Complex Pattern Formation of Simple Biochemical Amplification Reactions in Micro-Structured Flow Reactors

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We have studied the dynamics of a simple amplification reaction in micro-structured flow reactors. The autocatalytic amplification reaction $A + R \longrightarrow 2A$ serves as a model to describe the fundamental properties of amplification systems in an open reaction chamber. A constant inflow of resources R feeds the reaction and an outflow keeps the total mass constant. A characterization of the system in a well stirred reaction chamber is presented by discussing the steady states of the system and their bifurcation properties. In the non-stirred case, where the species diffuse freely in a spatially extended chamber, numerical solutions of a reaction-diffusion equation describe the dynamic behavior of the system. It turns out that inhibition reactions and death terms, which are unavoidable in micro-structured reaction chambers, play an essential role in the behavior of the system. The rich dynamical behavior shows three fundamental properties of non-variational nonlinear open systems: temporal order, such as limit cycle oscillation, spatially periodic order, and complex spatial-temporal pattern formation. The results are of special interest for recent experiments with evolutionary molecular ecosystems in micro-structured flow reactors.

Key words: Biochemistry; Amplification; Diffusion; Nonlinear Systems; Evolutionary Molecular Ecosystems.