CALIFORNIA STATE SCIENCE FAIR
2014 PROJECT SUMMARY

Name(s)

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Project Number

S0624

Project Title

Nanoscale Catalyst in Belousov-Zhabotinsky Reaction to Induce Self-Organization of Complex Spatiotemporal Structures

Abstract

Objectives/Goals

Pattern formation in nature has fascinating similarities to reaction-diffusion systems such as the classic oscillatory Belousov-Zhabotinsky (BZ) reaction in which an organic substrate is oxidized by bromate with a catalyst in an acidic environment. In existing approaches, BZ reactions occur globally in a continuous system of reactants and catalyst, oscillate between oxidized and reduced states, and produce spatiotemporal wave patterns. Contrarily, my investigation of a discrete BZ system with nanoparticle-based catalyst unveiled nanoscale-to-macroscale connections. I implemented a new approach to achieve three objectives:

(i) to discretize the BZ system by catalyzing the reaction on the nanoscale and analyze subsequent pattern formation,

(ii) to evaluate the effects of nanoparticle silica content on pattern formation, and

(iii) to determine how the presence of an external magnetic field influences pattern formation.

Methods/Materials

Malonic acid was oxidized by sodium bromate and sodium bromide in sulfuric acid under the influence of the photosensitive BZ catalyst known as ruthenium. I synthesized silica nanoparticles that encapsulated magnetic nanoparticles and ruthenium catalyst. To analyze effects of nanoparticle silica content, I tested varying silica amounts ranging from 1 to 250 mg. To control pattern formation with a magnetic field, I placed the Petri dish containing BZ reactants and nanoparticles in two different settings:

(i) on a hot plate above a magnetic stirrer, and

(ii) above neodymium magnets.

Results

BZ reaction waves propagated and self-organized into spatiotemporal structures on the macroscale. Labyrinthine-like Turing patterns formed and de-formed over time even after repetitive stirring. Greater silica content in nanoparticles increased nanoparticle size and resulting pattern initiation times. Further, a magnetic field guided nanoparticles to create new patterns including stripes and honeycombs.

Conclusions/Discussion

Unlike the traditional continuous system, this discrete system catalyzed the BZ reaction on the nanoscale to produce complex spatiotemporal structures on the macroscale. This linkage between the nanoscale and the macroscale induces self-organization of Turing patterns. My work explored new frontiers in complex pattern formation that enable the BZ reaction to serve as a model for other oscillatory systems.

Summary Statement

By incorporating nanoparticles into this discrete BZ system, I unearthed macroscale spatiotemporal structures that arise from nanoscale initiation sites, and potentially contributed to simulations of analogous oscillating networks.

Help Received

Used lab equipment at University of California, Los Angeles under the supervision of Dr. Chih-Ming Ho.