Self-sustained periodic oscillations: Reconstructed attractors from experiments at the nanoscale

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Many non-equilibrium reactions take place in very small systems: reactions in living cells, micelles or plasmas. Here we present nonlinear reactions arising at the surface of catalytic nanoparticles. The Field Electron Microscope (FEM) is a technique that makes it possible to image, in real time, a catalytic process occurring at the surface of a single catalytic grain. To do so, the microscope is run as a flow reactor far away from the equilibrium where nonlinear reaction dynamics can lead to the emergence of complex dissipative structures. More specifically, the FEM is based on measurements of the work function and its variation due to compositional changes of the adsorbed layer. The high spatial resolution of the method makes it possible to image reaction events on single nanosized facets of a metal particle conditioned to form a tip. The work function changes translate into a varying brightness which is recorded using video techniques.

In this contribution, we show how the dynamical attractors and the phase space dynamics of such reactive systems can be reconstructed from experimental time series. The specific system investigated here is the NO_2 hydrogenation over a platinum 3D crystallite. Periodic self-sustained oscillations can be linked to a limit cycle. Because of its size, the system is more sensitive to fluctuations, and the limit cycle defines a “stochastic crater” on the slopes of which dynamical trajectories can develop. This underlying structure persists even for very small systems, i.e. for localized areas as small as 7 nm^2.