Programme :

10h-12h

Chaouqi Misbah (LSP, Grenoble) : "Coarsening versus non coarsening of nonequilibrium surfaces."

Jean-Noël Aqua (ECM, Marseille) : "Nonlinear evolution of a morphological instability in a strained epitaxial film."

Isabelle Berbezier (IM2NP, Marseille) : "Auto-organisation de boîtes quantiques sur substrat de Silicium nanostructuré."

14h-16h

Dimitri D. Vvedensky (Imperial College, London) : "Continuum equation for self-organization during semiconductor heteroepitaxy."

Jérome Colin (LMP, Poitiers) : "Non-linear elastic effects on the morphological evolution and plasticity of stressed multi-layers and solids."

Rodolfo Cuerno (GISC, Madrid) : "Universal non-equilibrium phenomena at submicrometric surfaces and interfaces."

16h30-18h

Olivier Pierre-Louis (Oxford et LSP, Grenoble) : "Adhésion des membranes et filaments sur les surfaces patternées."

Vincent Repain (MPQ, Univ. Paris Diderot) : "Croissance organisée de nanostructures."

Alberto Pimpinelli (Université Clermont-2) : TBA

Chaouqi Misbah

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Coarsening versus non coarsening of nonequilibrium surfaces.

Several nonequilibrium systems exhibit patterns characterized by a lengthscale. The lengthscale may be fixed in time (at least its average over time, or in the statistical sense). It may alternatively, perpetually increase in time (typically as a power law). The perpetual increase of the lengthscale is a process which is called coarsening. An intermediate stage may occur : interrupted coarsening. We present a class of nonlinear equations that exhibit these three typical scenarios (no coarsening, coarsening, or interrupted coarsening). We provide

a simple criterion on which scenario prevails by just inspecting the portrait of *steady-state solutions*. This is made possible thanks to the extraction of analytical results based on phase diffusion equation of the pattern. We further provide a straightforward manner to evaluate the coarsening exponent by using information from phase diffusion. We exemplify the method on typical examples. We discuss how these results, which are obtained in one dimension, can be generalized to higher dimensions.

[1] P. Politi and C. Misbah, *When does coarsening occur in the dynamics of one-dimensional fronts?* Phys. Rev. Lett. 92, 090601 (2004).

[2] G. Danker, O. Pierre-Louis, K. Kassner and C. Misbah, *Peculiar effects of anisotropic diffusion on dynamics of vicinal surfaces*, Phys. Rev. Lett. 93, 185504 (2004).

[3] Paolo Politi and Chaouqi Misbah, *Nonlinear dynamics in one dimension: A criterion for coarsening and its temporal law* , Phys. Rev. E 73, 036133 (2006).

[4] J. Chang, O. Pierre-Louis, and C. Misbah, *Birth and Morphological Evolution of Step Bunches under Electromigration* Phys. Rev. Lett. 96, 195901 (2006).

[5] Paolo Politi and Chaouqi Misbah, *Modified Kuramoto-Sivashinsky equation: Stability of stationary solutions and the consequent dynamics*, Phys. Rev. E 75, 027202 (2007).

Jean-Noël Aqua*, Thomas Frisch, Alberto Verga

(ECM, IM2NP, Marseille)

Nonlinear evolution of a morphological instability in a strained epitaxial film.

A strained thin solid film deposited on a deformable substrate undergoes a morphological instability (the so-called Asaro-Tiller-Grinfeld instability) relaxing the elastic energy by surface transport. We study a dislocation free film coherently deposited on a substrate with a slightly different lattice parameter, which evolves through surface diffusion. When the film is infinitely thick or when the substrate is infinitely rigid, different approaches revealed finite-time blow-up solutions of the ATG instability which account well for experiments in thick enough films. However, these crack solutions do not describe experiments of thin films in the Stranski-Krastanov type of growth where instead, coarsening was measured.

It has been proposed that wetting interactions could regularize the evolution of such systems. We derived nonlinear and nonlocal equations which describe the dynamics of a thin film on a deformable substrate with a priori different

elastic properties and accostrongunt for wetting effects. When both nonlinear and wetting interactions are present, numerical simulations reveal a steady evolution. When the film initial height is heigher than some critical value given by wetting effects, the surface evolves towards an array of islands separated by a wetting layer. The final stage is then an isolated island with a chemical potential monotonously decreasing with its volume. Consistently, the system undergoes a non-interrupted coarsening characterized by a power-law decrease of the island number with time which depends noticeably on dimensionality.

J.-N. Aqua, T. Frisch, A. Verga, Phys. Rev. B., vol. 76, p.165319 (2007).

Isabelle Berbezier*, Antoine Ronda

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Auto-organisation de boîtes quantiques sur substrat de Silicium nanostructuré.

Le but de nos études est de comprendre, fabriquer et auto-assembler des nanostructures semiconductrices dont l'amélioration des propriétés physiques devrait permettre une augmentation de la fiabilité et des caractéristiques des objets technologiques dans lesquels elles seront utilisées. L'étude présentée ici vise pour application la fabrication de mémoires non volatiles à grille flottante en nanocristaux (NC) auto-assemblés sur des substrats de Silicium nano-structurés. Les principaux avantages de ce type de mémoire sont l'insensibilité aux fuites locales, une faible consommation et une meilleure endurance, des vitesses d'opérations plus rapides, la compatibilité avec la technologie CMOS et la possibilité de réduction ultime des taille des composants.

Dans ce contexte applicatif, nous avons développé deux procédés de réalisation NC qui s'appuient sur une première étape de nanostructuration du substrat de Si, suivie par une deuxième étape d'auto-organisation des NC sur les motifs [1]. Ces procédés visent à éliminer les problèmes observés généralement lorsque les NC sont déposés de façon aléatoire sur des substrats pleine plaque (distances entre les NC et tailles des NC inhomogènes, chargement des NC non reproductible).

La première partie concernera les différents procédés et mécanismes de nanostructuration des substrats en utilisant d'une part les mécanismes de croissance et d'autre part un procédé technologique tel que la gravure par faisceau d'ions focalisés de Ga+ [2].

La deuxième partie concernera les mécanismes d'auto-organisation des NC sur des substrats soit de Si soit de SiO2 nanostructurés. Le rôle des motifs sur la

mise en ordre des NC dans les différents cas sera mis en évidence [3] et en particulier l'influence de la contrainte, de la diffusion de surface et de l'énergie de surface sur cette mise en ordre. L'influence respective de ces différents paramètres explique par exemple la position des NC par rapport aux motifs: la contrainte induit une germination préférentielle des NC sur les parties convexes du substrat proches des trous alors que la diffusion de surface et l'énergie de surface induisent une germination préférentielle des NC dans les trous [4].

Finalement, je présenterai très brièvement le procédé complet de fabrication de la mémoire (qui s'appuie sur la nanolithographie par FIB d'une couche d'oxyde tunnel et l'auto-organisation des NC de Ge dans les nano-motifs FIB) [5] ainsi que les caractéristiques des capacités et des transistors obtenus ainsi que l'influence capitale de la taille des NC sur leurs propriétés de confinement quantique et de blocage de Coulomb [6].

[1] Ge Dots Organization on FIB Patterned Substrates, A. Karmous, A. Cuenat, A. Ronda, I. Berbezier , S. Atha, R. Hull, Appl. Phys. Lett. 85 (2004).

[2] Self-assembly and ordering mechanisms of Ge islands on Pre-Patterned Si(001), A. Pascale, I. Berbezier, A. Ronda, P.C. Kelires, PRB 2008, in print.

[3] Self-assembling of Ge dots on nanopatterns: Experimental investigation of their formation, evolution and control, I. Berbezier, A. Ronda, Phys. Rev. B 75 (2007) No. 195407.

[4] Formation and ordering of Ge nanocrystals on SiO2, A. Karmous, I. Berbezier, A. Ronda, Phys Rev. B 73 (2006) 075323.

[5] Ge quantum dot memory structure with laterally ordered highly dense arrays of Ge dots, A.G. Nassiopoulou, A. Olzierski, E. Tsoi, I. Berbezier, A. Karmous, J Nanosci Nanotechnol 7 (2007) 316.

[6] Memory and Coulomb blockade effects in germanium nanocrystals embedded in amorphous silicon on silicon dioxide, K. Gacem, A. El Hdiy, M. Troyon, I. Berbezier, P.D. Szkutnik, A. Karmous, A. Ronda, J. of Appl. Phys. 102 (2007) 093704.

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Continuum equation for self-organization during semiconductor heteroepitaxy.

Self-organization in strained heteroepitaxial systems has been the subject of many theoretical studies, including kinetic Monte Carlo (KMC) simulations, molecular dynamics and continuum theories. One of the "grand challenges" for computational materials science is the synthesis of such diverse descriptions into a multiscale theory of morphological evolution. However, despite the immense practical importance of heteroepitaxial nanostructures, general methodologies for thin film evolution in the presence of lattice misfit have been slow to develop. The main reason for this is that the rates of atomistic processes on strained surfaces are not determined solely by the local environment, as in the case of homoepitaxy, but depend on nonlocal factors such as the height above the substrate and lateral extent of a terrace, and the presence of neighboring islands. These effects are manifestations of long-range elastic interactions, which find a natural expression within a continuum framework. We have derived a stochastic differential equation for the morphological evolution of heteroepitaxial surfaces from an atomistic model for coherent three-dimensional (3D) island formation. Our approach is based on transforming the Chapman-Kolmogorov equation, which is the formal expression of KMC simulations, with discrete events at discrete times, into an exact lattice Langevin equation. We then systematically regularize the transition rules to obtain a Langevin equation for continuous space and time.

Our method produces an equation similar to that obtained by Golovin et al. [2] from classical elasticity. But there are crucial differences between our equation and this earlier work. Most important is that the coefficients in our Langevin equation have a direct relation to the underlying atomistic processes. Since the transition rates of these processes can be calculated with density functional methods, we have the basis for a genuine multiscale description of heteroepitaxial morphological evolution. Another important difference is the presence of noise terms that reflect the randomness of the deposition and diffusion processes. These are central for the quantitative description of the morphological evolution observed in experiments. On the other hand, Golovin et al. explicitly include the effect of a wetting layer in their formulation. This issue remains for further investigation.

Jérome Colin

(LMP, Poitiers)

Non-linear elastic effects on the morphological evolution and plasticity of stressed multi-layers and solids.

The emergence of nanostructures in stressed multilayers is first investigated considering the non-linear amplitude expansion of shape fluctuations emerging at the interfaces of a buried layer embedded in a matrix. A criterion simply

expressed in terms of the relative elastic hardness of the solids is proposed and the possibility of design of nano-structures is discussed.

In the general framework of non-linear elasticity, a plasticity effect recently observed in alloys at room temperature, i.e. the gliding instability of dislocations near axi-symmetrical precipitates has been explained by means of static atomistic simulations. It is demonstrated that the non-linear interaction usually neglected between three sources of strain identified as the dislocations, the external applied strain and the precipitates is responsible for the unusual localized cross-slip of the dislocations from the {111} to {100} planes in zone with the axis of the precipitates. It is believed that the third order interaction emphasized here plays a key role in many other problems of plasticity such as creep under irradiation or dislocation nucleation.

Rodolfo Cuerno

(GISC, Madrid)

Universal non-equilibrium phenomena at submicrometric surfaces and interfaces.

The recent widespread interest in processes occurring at micro and nanometric scales has increased the physical relevance of the surfaces and interfaces constituting system boundaries, both at and far from equilibrium. In the latter case, universal properties occur, such as scale invariance (surface kinetic roughening), surface pattern formation or domain coarsening. However, descriptions of these systems feature limited predictive power when based merely on universality principles. We review examples from Materials Science at nano and submicrometric scales, that underlie the importance of describing growing surfaces by means of (phenomenological) constitutive laws, in order to correctly describe the rich behaviors experimentally found across many different systems. Additionally, this approach provides new generic models that are also of interest in the wider contexts of Pattern Formation and Non-Linear Science.

Olivier Pierre-Louis

(Oxford et LSP, Grenoble)

Adhésion des membranes et filaments sur les surfaces patternées

L'adhésion d'un filament ou d'une membrane sur un surface patternée est étudiée dans le cadre d'un modèle simple. Dans le cas d'un pattern en tapis de fakir, il

apparait une serie infinie de transitions, menant a finalement a un décollement complet. Par contre, si le profil de la surface est sinusoidal, des transitions plus simples sont observées. Nous discuterons de la pertinence de ces resultats, pour plusieurs systèmes: graphène/SiO2, membranes lipidiques, et nanotubes de carbone.

Vincent Repain

(MPQ, Univ. Paris Diderot)

Croissance organisée de nanostructures

La réalisation de nanostructures supportées sur une surface est un préalable à l'étude de leurs propriétés nouvelles en optique, magnétisme, catalyse, transport électronique . L'auto-organisation des surfaces cristallines, phénomène naturel qui permet d'obtenir des structurations à l'échelle nanométrique, peut être mise à profit pour réaliser une croissance organisée de diverses nanostructures. Parmi ces surfaces, les surfaces vicinales sont des gabarits particulièrement réguliers, dû à leur faible symétrie. Je montrerai que l'étude par microscopie à effet tunnel de la croissance de nanostructures magnétiques (Fe, Co, Fe-Pt) sur des surfaces vicinales d'or permet effectivement d'obtenir des structures uniformes et régulières dans une certaine gamme de paramètres du dépôt (flux, température). Cette croissance organisée s'interprète bien à l'aide d'équations d'évolution des espèces diffusantes, traité en champ moyen. Des simulations par Monte-Carlo cinétique permettent de compléter la compréhension de certains mécanismes et d'obtenir des informations sur la distribution de taille des nanostructures dans ces systèmes.
