Anisotropy driven interrupted coarsening in nonlinear quantum dot growth

Aqua Jean-Noël ¹, Frisch Thomas ¹

1. Institut Microélectronique Matériaux Nanosciences de Provence

Anisotropy is known to dictate equilibrium crystal shapes. We investigate its influence on the dynamics of quantum dot growth and show that it can drive an interruption of the Ostwald ripening of the thin film elastic instability. We derive the dots statistical properties and characterize ways to tune order in the self-organization of such nanostructures.

When a film is coherently deposited on a substrate, it undergoes an elastic stress that can be relieved with a morphological instability. We derive a continuum description of surface diffusion including elasticity and anisotropic surface energy that describes the experimentally observed emergence of square-base pyramids. We compute analytically elasticity by treating the film free boundary in the small slope approximation and solve numerically for the nonlinear nonlocal evolution of the film height using large scale simulations. We find that a small anisotropy can originate a complete change in the dynamics. The Ostwald ripening at stake for isotropic films, which allows the minimization of the total energy by surface diffusion, is destroyed by a small anisotropy and the system is glued in a metastable state in accordance with experiments. We characterize the statistical properties of the resulting pyramids and show that their mean volume and density can both increase with the total amount of matter. We find on optimal mean film height for the island size distribution to be narrow. We devise a mean-field model that renders energetic pathways and exhibits the coupling between anisotropy, elasticity and wetting effects necessary to explain the interrupted coarsening.
Lyapunov Spectra and Conjugate-Pairing Rule for Confined Atomic Fluids

Stefano Bernardi $^1$, B. D. Todd $^2$, J. S. Hansen $^3$, Debra J. Searles $^4$, Federico Frascoli $^5$

1, 2. Centre for Molecular Simulation, Swinburne University of Technology, Melbourne, Victoria 3122, Australia, sbernardi@ict.swin.edu.au
3. Glass and Time, IMFUFA, Roskilde University, 4000 Roskilde, Denmark
4. Nanoscale Science and Technology, Centre School of Biomolecular and Physical Sciences, Griffith University, Brisbane, Qld 4111, Australia
5. Brain Sciences Institute, Swinburne University of Technology, Melbourne, Victoria 3122, Australia

The Lyapunov exponents measure the average rate of expansion and/or contraction of two initially nearby phase space trajectories of dynamical systems. They are one of the main tools for the characterization of chaos, providing also a quantitative measure. They have been used extensively to understand the chaotic properties of fluids in Molecular Dynamics (MD) and Non-Equilibrium Molecular Dynamics (NEMD) simulations and have proven to be a particularly useful tool for the characterization and theoretical analysis of systems far from equilibrium in thermostat-ted steady states. Until now the focus was on homogeneous systems in which the equations of motion were modified to include external forces and thermostatting terms and the dissipative character of the dynamics was distributed among all the degrees of freedom.

In this work we characterize Lyapunov spectra for inhomogeneous systems at a nonequilibrium steady state, thus obtaining an insight into what happens along different directions in the phase-space characterized by different dynamics with the use of NEMD. We show detailed results on the effect that real walls have on the Lyapunov spectra, computing the exponents for the phase space of both fluid and wall atoms. We focus the research on two types of flow, Couette and Poiseuille. We show how the spectra reflects the presence of two different dynamics in the simulation cell: wall and fluid atoms are of the same species but the selective application of the thermostatting mechanism on one species only creates two dynamics, one Hamiltonian and one dissipative. Our study also throws considerable light onto why homogeneously thermostatting highly confined fluids is an unsound practice.
Dynamics of self-replicating holes in a vertically vibrated dense suspension

Hiroyuki Ebata 1, Masaki Sano 1

1. Department of Physics, Graduate School of Science, The University of Tokyo, Tokyo, JAPAN

In vertically vibration, surface of complex fluid shows various instabilities, such as faraday wave and oscillon. We find self-replicating holes on the surface of a vertically vibrated potato starch suspension. Above certain acceleration, the finite-amplitude deformation of surface grows to make a hole which penetrates the layer of a suspension. Circular shape of the hole is not stable and it replicates just like self-replicating spots in reaction diffusion systems (K-L Lee et al., Nature, 369, 215 (1994)). It is notable that self-replicating hole is a first example of self-replicating spots in complex fluid systems. It is known that self-replicating spots in gray-scott model show spatiotemporal chaos (STC) in certain parameter. We find that patterns of holes also show STC at a high acceleration because of frequent replication and annihilation of holes. We apply statistical analysis often used in defect-mediated turbulence, and also in STC of gray-scott model (H. Wang et al., PRL, 99, 214102 (2007)). In contrast with STC in gray-scott model, the increase rate of holes is weakly dependent on the number of holes $n$ and the decrease rate of holes become quadratic function of $n$. By using the increase, decrease rates of holes and probabilistic description, the dynamics of the number of holes in steady state can be well explained. The success of probabilistic description implies that the correlation of holes is weak enough. However, power spectrum of the time series of $n$ and radial distribution function indicates some weak and nonstationary structure of holes.
Global avalanches, local clusters and front roughness in planar crack propagation

Lasse Laurson 1, Stephane Santucci 2, Adil Mughal 3, and Stefano Zapperi 1,4

1. ISI Foundation, Torino, Italy
2. ENS Lyon, France
3. Aberystwyth University, UK
4. IENI-CNR, Milano, Italy

We study avalanches in a line model for a slowly driven planar crack front propagating in a disordered medium. Due to the long-range elastic interactions between segments of the crack front, avalanches are formed by a set of spatially disconnected local clusters. The sizes of the clusters are power law distributed, but with an exponent different from the one characterizing the global avalanches. By considering the avalanche break-up process, we derive a scaling relation between the size exponents of the local clusters and global avalanches, which is found to be in agreement with the numerical and experimental values of the exponents. Due to the general nature of our arguments, we expect this scaling relation to be applicable quite generally for systems in which the avalanche dynamics is governed by long-range interactions.

We also consider the morphology of the local clusters and the roughness of the crack front. Above a cross-over length proportional to the Larkin length, the aspect ratio of the local clusters scales with the roughness exponent of the crack front. Furthermore, to understand the experimentally observed short length-scale multiscaling, also an extension of the crack line model is studied, in which the motion of the crack front is taken to be always along the local normal direction, thus leading to the possibility of overhangs in the crack front.
The Belousov-Zhabotinskii reaction is probably the most famous example of an oscillating chemical reaction in the liquid phase. At the nanometer scale, such a chemical clock can also remarkably emerge from the molecular fluctuations. The present presentation overviews our multiscale approach to model such phenomena, where density functional theory (DFT) is used to determine the kinetic constants of our statistical mechanical model.

We demonstrate that field ion microscopy (FIM) experiments along with corresponding DFT calculations strongly indicate that a positive electric field promotes the oxidation of a rhodium field emitter tip. We also show that the nonequilibrium oscillatory nanopatterns, as observed when H₂ and O₂ are exposed on a rhodium field emitter tip, find their origin in the anisotropic catalytic properties of the nanofacets that are simultaneously exposed at the tip's surface. The basis of such conclusions is a kinetic model for hydrogen, oxygen and subsurface oxygen, which takes into account the anisotropy of the surface by expanding the kinetic constants into cubic harmonics suitable for the underlying fcc crystal.

In the case of platinum field emitter tips, the dependence of the decomposition barrier of NO, (NO)₂ and NO₂ on the underlying facet orientation is examined with DFT and compared to experimental results. In particular, the adsorption behavior of NO₂ on Pt(012) in the presence and in the absence of an electric field is undertaken so as to better understand the regular oscillations that are observed when H₂ and NO₂ are exposed to platinum.
The Amplitude Equation for the Rosensweig Instability

Stefan Bohlius \(^1\), Harald Pleiner \(^1\), Helmut R. Brand \(^2\)

1. Max Planck Institute for Polymer Research, Mainz, Germany
2. Department of Physics, University of Bayreuth, Germany

The Rosensweig instability has a special character among the frequently discussed instabilities. One distinct property is the necessary presence of a deformable surface, another very important fact is, that the driving force acts purely via the surface and shows no bulk effect. These properties make it rather difficult to give a correct weakly nonlinear analysis. Here we give a derivation of the appropriate amplitude equation based on the hydrodynamic equations. We stress the fact, that even though the stability is static, the system has to be treated dynamically. The observed static pattern has to be interpreted as the limiting case of a frozen-in characteristic mode.

The amplitude equation finally obtained contains quadratic (for the hexagonal case) and cubic nonlinearities in the amplitudes and the typical first order time derivative describing, above the linear threshold, the growth of the surface spikes or the relaxation to their stationary state. This time scale is proportional to the viscosity, decreasing for increasing surface tension and shear moduli. Additionally, however, we get a second order time derivative in the case of magnetic gels giving rise to an internal frequency proportional to the elastic modulus and depending on the surface tension and the actual amplitude or external field.
Generalized synchrony in stochastic and chaotic dynamics

Ram Ramaswamy
School of Physical Sciences, Jawaharlal Nehru University, New Delhi 110067, INDIA

When one system is driven by another, the state of generalized synchronization is the condition that the response, \( x \), is a unique function of the drive, \( u \), namely \( x = \Phi[u] \). The function \( \Phi \) may be differentiable or not, and furthermore, the dynamics of both the drive and the response may be chaotic or stochastic.

We describe distinct scenarios for generalized synchronization in deterministic as well as stochastic dynamics. For a nonlinear mapping that is driven by an ergodic (baker) mapping, exact results are possible and we show the existence of attracting invariant graphs on which synchronized motion takes place. For stochastic systems we show that a form of phase synchronization arises when stochastic oscillators are driven by noise. Applications are made to specific examples of biological oscillators where we believe such effects are significant in cellular mechanisms for keeping time.
Temporal fluctuations of laminar-turbulent patterns in transitional plane Couette flow

Joran Rolland 1, Paul Manneville 1

1. LadHyX, Palaiseau, France

We investigate the formation of oblique turbulent bands in plane Couette flow using low resolved direct numerical simulations in order to reduce computational load. Provided that the wall normal resolution is larger than some minimum, the qualitative behaviour of the flow appears to be preserved, although the values of bifurcation thresholds are shifted. 1

We show that the pattern formation is well described in terms of Ginzburg-Landau equations for appropriately defined order parameters, which are quantitatively coherent with experimental results. 2 Near $R_t$, the value of the Reynolds number for which the flows becomes uniformly turbulent, the pattern undergoes orientation fluctuations. We show that the distributions of lifetimes of pure states is Poissonian, and that the average lifetime can be predicted using a simple stochastic model with two wells, one for each orientation. 3 Defective patterns in large systems are also investigated.

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Pattern formation in frictional fluids

Bjornar Sandnes ¹,², Henning Arendt Knudsen ², Eirik Grude Flekkoy ², Knut Jorgen Maløy²

1. School of Chemical and Biomolecular Engineering, University of Sydney, Sydney, NSW, Australia
2. Department of Physics, University of Oslo, Oslo, Norway

We observe a remarkable diversity in pattern formation dynamics and displacement structures in a confined granular suspension. The rheology of this “frictional fluid” is governed by the non-linear frictional response as internal stresses are mediated by grain-grain contacts, and as the material rapidly jumps from solid to fluid like behaviour beyond a critical yield stress.

Air is slowly injected into a quasi 2D layer of submerged granular material. The invading front accumulates mass, and becomes unstable due to a competition between frictional, viscous and capillary forces. By controlling the rate, filling fraction and the elasticity of the system, we are able to drive the pattern formation through different modes according to the relative influence of the different forces, resulting in a range of distinct morphologies.

At low rate and high elasticity, the dynamics is highly intermittent, with individual bubbles of air progressing in a stick slip fashion. In an analogue with tribology and the classic sliding block system, we observe a transition from stick slip to steady motion of the front as the rate is increased. By increasing the system stiffness yet another pattern formation phase emerges.

We present a mapping of these novel pattern formation processes onto phase diagrams, and discuss the physical mechanisms responsible for the observed dynamics.
Transient spatiotemporal chaos in reaction-diffusion networks

Renate Wackerbauer, Dan Stahlke

1. Physics Department, University of Alaska, Fairbanks, USA

Complex transient dynamics is reported in various extended systems, including transient turbulence in shear flows, transient spatiotemporal chaos in reaction-diffusion models, and non-chaotic irregular transient dynamics in neural networks. The asymptotic stability is difficult to determine since the transient lifetime typically increases exponentially with the system size. Our studies show that transient spatiotemporal chaos is extensive in three reaction-diffusion systems; the Lyapunov dimension increases linearly with the network size. A master stability analysis provides insight into the asymptotic stability for the Baer-Eiswirth reaction-diffusion network and for the Gray-Scott reaction-diffusion network. The asymptotic state is characterized by negative transverse Lyapunov exponents on the attractor of the invariant synchronization manifold. The average lifetime depends on the number of transverse directions that are unstable along a typical excitation cycle.