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Active Emulsions: Synchronization of Chemical Oscillators

SETH FRADEN, Brandeis University

We explore the dynamical behavior of emulsions consisting of nanoliter volume droplets of the oscillatory Belousov-Zhabotinsky (BZ) reaction separated by a continuous oil phase. Some of the aqueous BZ reactants partition into the oil leading to chemical coupling of the drops. We use microfluidics to vary the size, composition and topology of the drops in 1D and 2D. Addition of a light sensitive catalyst to the drops and illumination with a computer projector allows each drop to be individually perturbed. A variety of synchronous regimes are found that systematically vary with the coupling strength and whether coupling is dominated by activatory or inhibitory species. In 1D we observe in- and anti-phase oscillations, stationary Turing patterns in which drops stop oscillating, but form spatially periodic patterns of drops in the oxidized and reduced states, and more complex combinations of stationary and oscillatory drops. In 2D, the attractors are more complex and vary with network topology and coupling strength. For hexagonal lattices as a function of increasing coupling strength we observe right and left handed rotating oscillations, mixed oscillatory and Turing states and finally full Turing states. Reaction – diffusion models based on a simplified description of the BZ chemistry and diffusion of messenger species reproduce a number of the experimental results. For a range of parameters, a simplified phase oscillator model provides an intuitive understanding of the complex synchronization patterns.

"Coupled oscillations in a 1D emulsion of Belousov–Zhabotinsky droplets," Jorge Delgado, Ning Li, Marcin Leda, Hector O. Gonzalez-Ochoa, Seth Fraden and Irving R. Epstein, *Soft Matter*, **7**, 3155 (2011).