monolayer network of one-dimensional Au nanoparticle necklaces. The necklace network architecture is the first example of a conducting array that operates as an electrochemical nanoelectrode to sustain a continuous redox reaction. What makes the architecture unique is the local quantum mechanical single-electron traps (at room temperature) that operate as a transistor to allow isolation of the electrodes in the dark while electronically coupling them to harvest light.

Year 1, the fundamental study will address the nature of enzymes and the array architecture at two levels: (i) design, fabrication, and characterization of the device for CO_2 fixation by light; and (ii) experimental and theoretical investigation to understand the device physics to develop design rules for efficient energy conversion. The fundamental study will be extended to Year 2 with emphasis on the device and its scalability. If successful, the outcome will be a platform technology emulating photosynthesis with electronic coupling.