Lecture 2: Wetting and dewetting of solids and liquids

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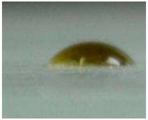
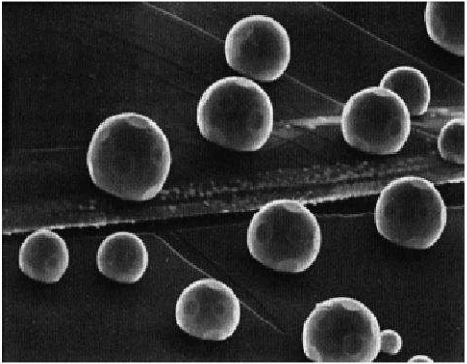
Some examples



J.-J. Métois, Au/Graphite



Differences between liquids and solids

	Simple Liquids	Crystalline solids
Structure	Isotropic	Anisotropic
Energy	Surface & Interface	Surface & Interface + Elastic
Mass Transport	Bulk hydrodynamics	Surface diffusion

Other cases: Liquid crystals, Non-Newtonian Fluids, amorphous solids, etc.

→ Similar or different behabiors?

Equilibrium equations

Free energy

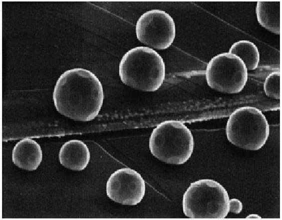
$$\mathcal{F} = \int_{VS} \mathrm{d}s\, \gamma_{VS}(\theta) + \int_{SA} \mathrm{d}s\, \gamma_{SA}(\theta) + \int_{AV} \mathrm{d}s\, \gamma(\theta)$$

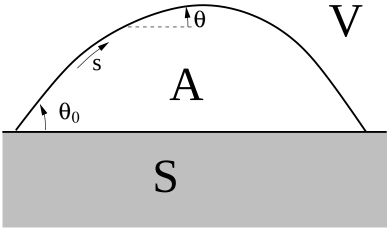
Total number of atoms

$$\mathcal{N} = \Omega^{-1} \int \int_{A} \mathrm{d}^2\mathbf{r}$$

Vanishing variation
$\delta(\mathcal{F} - \mu\mathcal{N}) = 0$
$\rightarrow$ Equilibrium equations

J.-J. Métois, Au/Graphite

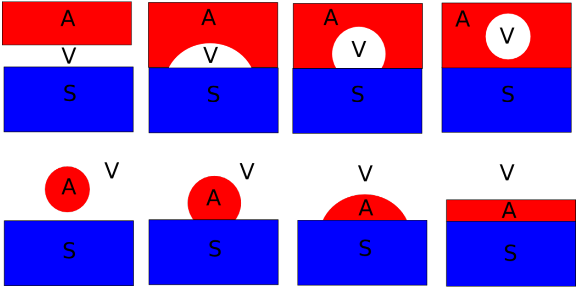




Spreading or not spreading

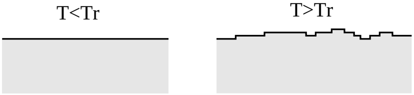
Spreading coefficient $\mathcal{S} = \gamma_{SV} - \gamma_{SA} - \gamma(0)$

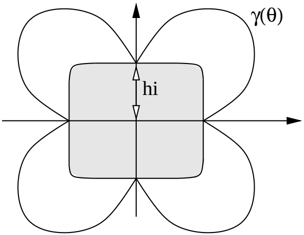
Complete dewetting	Partial Wetting	Total Wetting
$\gamma_{SV} + \gamma(0) < \gamma_{SA}$	$-\gamma(0) < \gamma_{SV} - \gamma_{SA} < \gamma(0)$	$\gamma_{SV} > \gamma_{SA} + \gamma(0)$
$\mathcal{S} < -2\gamma(0)$	$-2\gamma(0) < \mathcal{S} < 0$	$\mathcal{S} > 0$



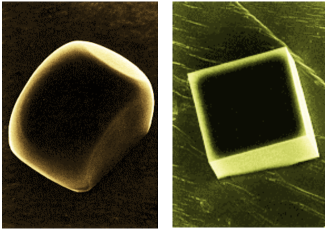
Facets

Roughening temperature T_r





NaCl, Métois et al (620-710^{o}C)



For usual crystals $T_r \sim T_M$

Equilibrium shape, Wulff 1901

Away from the substrate: Wulff Shape

- Discrete with facets

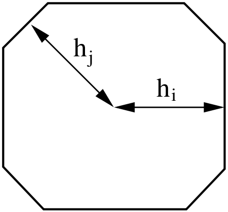
$$h_i = \frac{\Omega\gamma_i}{\mu}$$

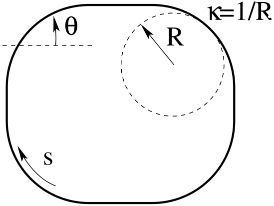
Facet free energy γ_i

- Continuum

$$\mu = \Omega\tilde{\gamma}(\theta)\kappa$$

Stiffness $\tilde{\gamma}(\theta) = \gamma(\theta) + \gamma''(\theta)$





Remarks:

- Wulff construction
- Equilvalence discrete - continuum
- Possible coexistence of smooth and facetted parts

Wetting equil. shape / flat substrate: Kaishew 1950, Winterbottom 1967

Main idea: flat substrate $\leftrightarrow$ facet

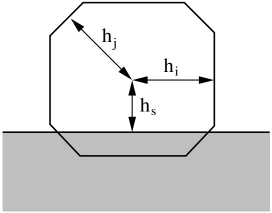
- Global condition: Truncation

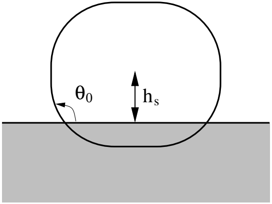
$$h_s = -\frac{\Omega(\gamma_{VS} - \gamma_{SA})}{\mu}$$

OR

- At the triple line if no facet: Young equation

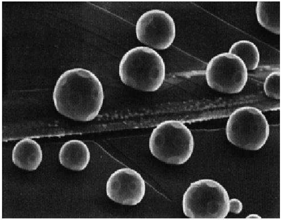
$$\gamma_{VS} - \gamma_{SA} \quad = \quad \gamma(\theta_0)\cos(\theta_0) - \gamma'(\theta_0)\sin(\theta_0)$$





Contact angle not a good parameter for facetted crystals!

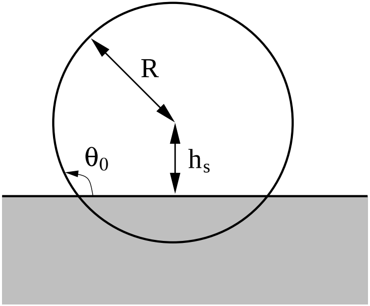
Isotropic



Isotropic solid or liquid: $\gamma(\theta) = \bar{\gamma}$

$$\mu = \Omega\bar{\gamma}\kappa \quad \Leftrightarrow \quad R = \frac{\Omega\bar{\gamma}}{\mu}$$

$$\bar{\gamma}\cos(\theta_0) = \gamma_{VS} - \gamma_{SA} \quad \Leftrightarrow \quad h_s = -\frac{\Omega(\gamma_{VS} - \gamma_{SA})}{\mu}$$



Finite size effects

Expansion of the thermodynamic energy in 3D

$$\mathcal{E} \sim \gamma_3 \mathcal{N} + \gamma_2 \mathcal{N}^{2/3} + \gamma_1 \mathcal{N}^{1/3} + \ldots$$

- $\gamma_3 \sim$ chemical potential $\mathcal{N} \sim L^3$
- $\gamma_2 \sim$ surface energy $\mathcal{N}^{2/3} \sim L^2$
- $\gamma_1 \sim$ line energy $\mathcal{N}^{1/3} \sim L$

higher orders are non-trivial!

Perstipino, Laoi, Tosatti PRL2012, J.Chem.Phys. 2013

Edges between facets or Triple line $\sim L \sim \mathcal{N}^{1/3}$
$\Rightarrow$ corrections to the equilibrium shape.

Contact angle influenced by triple line tension

γ_{TL} positive or negative

3D isotropic with line tension

$$\mathcal{G} = \bar{\gamma}\mathcal{A} + (\gamma_{AS} - \gamma_{SV})\mathcal{A}_S + \gamma_{TL}\mathcal{L}_{TL} - \mu\mathcal{N}$$

Spherical cap

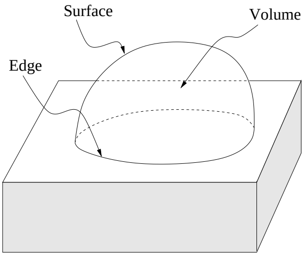
$$R = \frac{\Omega\bar{\gamma}}{\mu}$$

Modified truncation

$$\bar{\gamma}\frac{h_s}{R} = \gamma_{AS} - \gamma_{SV} + \frac{\gamma_{TL}}{(R^2 - h_s^2)^{1/2}}$$

Modified contact angle

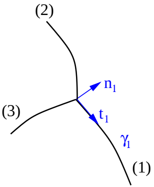
$$\bar{\gamma}\cos\theta = \gamma_{SV} - \gamma_{AS} - \frac{\gamma_{TL}}{R\sin\theta}$$

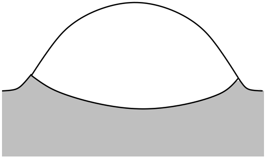


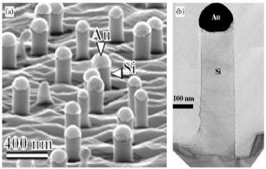
Non-frozen substrate

C. Herring (1951): Triple-point (triple-line):

$$\sum_{i=1}^{3} (\gamma_i \mathbf{t}_i + \gamma_i' \mathbf{n}_i) = 0$$







Zakharov et al Physica E (2007)

Thin film Wetting potential

Flat film thickness h

free energy $f(h)$

- $f(h=0) = \gamma_{SV}$
- $f(h \to +\infty) = \gamma_{SA} + \gamma(\theta = 0)$

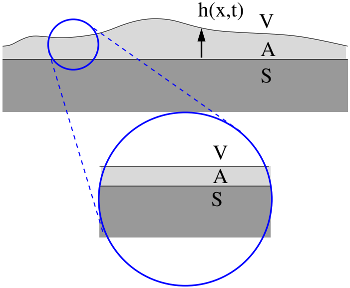
Relation $f \leftrightarrow W$

$$f(h) = \gamma_{SA} + \gamma(0) + W(h)$$

wetting potential $W(h)$

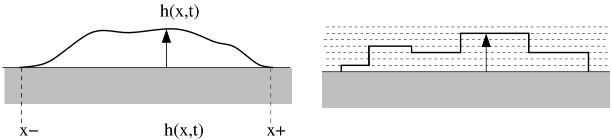
- $W(0) = \mathcal{S}$
- $W(+\infty) = 0$

Disjoining Pressure
$\Pi = -W'(h)$

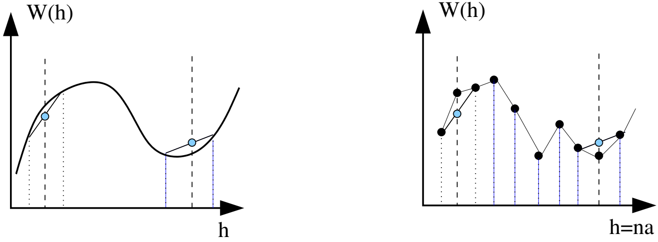


Thin film Wetting potential

Stability

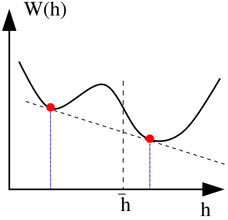


$W''(h) > 0$ $\qquad$ $W_{n+1} - 2W_n + W_{n-1} > 0$



Thin film Wetting potential

Equilibrium: Double tangent construction

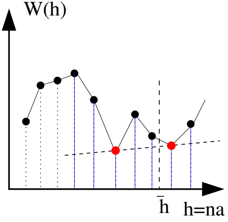


Film Tension

$$\gamma_{film}^{flat} = f(h) - hf'(h)$$

Equilibrium with substrate

$$\gamma_{film}^{flat} = \gamma_{SV}$$



Film Tension

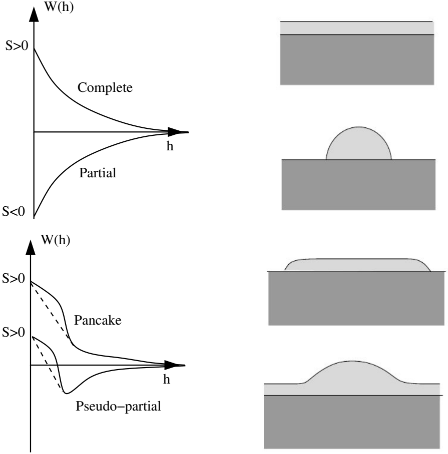
$$\gamma_{film}^{+} = f_n - n(f_{n+1} - f_n)$$
$$\gamma_{film}^{-} = f_n - n(f_n - f_{n-1})$$

Equilibrium with substrate

$$\gamma_{film}^{+} < \gamma_{SV} < \gamma_{film}^{-}$$

Thin film Wetting potential

Wetting Regimes



Small slope free energy

$$f(h) = \gamma_{SA} + \gamma(0) + W(h) + \frac{\Gamma(h)}{2}(\partial_x h)^2,$$

$\Gamma(h) \to \tilde{\gamma}(0)$ when $h \to \infty$

Macroscopic contact angle

$$\tilde{\gamma}(0)\frac{\theta_0^2}{2} = W(\infty) - W(0) = -S$$

Line tension

$$\gamma_{TL} = \int_0^\infty dh \quad \left\{ \left[2\Gamma(h)(W(h) - S)\right]^{1/2} - \left[2\tilde{\gamma}(0)(-S)\right]^{1/2} \right\}$$

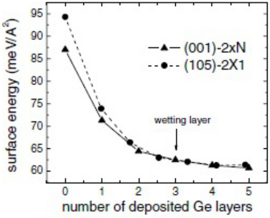
...Small slope model → lecture notes OPL

Thin film Wetting potential

Bonds and structural effects

Type	form	prefactor	range
Chemical bonds	$W_0 e^{-h/d_0}$	$W_0 \sim J/a^2$	$d_0 \sim a$
Layering of Liquids and Polymers	$W_0 \cos(2\pi h/a_0) e^{-h/d_0}$	$W_0 \sim k_B T/a^2$	$d_0 \sim a$
Structural effects solids $T < T_R$	$W_0 \cos(2\pi h/a_0)$	$W_0 \sim J/a^2$, $k_B T \ll J$	$(a_0 = a)$

Wetting potential Ge/Si

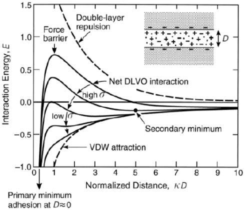


G.-H. Lu and F. Liu, PRL, 94 176103 (2005)

Thin film Wetting potential

DLVO-like contributions

Type	form	prefactor	range
Electrostatic effects	$W_0 e^{-h/\lambda_D}$	$W_0 = 2\frac{\sigma^2 \lambda_D}{\epsilon_0 \epsilon}$	λ_D
Van der Waals Interactions	$-\frac{A}{12\pi h^2}$	$A \sim 10^{-20} - 10^{-19}$ J	—



Israelachvili, Intermolecular and surface Forces (1985)

Polymers Layering J. Krawczyk et al EPL 70 726 (2005)

Liquids Layering: Hansen and McDonald, Theory of Simple Liquids (2006)

Thin film Wetting potential

... and many other possible contributions!

Type	form	prefactor	range
Electronic confinement	$\frac{E_{fb}}{h^2} cos(2k_{fb}h + \phi)$	$E_{fb} = 5.55$eV (Ag)	osc. $\lambda_f/2$

Z. Zhang et al, Phys.Rev.Lett.1998,1999
B. Wu and Z. Zhang, Phys. Rev. B 77, 035410 (2008)
Yong Han and Da-Jiang Liu PRE 80 155405 (2010)

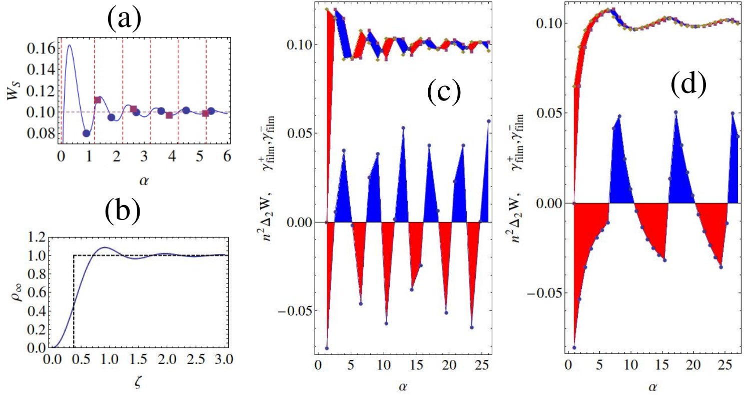
Debate in the literature: $1/h$ or $1/h^2$?

Electronic Quantum confinement

Free electron model

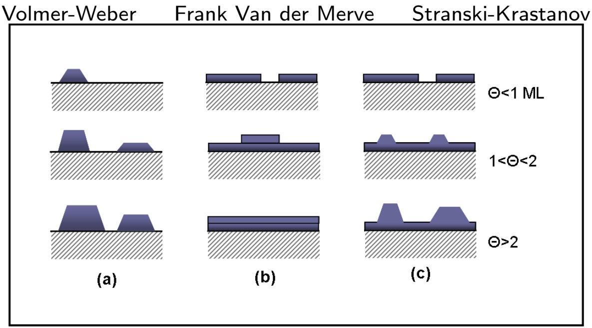
$$W_{EC}(h) \approx -\frac{E_{fb}}{(h+2b)^2}\frac{\pi}{36\sqrt{3}}\cos(2k_{fb}h)$$

E_{fb}, k_{fb} Fermi energy and wavevect,
$b = 3\pi k_{fb}/8$



(a) Al(111) (purple squares), Ag(111) (blue circles)
(c) Al(111) ,(d) Ag(111) blue-Stable, red-Unstable

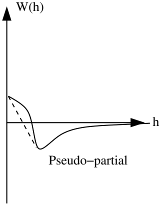
Growth modes

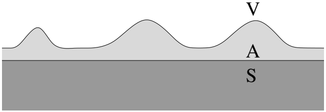


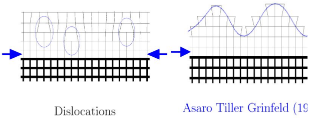
Pseudo-partial wetting vs ATG

Stranski-Krastanov

Pseudo-partial wetting vs ATG

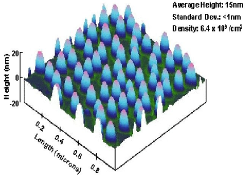


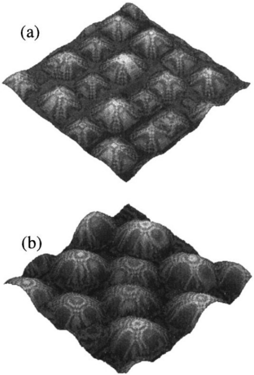




Fils quantiques

Boîtes quantiques





SiGe MBE growth

Floro et al 1999

recent developments ...

Aqua, Frisch, Berbezier, et al PRB (2010) PRL (2013)

ATG instability

Hetero-epitaxial strain $\epsilon_0 = (a_f - a_s)/a_s$
In plane strain $u_{xx} = u_{yy} = \epsilon_0$
Stress $\sigma_0 = -Y\epsilon_0/(1-\sigma)$
Flat film energy

$$\mathcal{E}_{el} = -h\epsilon_0\sigma_0 = \frac{Y}{1-\sigma}h\epsilon_0^2$$

Periodic perturbation δh, ℓ

$$\delta\mathcal{E}_{el} \sim -\delta h\epsilon\sigma_0 + C\epsilon^2\ell$$

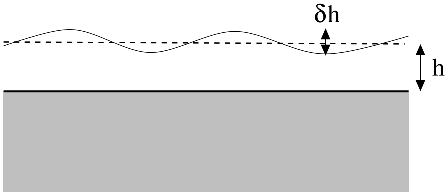
Minimize $\epsilon \sim \delta h\sigma_0/C\ell$
Total perturbation energy

$$\delta\mathcal{E} = \frac{\gamma}{2}q^2\delta h^2 - C\epsilon_0^2\delta h^2 q$$

Wavelength

$$\ell_{ATG} \approx 2\pi\frac{\gamma}{C\epsilon_0^2}.$$

$C \sim Y \sim 10^{11}$Pa, $\gamma \sim 1\text{Jm}^{-2}$, and $\epsilon = n\%$
$\rightarrow \ell_{ATG} \sim n^{-2}\mu$m
(1μm for 1% misfit to 10nm for 10% misfit)

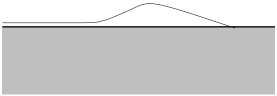


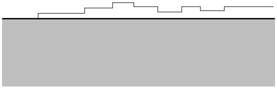
ATG instability

Almost flat surface: 2D absorbate on flat surface
height $h \sim$ surface stress $\sigma = \sigma_0 + \alpha h$
Local surface forces $\mathbf{f}$ and elastic energy $\mathcal{F}_{elas}$

$$\begin{aligned}
\mathbf{f} &= -\nabla\sigma = -\nabla\sigma_0 - \alpha\nabla h \\
\mathcal{F}_{elas} &= \frac{1}{2}\int \mathrm{dr}_1 \int \mathrm{dr}_2 \phi_{12} \\
\phi_{12} &= -\frac{1+\sigma}{\pi E}\left[(1-\sigma)\frac{\mathbf{f}_1\cdot\mathbf{f}_2}{|\mathbf{r}_{12}|} + \sigma\frac{(\mathbf{f}_1\cdot\mathbf{r}_{12})(\mathbf{f}_2\cdot\mathbf{r}_{12})}{|\mathbf{r}_{12}|^3}\right]
\end{aligned}$$

Edges and steps $\rightarrow$ force lines
$\mathbf{f}(\mathbf{r}) = \mathbf{f}_0(\mathbf{n}_0(s))\delta(\mathbf{r}-\mathbf{r}_0(s))$





Islands

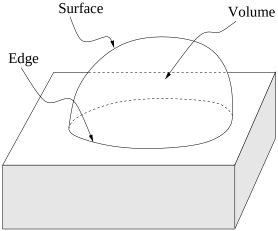
Contributions to the energy in 3D

Misfit $\epsilon = \Delta a/a$

$\mathcal{G}_{isl} = \mathcal{F}_{isl} - \mu\mathcal{N}$:

$$\begin{aligned} \mathcal{G}_{isl} = \quad & +\Gamma_{surf}\, a^2\mathcal{N}^{2/3} && \text{Surface} \\ & +\gamma_{e1}\, a\mathcal{N}^{1/3} && \text{Edge} \\ & -(\mu + f_1\lambda\epsilon^2)a^3\mathcal{N} && \text{Volume Elastic} \\ & -\gamma_{e2} f_2 a\mathcal{N}^{1/3}\ln[\mathcal{N}] && \text{Edge Elastic} \end{aligned}$$

Γ_{surf}, γ_{e1}, γ_{e2} renormilzed by ϵ



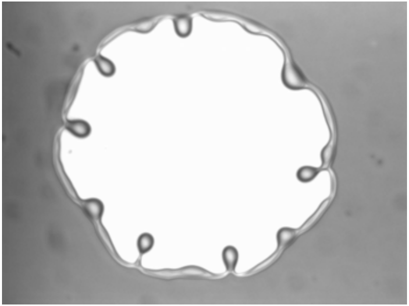
Schukin and Bimberg Rev Mod Phys 1999

Müller and Saúl Surf. Sci. Rep. 2004

Liquid-state Dewetting

Polymer film (PDMS/Si)

G. Reiter et al PRL2000,2001, Fetzer et al



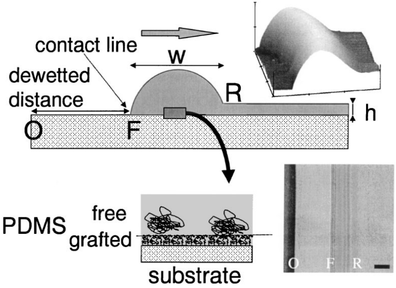


FIG. 1. Schematic representation of the experimental setup. A typical shape of the rim, as measured by atomic force microscopy, is shown in the upper right corner. The size of the image is $60 \times 60 \times 0.4\ \mu m^3$. Note that the lateral scale is about a factor of 100 larger than the vertical scale. In the lower right corner we show an optical micrograph representing the top view corresponding to the scheme. The length of the bar equals $50\ \mu m$.

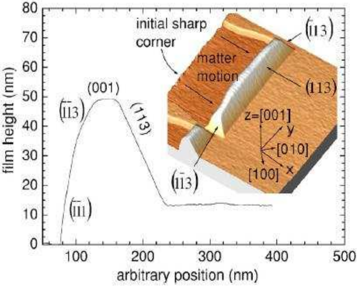
Dewetting experiments: surface diffusion + anisotropy

Experiments SOI: Si(100)/a-SiO_2

P. Müller et al Cinam Marseille

SOI (Si/SiO_2), AFM

Dornel Barbe Crecy Lacolle Eymery PRB2006



Surface Diffusion Mullins' Model

Local chemical potential $\mu = \Omega\tilde{\gamma}\kappa$.
Mullins model:

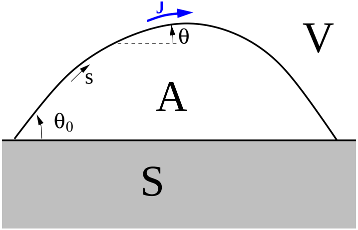
$$j = -\frac{Dc}{k_B T}\partial_s \mu$$
$$v_n = -\Omega\partial_s j$$

Triple Line
Equilibrium contact angle $\theta = \theta_0$

$v_n \sim \partial_{ss}\kappa$
Relaxation time of island perturbations
$t \sim L^4$
Small slope limit

$$\partial_t h = -B\partial_{xxxx} h$$

Linear but free boundary



Liquids: viscosity and substrate friction

Viscous dissipation under shear $\dot\gamma = \partial_y v_x + \partial_x v_y$

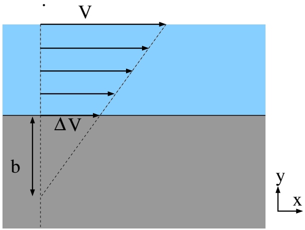
$$dQ \sim \eta \dot\gamma^2 dV$$

Continuity of tangential stress Navier 1823

$$\eta \partial_y v|_{wall} = \lambda \Delta v \quad \rightarrow \quad \Delta v = b \partial_y v|_{wall}$$

Slip length

$$\ell_s = \frac{\eta}{\lambda}$$



ℓ_s is usually small!
Link to wetting: hydrophobic $\Rightarrow$ depletion $\Rightarrow$ b increases
$\ell_s \sim (1+\cos\theta)^{-2}$ D. M. Huang, *et al* Phys. Rev. Lett. 101, 226101 (2008)
at max tens of nm for water on atomically flat hydrophobic surfaces

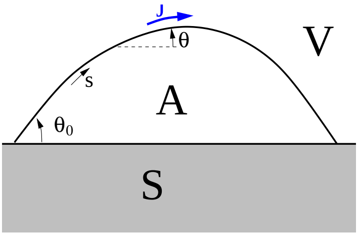
Hydrodynamics, lubrication Model

Local pressure variation $\Delta p = \tilde{\gamma}\kappa$.
Lubrication Model $\partial_x h \ll 1$, viscosity η, slip length ℓ_s

$$
\begin{aligned}
j &= -\frac{1}{\eta\Omega}(h^3/3 + \ell_s h^2)\partial_x \Delta p \\
\partial_t h &= -\Omega \partial_x j \\
\partial_t h &= -\frac{\gamma}{\eta}\partial_x[(h^3/3 + \ell_s h^2)\partial_{xxx} h]
\end{aligned}
$$

Triple Line
Equilibrium contact angle $\theta = \theta_0$

Linear peturbations $h = h_* + \delta h$
$\partial_t \delta h \sim \partial_{xxxx} \delta h$
Relaxation time of small perturbations
$t \sim L^4$



Generalized Model predictions 1D & small slopes

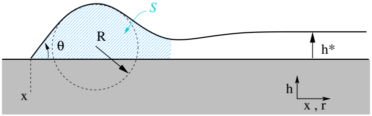
$$\partial_t h = \partial_x [h^n \partial_{xxx} h]$$

Scaling $\theta \ll 1$

$$\partial_{xx} h \sim \frac{1}{R} \quad h \sim R\theta^2 \quad x \sim R\theta$$

Triple line velocity

$$v = \frac{1}{\theta}\partial_t x_0 = \frac{1}{\theta}\partial_x [h^n \partial_x \frac{1}{R}] \sim \frac{\theta^{2n-3}}{R^{3-n}}$$



Mass conservation

$$\partial_t \mathcal{S} = v h^* \quad \rightarrow \quad \theta^3 \partial_t R^2 \sim \frac{\theta^{2n-3}}{R^{3-n}} h^*$$
$$\mathcal{S} \quad \sim \quad hL \sim R^2\theta^3$$

Asymptotic scaling

$$R \quad \sim \quad \theta^{-2(3-n)/(5-n)} h_*^{1/(5-n)} t^{1/(5-n)}$$
$$x_0 \quad \sim \quad \theta^{(3+n)/(5-n)} h_*^{-(3-n)/(5-n)} t^{2/(5-n)}$$

Multi-scale expansion / Example: $n = 0$, solid-state dewetting

Wong, Vorrhees, Miskis, Davis (2000)
small slope limit $\partial_x h \ll 1$
Mullins model

$$\partial_t h = -\partial_{xxx} h$$
$$h(x_0(t)) = 0, \qquad \partial_x h = \tan\theta = \alpha, \qquad \partial_x^3 h(x_0(t)) = 0, \qquad h(x\to\infty) = 1.$$

normalized varibales

$$X = \alpha(x - x_0(t)), \quad Y = h, \quad T = \alpha^4 t, \quad b = \alpha^{-3}\frac{dx_0}{dt}.$$

Boundary conditions

$$Y(X=0) = 0, \quad \partial_X Y(X=0) = 1, \quad \partial_X^3 Y(X=0) = 0, \quad Y(X\to\infty) = 1.$$

Slow dynamics $Y = Y_0 + Y_1 + Y_2 + ...$, with $Y_{n+1} \ll Y_n$

$$\partial_X^4 Y_0 - b^3 \partial_X Y_0 = 0$$
$$\partial_X^4 Y_n - b^3 \partial_X Y_n = -\partial_T Y_{n-1}$$

Solve Y_n order by order and then impose no-flux condition

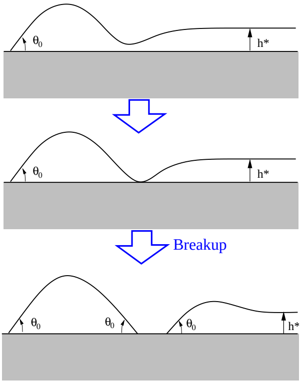
$$x_0(t) = \alpha\left(\frac{5t}{2\alpha}\right)^{2/5} - \frac{5}{4}\left(\frac{5t}{2\alpha}\right)^{1/5} + ...$$

Example: $n = 0$, solid-state dewetting

Asymptotic scaling

$$R \sim \theta^{-6/5} h_*^{1/5} t^{1/5}$$
$$x_0 \sim \theta^{3/5} h_*^{-3/5} t^{2/5}$$

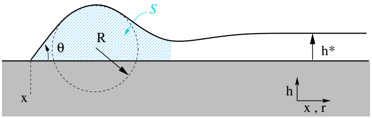
Mass shedding Wong, Vorrhees, Miskis, Davis (2000)



Example: $n = 2, 3$, liquid-state dewetting

Asymptotic scaling $n = 2$

$$R \sim t^{1/3}$$
$$x_0 \sim t^{2/3}$$



Asymptotic scaling $n = 3$

$$R \sim t^{1/2}$$
$$x_0 \sim t$$

No Mass shedding!

critical value $n = 3/2$

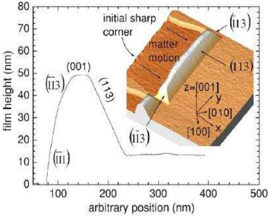
Evidences of facets on the rim

Ni(110)/MgO

J. Ye and C.V. Thompson, Acta Materialia 59, 582 (2011).

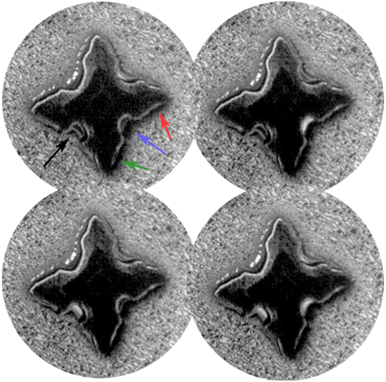
SOI (Si/SiO_2), AFM

Dornel Barbe Crecy Lacolle Eymery PRB2006



SOI (Si/SiO_2), LEEM

E. Bussman et al, New J. Phys. 2011



DEWETTING WITH FACETS?

Nucleation barrier

Dynamics limited by peeling or nucleation

Combe, Jensen, Pimpinelli, Phys Rev Lett 2000

Mullins and Rohrer, J. Am. Ceram. Soc. 2000

Cost: $2\pi\rho\gamma_{step}$

Gain: $\pi\rho^2\Delta\mu$ per atom, with $\Delta\mu = \Omega(-\mathcal{S})/h$

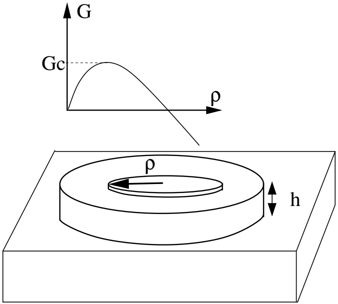
Total:

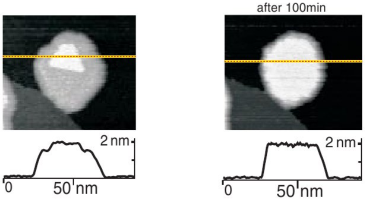
$$G = \gamma_{step} 2\pi\rho - \frac{-\mathcal{S}}{\Omega h}\pi\rho^2$$

$$G_c = \Omega\pi \frac{\gamma_{step}^2 h}{-\mathcal{S}}$$

$$\mathcal{I} = \rho_0 \Gamma_{+c} \left(\frac{-a^4 \partial_{ss} G_c}{2\pi T} \right)^{1/2} \mathrm{e}^{-G_c/T},$$

Slow relaxation time $t \sim \mathrm{e}^{G_c/k_B T} \sim \mathrm{e}^{h}$





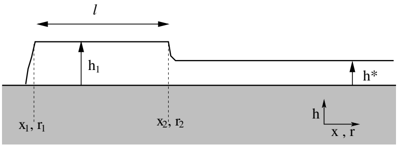
Experiments Ice/Pt(111)

Thurmer, Bartelt P.R.L. 2008

Facetted rim dynamics

Surface diffusion on top facet:

$$\begin{aligned} \Delta\mu &= \Omega\frac{-\mathcal{S}}{h_1} \\ h_1\partial_t x_1 &\sim \frac{\Delta\mu}{\ell} \\ \ell(h_1 - h^*) &= x_1 h^* \\ h_1 \gg h_* \Rightarrow x_1 &\sim t^{1/2} h_1^{-1/2} \end{aligned}$$



We recover the previous law:
$\ell \sim h_1 \Rightarrow h_1^2 \sim x_1 \Rightarrow x_1 \sim t^{2/5}$

Facetted rim

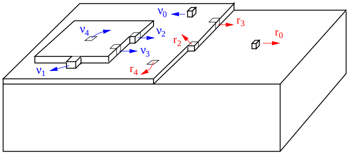
$$\begin{aligned} \partial_t h_1 \sim \mathrm{e}^{-G_c} &\sim \mathrm{e}^{-\Omega\pi\gamma_{step}^2 h_1/(-\mathcal{S})} \\ \Rightarrow h_1 &\sim \ln t \\ \Rightarrow x_1 &\sim t^{1/2}(\ln t)^{-1/2} \end{aligned}$$

OPL, A. Chame, Y. Saito, PRL 2009

Distinguish $\ln t$ from $t^{1/5}$ in experiments??
Si/SiO_2 Leroy et al $x \sim t^{1/3}$??
Metal GH Kim et al $x \sim t^{2/5}$.

SOS KMC model

- KMC simulations SOS Hopping rates
  A/S: $r_n = \nu_0 \, \mathrm{e}^{-nJ/T+E_S/T}$
  A/A: $\nu_n = \nu_0 \, \mathrm{e}^{-nJ/T}$
  J bong energy; E_S substrate contact energy



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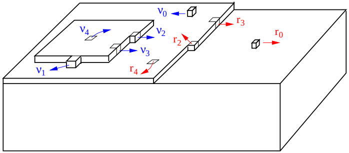
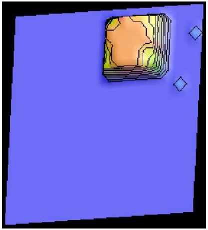


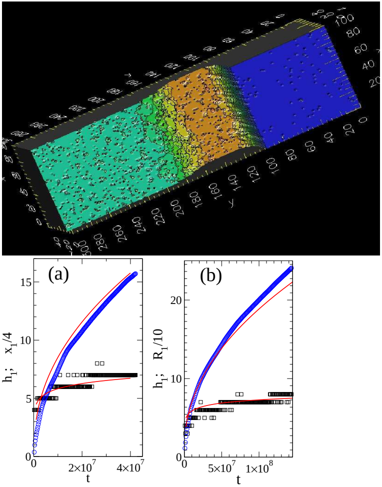


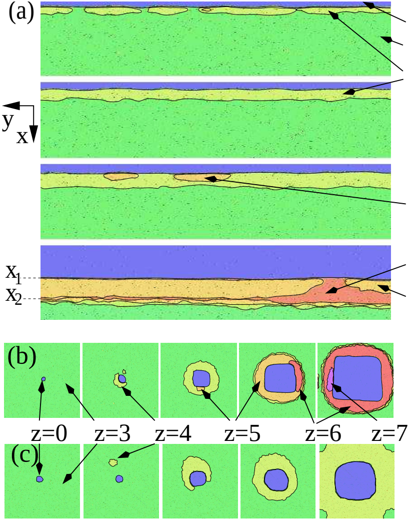
- Equilibrium shape Low temperatures:
  $h = E_S^{2/3} J^{-2/3} N^{1/3}$; $h/L = E_S/J$
  $E_S = 1$, $N = 900$, $\rightarrow h = 8.7$, simul at $T/J = 0.35$

- Link $T \rightarrow O$:

$$\gamma(0) = J/2$$
$$\mathcal{S} = -E_S$$

Facetted rim





OPL, A. Chame, Y. Saito, PRL 2009

Rim instability

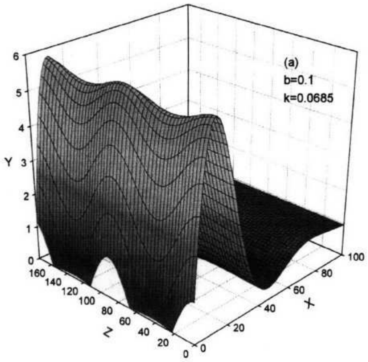
$$\partial_t h = \nabla \cdot [h^n \nabla \Delta h]$$

Transversal direction y, perturbation $q = 2\pi/\lambda$
Assuming $y \sim x$

$$\rightarrow q \sim \frac{1}{\theta R} \sim \frac{1}{\theta^{(n-1)/(5-n)} h_*^{1/(5-n)} t^{1/(5-n)}}$$

$n = 0 \rightarrow \lambda \sim t^{1/5}$
$n = 2 \rightarrow \lambda \sim t^{1/3}$
$n = 3 \rightarrow \lambda \sim t^{1/2}$

OPL 2013, Münch-Wagner 2014

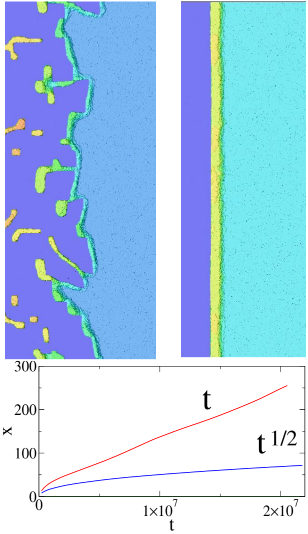


Kan, Wong J.Appl. Phys. 2005

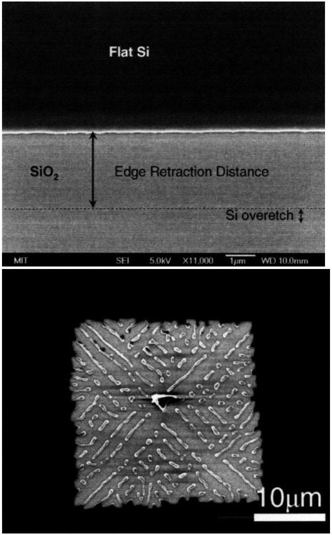
Final finger wavelength?

10 fronts: Metastability?

KMC



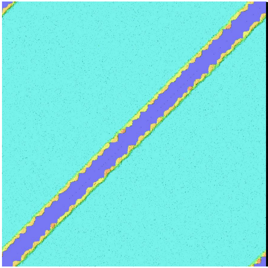
Danielson PhD Thesis, MIT 2008

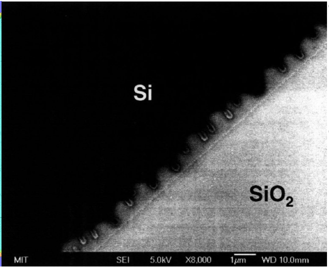


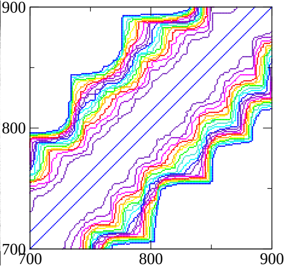
11 fronts

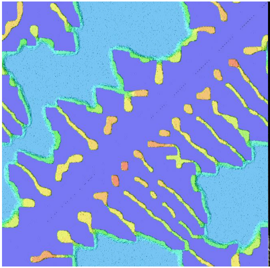
$h = 3, \; h_1 = 9, \; T = 0.5, \; E_S = 1.5,$

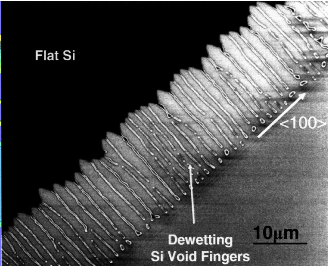
Danielson PhD Thesis, MIT 2008







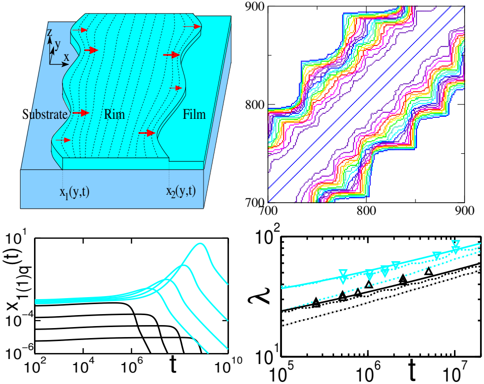




Instability of a facetted rim: Linear Coarsening

Instability on a - non-steady-state:

- (110) -rough orientation $\tilde{\gamma}_1 \approx \gamma$ constant
  Coarsening: $\lambda \sim t^{1/4}(\ln t)^{-1/2}$
  Numerical power-law fit $\lambda \sim t^{0.2}$

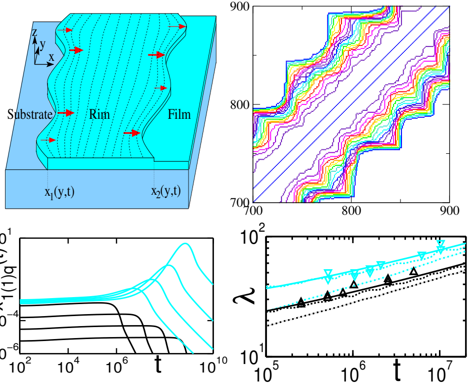


M. Dufay, OPL, PRL 2011

Instability of a facetted rim: Linear Coarsening

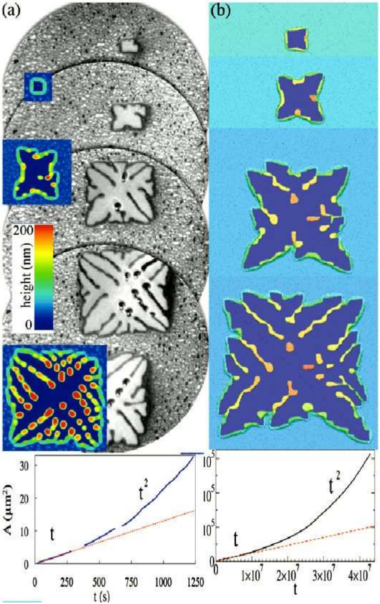
Instability on a - non-steady-state:

- (110) -rough orientation $\tilde{\gamma}_1 \approx \gamma$ constant
  Coarsening: $\lambda \sim t^{1/4}(\ln t)^{-1/2}$
  Numerical power-law fit $\lambda \sim t^{0.2}$
- (100) -vertical (100) facet
  $\tilde{\gamma}_1 = Ta/\beta^2 \approx (T/2a)\mathrm{e}^{\gamma h_1/T}/h_1$
  Stable

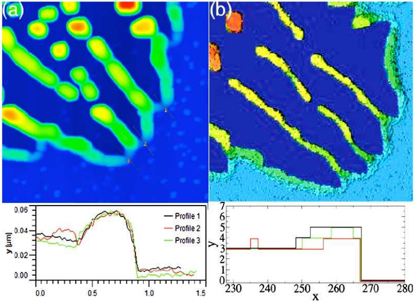


M. Dufay, OPL, PRL 2011

KMC vs SOI



$h = 3,\ E_S = 1,\ T = 0.5$



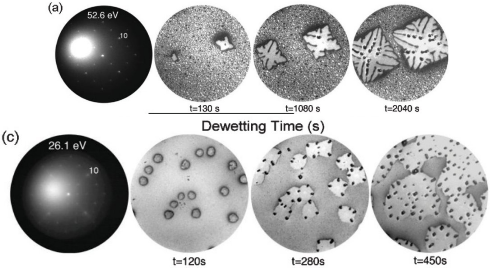
SOI system LEEM Experiments:

E. Bussman, F. Leroy, F. Cheynis, P. Müller, OPL NJP(2011)

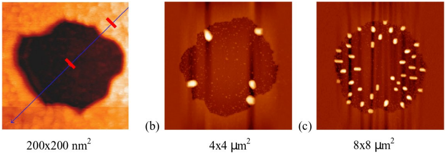
Isotropic

More or less isotropic?

Müller et al LP2MC Marseille



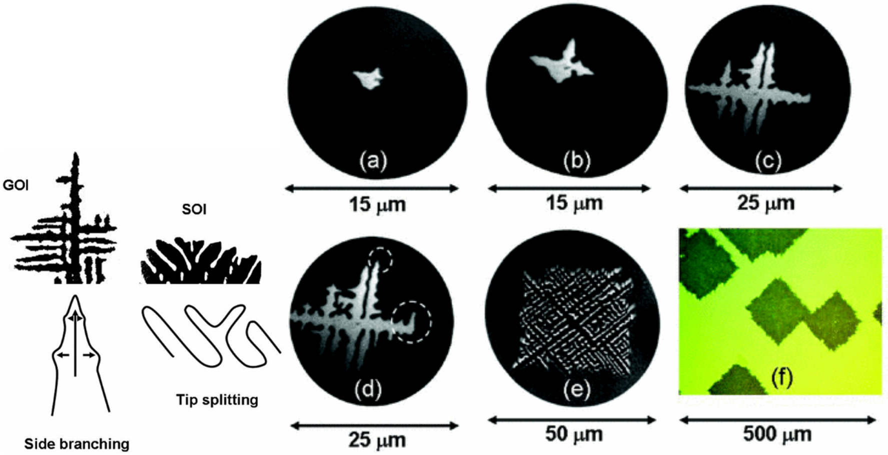
Berbezier et al LP2MC Marseille



Dendritic shapes

More or less dendritic shapes?

Müller et al LP2MC Marseille

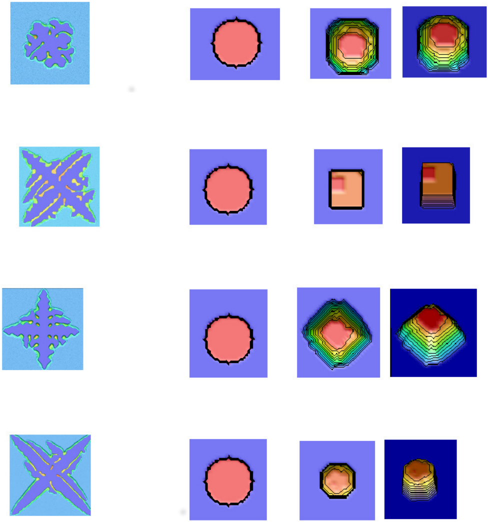


Dewetting hole of shapes NNN KMC

- Seaweed
  Isotropic
  Example: dirty SOI??

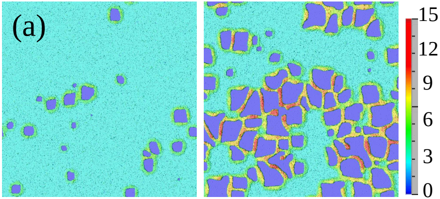
- Anisotropic Ramified
  Simple 4-fold
  Example: SOI

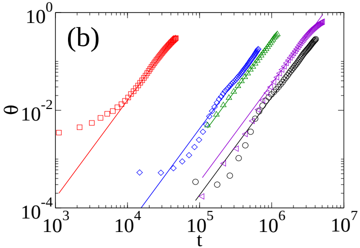
- Dendritic
  4-fold with secondary facet
  Example: GOI



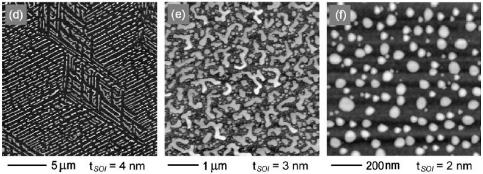
Dewetting of a complete film / Hole nucleation and growth

$h = 3,\ E_S = 0.7,\ T = 0.5$





Burhanudin et al Surf. Sci 2006



hole radius $R \sim t^{1/2}$

hole area $A \sim R^2 \sim t$

uncoverage $\theta \sim t^2$

Continuum model with Wetting potential

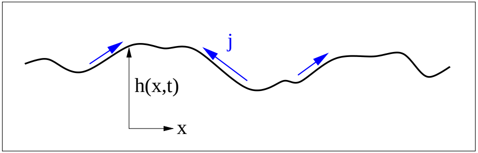
Substrate at $h = 0$
Free energy per unit area :

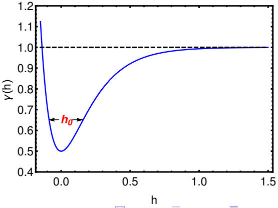
$$\gamma(h) = \gamma_\infty + \mathcal{W}(h)$$

Wetting potential $\mathcal{W}(h) \to 0$ as $h \to \infty$

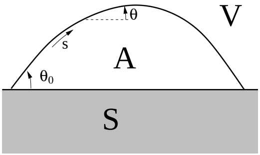
$$\begin{aligned} \mu(x) &= -\gamma_\infty \partial_{xx} h + \gamma'(h) \\ \mathbf{j} &= -\mathcal{M}(h) \nabla \mu \\ \partial_t h &= -\nabla \cdot \mathbf{j} \end{aligned}$$

Far from the substrate: $h \to \infty$
$\mathcal{M}(h) \to \mathcal{M}_\infty$
$\gamma(h) \to \gamma_\infty$





Non-equilibrium boundary condition



Equilibrium condition at Triple Line
Young-Dupré
$\gamma \cos\theta_{eq} + \gamma_{int} = \gamma_{sub}$

Liquids
P.G. de Gennes
Grain Boundaries
U. Czubayko et al, Acta Mater. (1998); M. Upmanyu et al Acta Mater. (2002).
Solid-state wetting
Wang, Jiang, Bao, Srolovitz (2015)

$$v = K(\cos\theta - \cos\theta_{eq})$$

Microscopic origin of the kinetic coefficients:

- Wetting potential?
- Microscopic Kinetic coefficients affected by the vicinity of substrate?

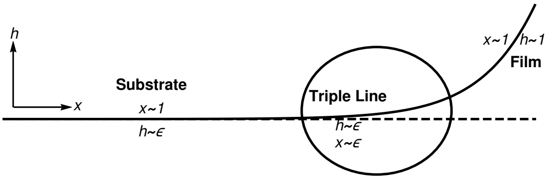
Is this the correct triple line BC?
Derive K from mesoscopic model?

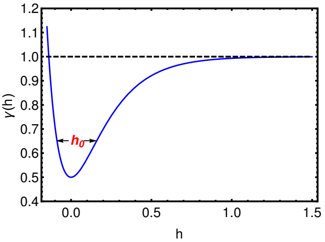
Matched asymptotic Expansion

- Expand in small parameter $\epsilon \sim h_0$

Matched asymptotic Expansion

- Expand in small parameter $\epsilon \sim h_0$





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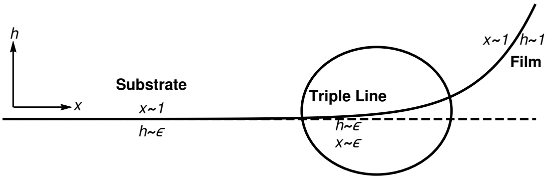
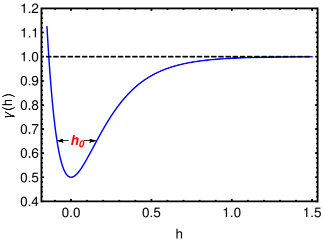
Matched asymptotic Expansion

- Expand in small parameter $\epsilon \sim h_0$





-

(a) Film region $\begin{cases} h \sim O(1) \\ x \sim O(1) \end{cases}$

(b) TL region $\begin{cases} h = \epsilon H(X,t) \\ x = x_{TL} + \epsilon X \end{cases}$

(c) Substrate region $\begin{cases} h(x,t) = \epsilon \mathcal{H}(\chi,t) \\ \chi = x \end{cases}$

Kinetic Boundary Conditions

To 0th order, Young & no-flux

$$\theta = \theta_{eq} \qquad \frac{\gamma_\infty}{2}\theta_{eq}^2 = \gamma_\infty - \gamma_{min} \qquad J = 0$$

... To 3rd order, KBC (Linear / Onsager)

$$\mathcal{L}\begin{bmatrix} v \\ J \end{bmatrix} = \begin{bmatrix} [U] \\ -[\mu] \end{bmatrix}$$

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  v : velocity of triple line
  J : mass flux through triple line

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- Thermodynamic Forces :

$$\begin{aligned} [U] &= (U_+ - U_-) = \gamma_\infty(\cos\theta - \cos\theta_{eq}) \\ [\mu] &= (\mu_+ - \mu_-) \propto \gamma_\infty \kappa - h\gamma''_{min} \end{aligned}$$

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- Thermodynamic Fluxes :
  v : velocity of triple line
  J : mass flux through triple line

- Kinetic Coefficients :

$$\mathcal{L} = \begin{bmatrix} \mathcal{L}_{2v} & \mathcal{L}_{1v} \\ \mathcal{L}_{1v} & \mathcal{L}_{1J} \end{bmatrix}$$

Kinetic Coefficients

$$\mathcal{L}\begin{bmatrix} v \\ J \end{bmatrix} = \begin{bmatrix} [U] \\ -[\mu] \end{bmatrix}$$

Kinetic coefficients

$$\mathcal{L}_{1J} = \int_{-\infty}^{\infty} dX \left(\frac{1}{M(H_0)} - \frac{\Theta(X)}{M(\infty)} - \frac{\Theta(-X)}{M(0)} \right) \sim \frac{\epsilon}{M}$$

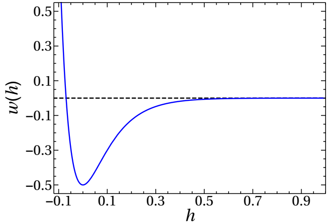
$$\mathcal{L}_{1v} = \int_{-\infty}^{\infty} dX \left(\frac{H_0}{M(H_0)} - \Theta(X) \frac{X\partial_x h_0(x_{TL})}{M(\infty)} \right) \sim \frac{\epsilon^2}{M}$$

$$\mathcal{L}_{2v} = \int_{-\infty}^{\infty} dX \left[\frac{H_0^2}{M(H_0)} - \frac{\Theta(X)}{M(\infty)} (X\partial_x h_0(x_{TL}))^2 \right] \sim \frac{\epsilon^3}{M}$$

In most cases $\theta \sim \theta_{eq}$?

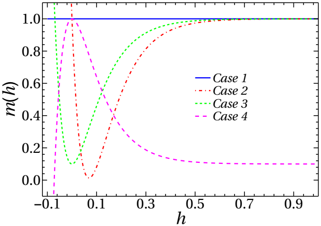
Numerical simulations

Wetting potential

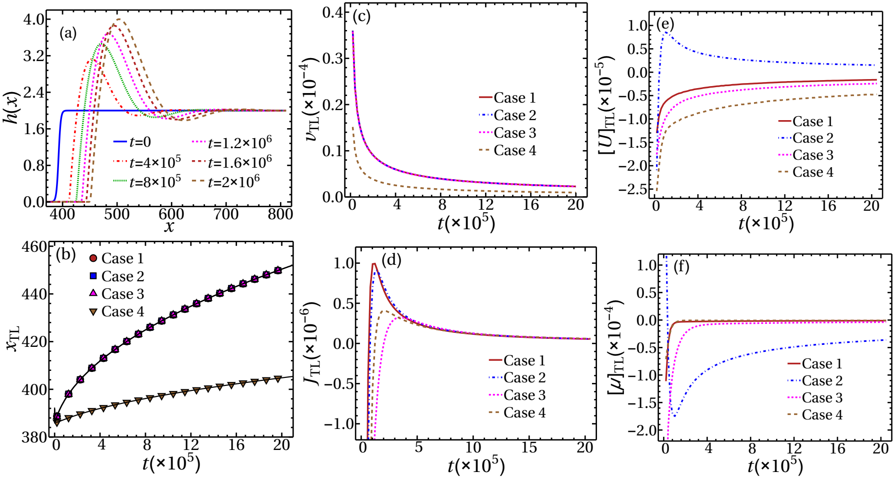


Mobility

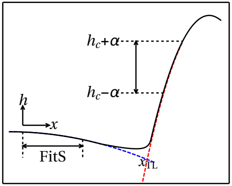
- case 1 constant mobility
- case 2 reduced mobility in the triple line region
- case 3 asymmetric: lower mobility in the substrate
- case4 asymmetric: lower mobility in the film

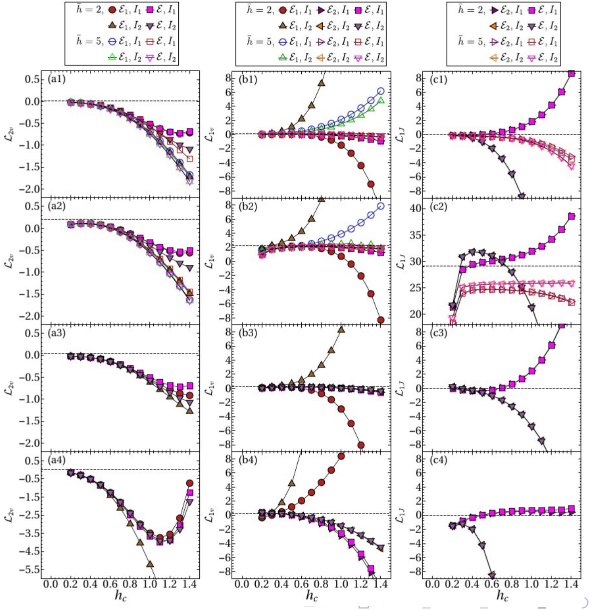


Numerical simulations



Numerical simulations



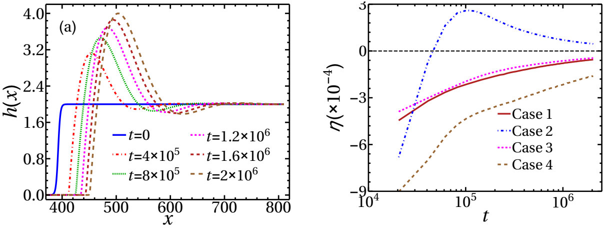


Numerical simulations

Dynamic contact angle θ_D

$$\eta = \frac{\theta_{eq} - \theta_D}{\theta_{eq}}$$

Dewetting dynamics



Summary on Kinetic Boundary Condition

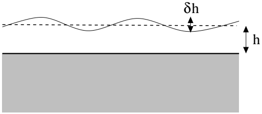
- 2 Kinetic Boundary Conditions for v and J
- Numerical validation
- Convergence of kinetic coefficients.
  $W(h) - W(\infty) \sim h^{-n}$, with $n > 3$
  $M(h) - M(\infty) \sim h^{-m}$, with $m > 3$
  Van der Waals $n = 2$??

Small thicknesses: spinodal dewetting

Linear stability analysis : $h = \bar{h} + \delta h$
$\delta h \sim \mathrm{e}^{i\omega t + iqx}$

$$i\omega = \mathcal{M}(\bar{h})\, q^2[-\gamma_\infty q^2 + W''(\bar{h})]$$

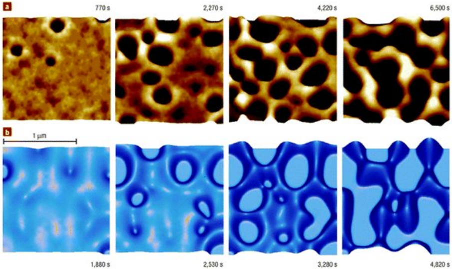
Spinodal Instablility if $W''(\bar{h}) \leq 0$



$$\lambda_{LS} = \frac{2^{3/2}\pi\bar{\gamma}^{1/2}}{W''(\bar{h})^{1/2}}$$

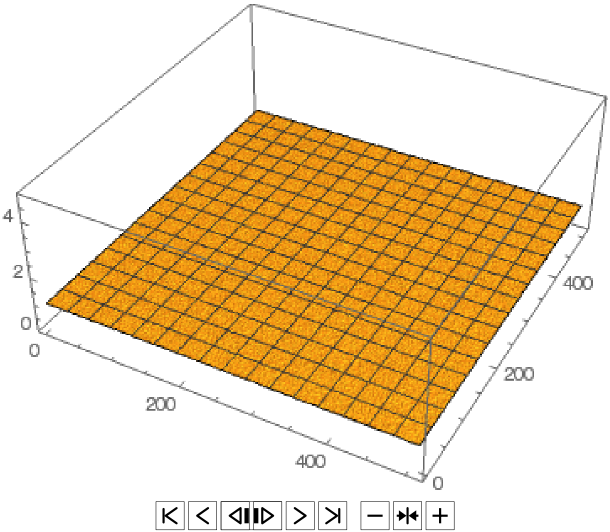
$$T_{LS} = \frac{4\bar{\gamma}}{\bar{\mathcal{M}}W''(\bar{h})^2}$$

Liquids



Becker, Grün, Seemann, Mantz, Jacobs, Mecke and Blossey, Nat. Mater. (2003)

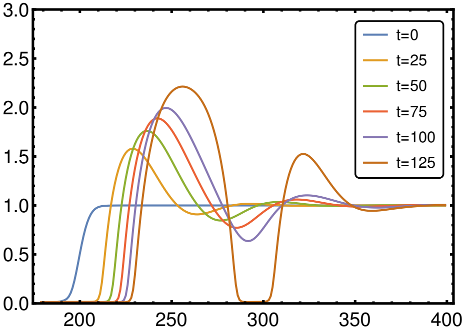
Embedded Animation

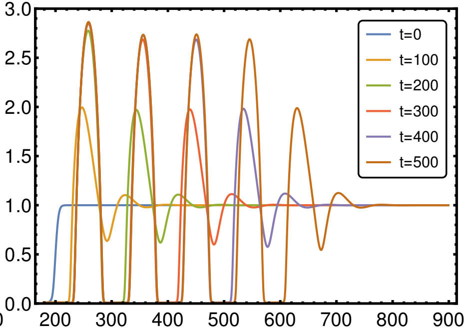


Aswani Tripathi, ILM-Lyon

Mass Shedding

Periodic Mass shedding
$\theta_0 = 60^o$ and $h_0 = 0.1$



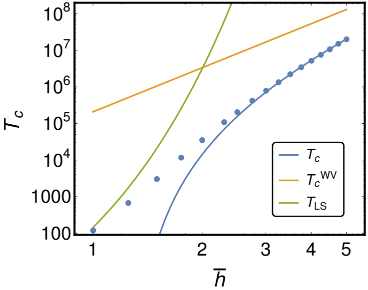


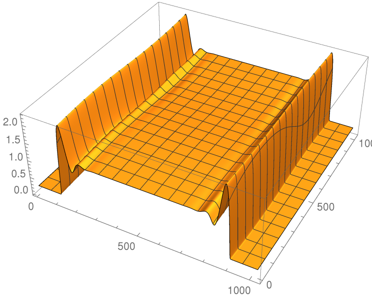
Small thicknesses: spinodal dewetting

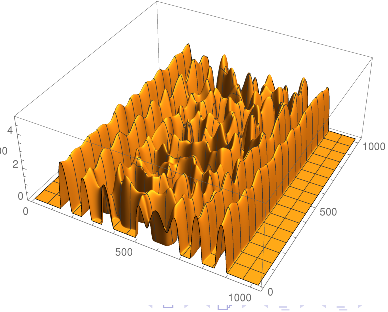
Linear stability analysis : $h = \bar{h} + \delta h$
Spinodal Instablility if $W''(\bar{h}) \leq 0$

$$T_c^{WV} = \frac{\bar{h}^4}{\bar{\mathcal{M}}\bar{\gamma}\theta_0^4}$$

$$T_{LS} = \frac{4\bar{\gamma}}{\bar{\mathcal{M}}W''(\bar{h})^2}$$





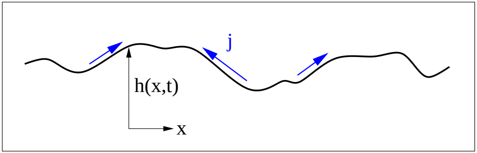


Continuum model with Wetting potential

Substrate at $h = 0$
Free energy per unit area :

$$\begin{aligned}\gamma(h) &= \gamma_\infty + \mathcal{W}(h) + \mathcal{E}_{el} \\ \mu(x) &= -\gamma_\infty \partial_{xx} h + \gamma'(h) + C\epsilon_0^2 \mathcal{H}(\partial_x h) \\ \mathbf{j} &= -\mathcal{M}\nabla\mu \\ \partial_t h &= -\nabla\cdot\mathbf{j}\end{aligned}$$

$\mathcal{H}[\partial_x h] = \mathcal{F}^{-1}\{|q|\mathcal{F}[h]\}$



Schifani, Frisch, Argentina, Aqua, PRE 20016

Continuum model with Wetting potential

Stabilizing exponential $W(h)$ and Anisotropy

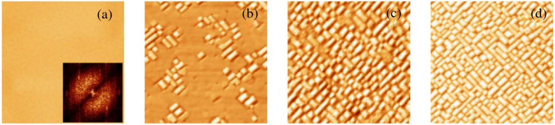


FIG. 1 (color online). AFM images of a 5-nm-thin $Si_{0.70}Ge_{0.30}$ layer (a) as grown (Fourier transform in inset), (b) after 18-h annealing, and (c) after 54-h annealing at 550 °C. (d) Image of a 8-nm film after 18-h annealing. The [110] direction is horizontal. (The scan area is $3 \times 3\ \mu m^2$, and the vertical scale is 32 nm.)

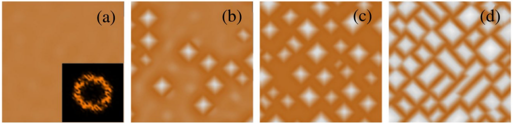


FIG. 2 (color online). Numerical resolution of the diffusion equation (1) for a strained anisotropic film for (a) a 5-nm film and $t = 0$ (Fourier transform in inset), (b) 18 h ($240t_0$), (c) 54 h ($720t_0$), and (d) an 8-nm film and $t = 18$ h ($240t_0$). [The scan area is $1.2 \times 1.2\ \mu m^2 (= \sqrt{2}64 l_0)$, and the vertical scale is 31 nm.]

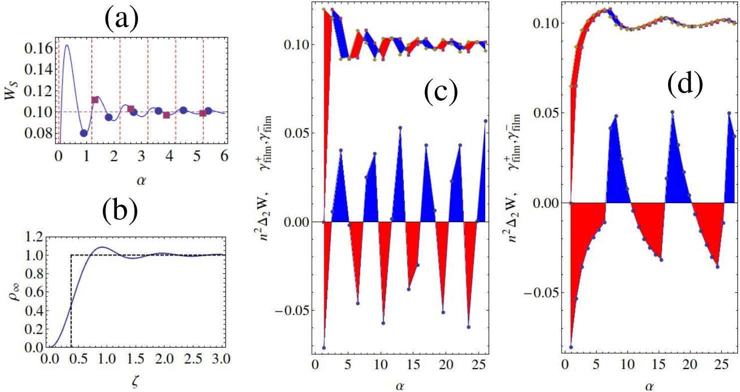
Aqua, Gouye, Ronda, Frisch, Berbezier, PRL 2013

Electronic Quantum confinement

Free electron model

$$W_{EC}(h) \approx -\frac{E_{fb}}{(h+2b)^2}\frac{\pi}{36\sqrt{3}}\cos(2k_{fb}h)$$

E_{fb}, k_{fb} Fermi energy and wavevect,
$b = 3\pi k_{fb}/8$

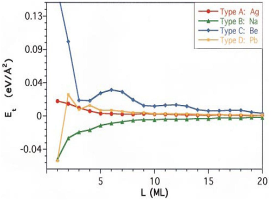


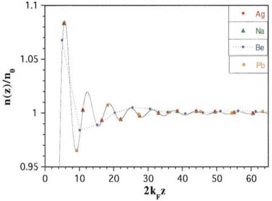
(a) Al(111) (purple squares), Ag(111) (blue circles)
(c) Al(111) ,(d) Ag(111) blue-Stable, red-Unstable

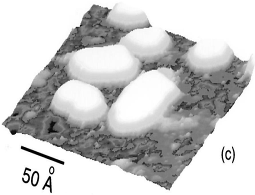
Magic heights and labyrinthine patterns

Metals/ semicon or insulator: Electronic confinement → Magic thickness

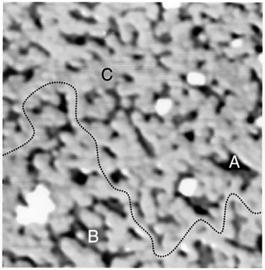
Z. Zhang et al, Phys.Rev.Lett.1998,1999







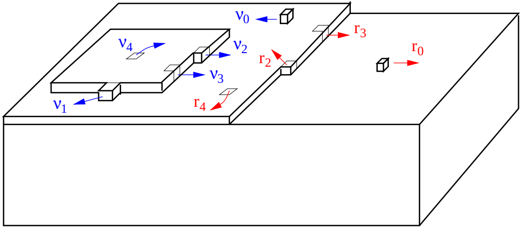
Experiments Ag/Si(111)



SOS KMC model with magic height

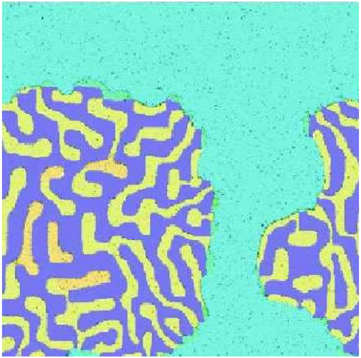
KMC simulations SOS

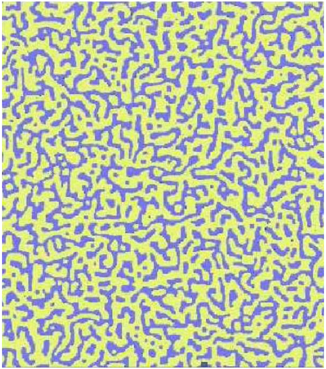
$$z \neq 1 \text{ and } z \neq h_* \qquad \nu_n = \nu\, \mathrm{e}^{-(nJ+J_0)/T}$$
$$z = 1 \qquad r_n = \nu\, \mathrm{e}^{-(nJ+J_0-E_S)/T}$$
$$z = h_* \qquad r_n^* = \nu\, \mathrm{e}^{-(nJ+J_0-E_*)/T}$$



KMC simualtions with magic height

A. Chame, OPL, Phys Rev B 2014





$\lambda \sim 30$nm

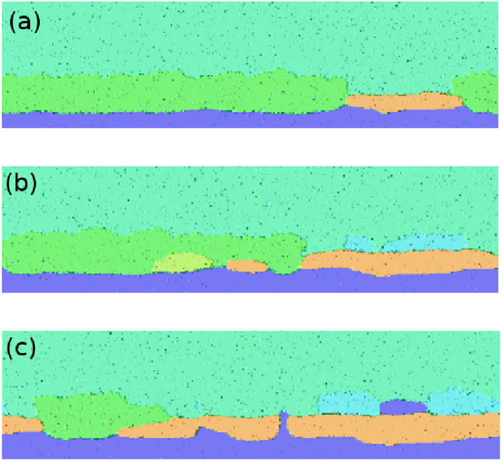
Semi-quantitative agreement with experiments

Magic-height rim

$800 \times 800,\ T = 0.4,\ h = 3,\ E_S = 0.4,\ h_* = 7,\ E = -0.5$

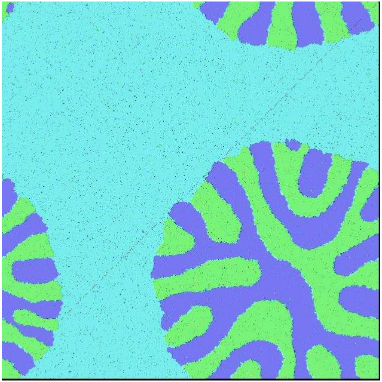
Induced nucleation and incomplete closure

A. Chame, OPL, Phys Rev B 2014



Monolayer → no rim

$V_{zip} \sim V_{front}$



OPL, A. Chame, Y. Saito, PRL 2007

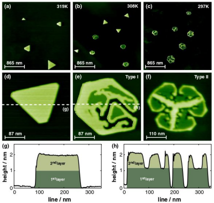


FIG. 1 (color online). (a)–(c) NC-AFM images of C_{60} islands on $CaF_2(111)$ at three different growth temperatures. (d)–(f) Magnified images of single islands: a compact triangle (d), and hexagonal islands with morphologies I (e) and II (f). (g), (h) Height profiles along lines scans shown in (d),(e).

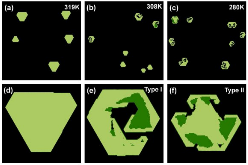
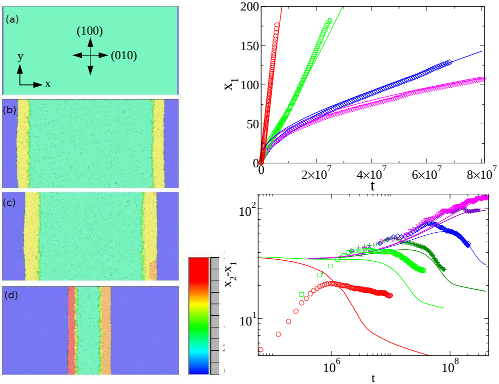


FIG. 2 (color online). (a)–(c) Simulated configurations of the growth model at different temperatures. (d)–(f) Magnified single island structures from the simulations resemble the same morphologies as found in experiments [Figs. 1(d)–1(f)].

P. Maas et al, PRL 2011

Dewetting with substrate mediated evaporation

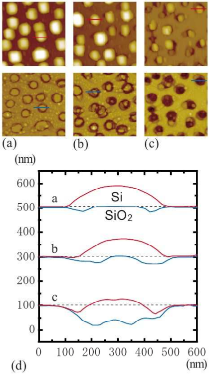
- Constant velocity
- Non-monotonous rim width



A. Chame, OPL, PRE 2013

Interface Reaction in SOI systems: substrate profile

Experiments



Sudoh, Naito, JAP 2010.

($2\mu m \times 2\mu m$, 1050°).

OPL, P. Müller et al PRB (2014), APL (2015)

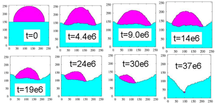
Kinetic Monte Carlo

Interface: Si+SiO_2 ↔2Si+2O

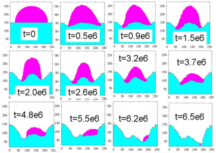
Interface: O diffusion

Triple Line: Si+O→ SiO(evap)

Si Surface: Si diffusion



$$\nu_O = 10/\tau_A, \nu_E = 0.01/\tau_A.$$



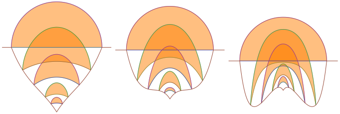
$$\nu_O = 10/\tau_A, \nu_E = 0.1/\tau_A.$$

Analytic

Reaction-Diffusion

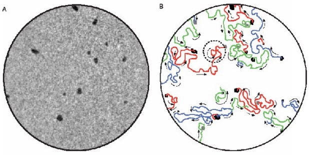
$$\partial_t C_O = D\partial_{xx} C_O + K_0 - K_1 C_O^2$$
$$\partial_t h_I = K_0 - K_1 C_O^2$$
$$\theta_{TL} = \theta_{eq}$$

$$h = -\pi \frac{D_O^{1/2} K_0^{3/4}}{2^{1/2} K_1^{1/4}} \cosh \frac{x}{x_s} \int_{R_0/x_s}^{x/x_s} \frac{u du}{\sinh u}$$

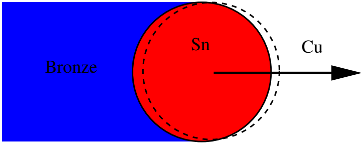


Interface Reaction: running droplets

Running sild-clusers Sn/Cu(111)

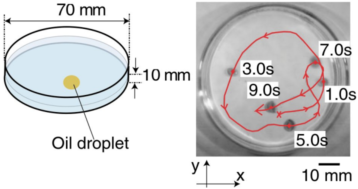


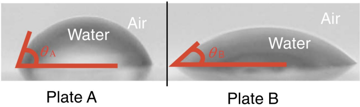
LEEM, 1.5μm, 290K



Schmid, Bartelt, Hwang, Science Reports (2000).

Liquid Running oil Droplet





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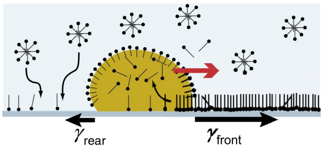
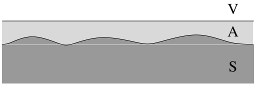


Sumino, Magome, Hamada, Yshikawa PRL2005

Guided Self-Organisation vs Healing

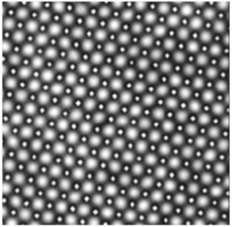


Healing length

$$\xi_{heal} = \left(\frac{\gamma(\bar{h})}{W''(\bar{h})} \right)^{1/2}$$

Guided self-organization

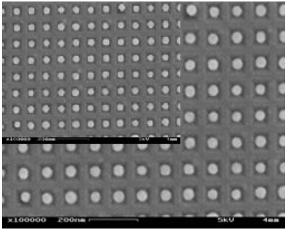
$$\xi_{heal} = \left(\frac{\gamma(\bar{h})}{-W''(\bar{h})} \right)^{1/2}$$



Ge/Si, $5 \times 5\mu m$

Zhong et al PRL 2007

Aqua and Xu PRE 2014



Au/Si

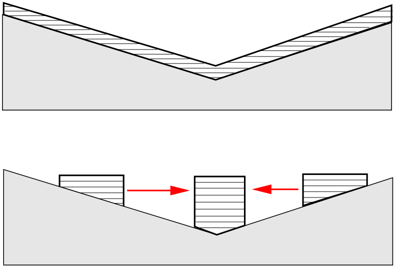
C.V. Thompson

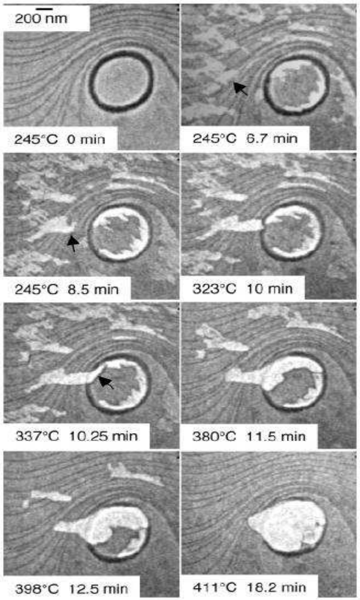
Guided Self-Organisation: Drift Experiments

Controlled positionning of mass in holes

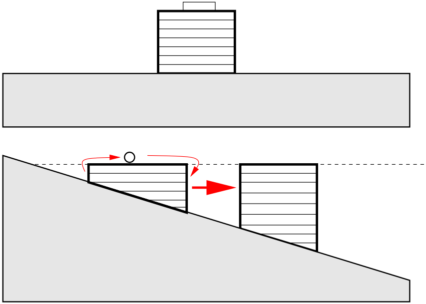
Ling *et al* Surf. Sci 2006

McCarty NanoLetters 2006 Ag/W(110)





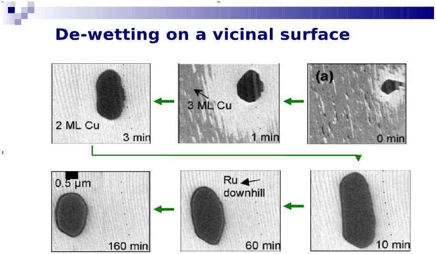
Nucleationless motion



Going back to equilibrium height without nucleation on top??

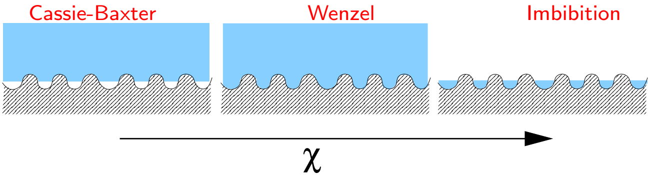
island position $\sim t^{1/4}$

M. Dufay, OPL, Phys Rev B, 2010



W. L. Ling et al. Surf. Sci. Lett. (2004)

Three wetting states for liquids on patterns



Wettability: $\chi = (1 + \cos\theta_0)/2$

Bico, Marzolin, Quéré (1999)

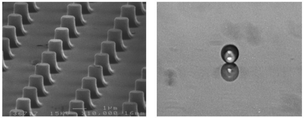
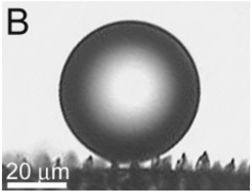


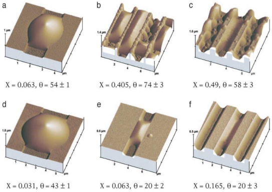
Figure 12. Substrate decorated with posts (the bar indicates 1 μm). If coated with a monolayer of fluorinated silanes, this substrate is found to be super-hydrophobic [37].

Watson et al PLoS ONE (2011)



Seemanet *al* (2005)

Polystyrene drops on Silicon



3D KMC Model

3D KMC
Hopping along the surface

$\nu = \nu_0 \, e^{-(n_1 J_1 + n_2 J_2 + n_{s1} J_{s1} + n_{s2} J_{s2})/T}$

J bond energy, n_i nb neighbors
$i = 1, 2$ NN, NNN adsrobate
$i = s1, s2$ NN, NNN substrate
Moves to NN
Allowed when there is NN or NNN

Shape controlled by

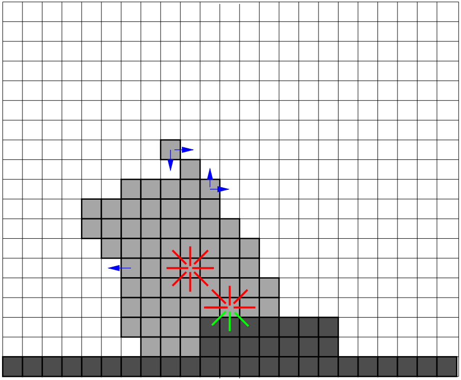
$$\zeta = \frac{J_2}{J_1} = \frac{J_{s2}}{J_{s1}}$$

Wetting controlled by

$$\chi = \frac{J_{s1}}{J_1}$$

Link $T \to O$:

$$1 - \chi = \frac{-\mathcal{S}}{2\gamma(0)}$$



$\chi \to 0$: Complete de-wetting
$\chi \to 1$: Complete Wetting

ψ parameter

Contact angle not a good parameter for facetted crystals!

$$\psi = \frac{\mathcal{S}_{AV}}{\mathcal{S}_{AS}}$$

3D Isotropic crystal $\gamma(\theta) = \bar{\gamma}$

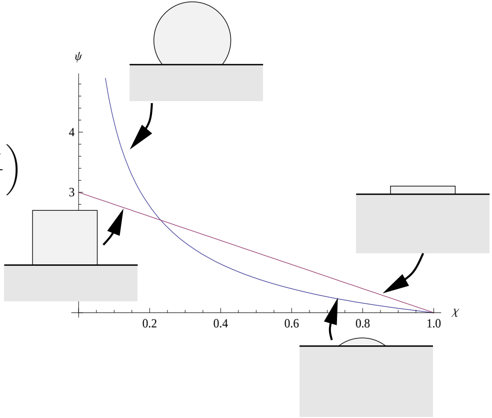
$$\chi = \frac{1}{2}(1 + \cos\theta_0) = \frac{1}{2}\left(1 + \frac{\gamma_{SV} - \gamma_{AS}}{\bar{\gamma}}\right)$$

$$\psi = \frac{1}{\chi}$$

3D Square crystal γ_0

$$\chi = \frac{1}{2}\left(1 + \frac{\gamma_{SV} - \gamma_{AS}}{\gamma_0}\right)$$

$$\psi = 5 - 4\chi$$



$\chi \to 0$: Complete de-wetting
$\chi \to 1$: Complete Wetting ($\psi = 1$)

Wetting on a flat substrate

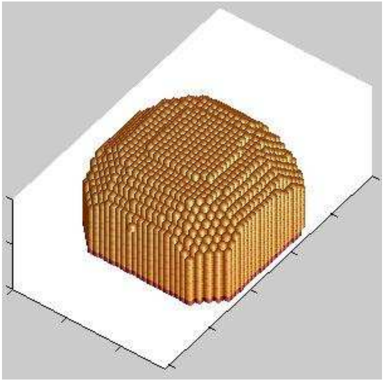
Wetting control parameter

$$\chi = \frac{J_{s1}}{J_1}$$

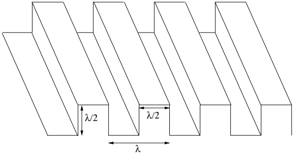
Cube $\zeta = 0$

$$\psi = 5 - 4\chi$$

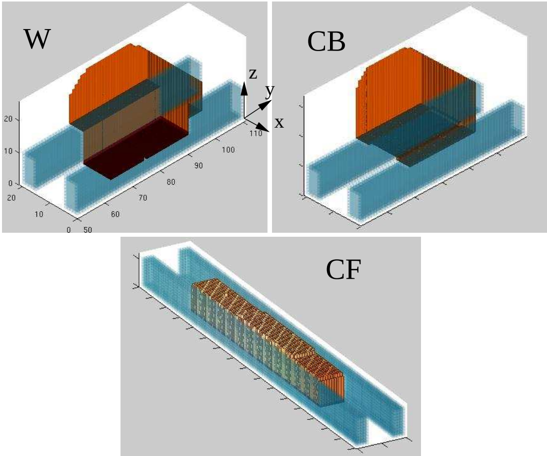
KMC:
$N = 11025$, $\zeta = 0.2$, $\chi = 0.4$, $T/J_1 = 0.5$
Error: Energy 1%; ψ 3%.



Parallel nano-grooves



$N = 10^4$
$\lambda = 20$
$\zeta = 0.2$
$\chi = 0.4$
$T/J_1 = 0.5$
Parallel grooves:
Cassie-Baxter state (CB)
Wenzel state (W)
Capillary filling (CF)



ψ

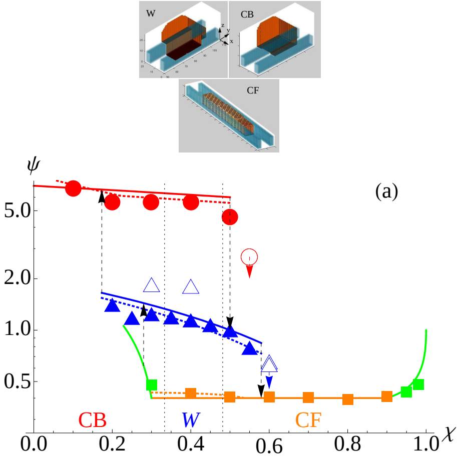
Wetting parameter

$$\psi = \frac{\mathcal{S}_{AV}}{\mathcal{S}_{AS}}$$

neglecting (110) and (111)

$$\psi_{CB} = 7 - 2\chi$$
$$\psi_{W} = 2 - 2\chi$$
$$\psi_{CF} = \frac{1}{3} + \frac{1}{12v}.$$

$v = Na^3/\lambda^3$



Hysteresis/Stability

Instability thresholds

$$\chi_{CB\rightarrow W} = \frac{1}{2}.$$

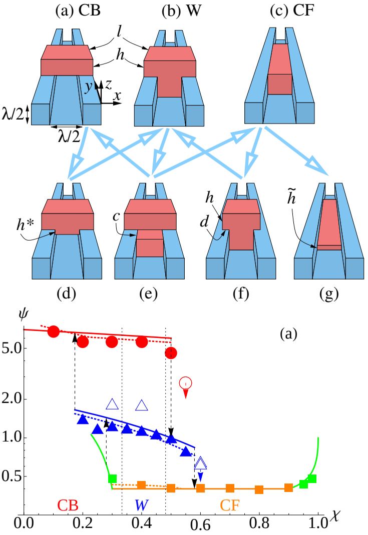
$$\chi_{W\rightarrow CB} = \frac{1}{3} - \frac{1}{36v}\left[1 + (1+30v)^{1/2}\right],$$

$$\chi_{W\rightarrow CF} = \frac{2}{3} - \frac{1}{36v}\left[1 + (1+6v)^{1/2}\right],$$

$$\chi_{CF\downarrow} = 1 - \frac{1}{8v}$$

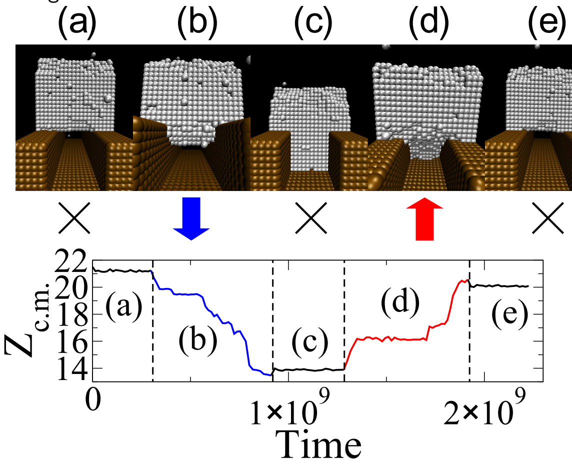
$$\chi_{CF\uparrow} = \frac{1}{3} - \frac{1}{24v}$$

Finite temperature effects $CF \rightarrow W$



Migration-induced switching

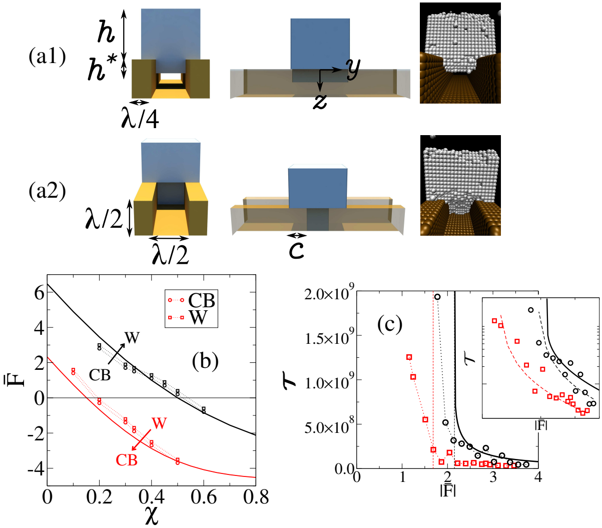
Nanoswitch controlled by an electron beam
KMC wih imposed migration



M. Ignacio, OPL, PRE (2015)

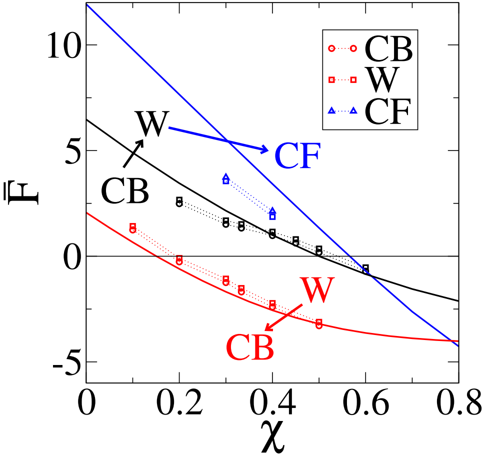
Migration-induced switching

Phase diagram $\bar{F} = FN/(\gamma_{100}\lambda)$



Migration-induced switching

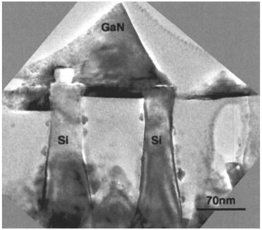
Phase diagram $\bar{F} = FN/(\gamma_{100}\lambda)$



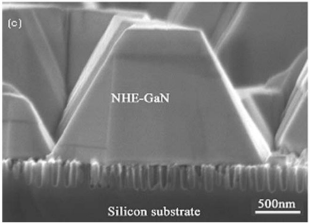
Nanocrystals in Cassie-Baxter state

Growth of GaN on Si nano-pillars

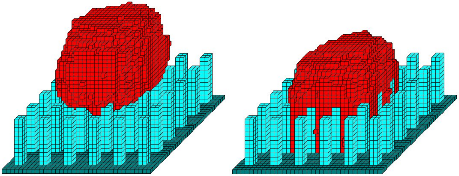
Hersee *et al* J.A.P. 2005



Zang et al, APL 2006



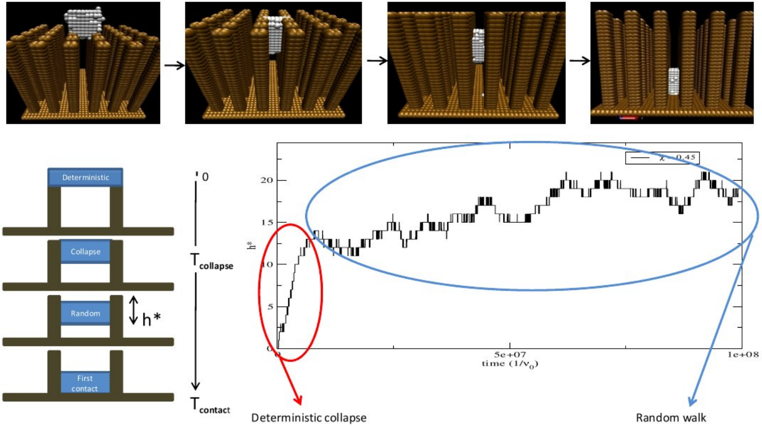
- Avoiding dislocations?
- Growing without collapse?
- Stability?



(a) (b)

$\chi = 0.390$, $\chi = 0.405$

Dynamics of the island: 3 Stages



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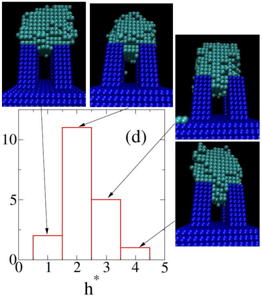
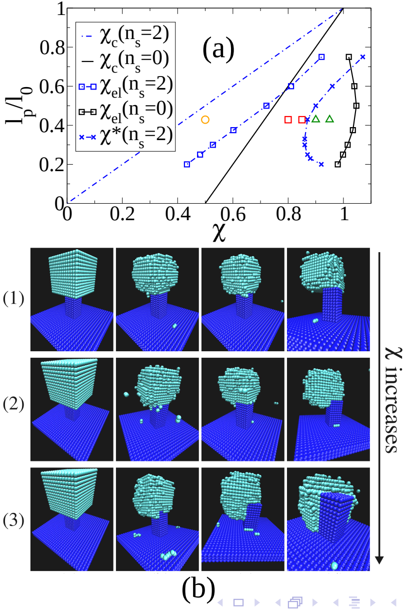
Elastic islands on nano-pillars

3D KMC with elastic effects

- Extended stability
- Asymmetric CB state
- Partially collapsed state

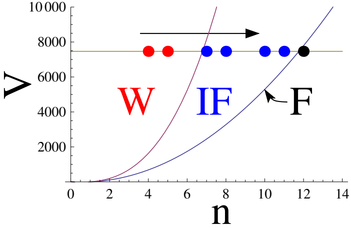


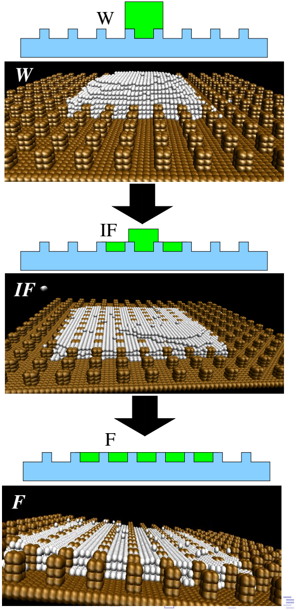
M. Ignacio, Y. Saito, P. Smereka, OPL, PRL 2014



Imbibition criterion

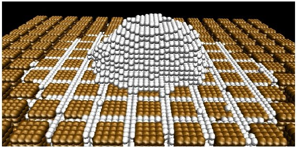
$$1 > \chi > \chi_{imb} = \frac{1}{2}\left(1 + \frac{\ell_x^2 - \ell_p^2}{\ell_x^2 + 4h\ell_p - \ell_p^2}\right)$$

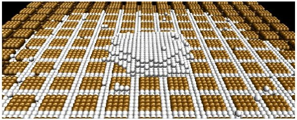




Diffusion-limited spreading

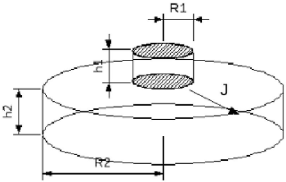
$\chi = 0.8,\ \ell_x = 6,\ h = 3,\ \ell_p = 4$

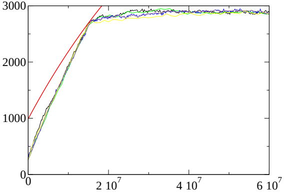




$L \sim t^{1/2}$, and $A \sim t$ with log corrections

$$(V - A_2 h(1-\phi))(1 - \ln[(\frac{(1-\phi)\pi h}{V})^{\frac{3}{2}} \frac{V - A_2 h(1-\phi)}{\pi 2\phi(1-\chi)}])$$
$$= \frac{3}{2}\pi\Omega^2 D C_{eq} \frac{\gamma}{k_b T} \frac{(t_0 - t)}{(1-\phi)h}[\phi\rho(2\chi - 1) - 2(1-\chi)(1-\phi)]$$

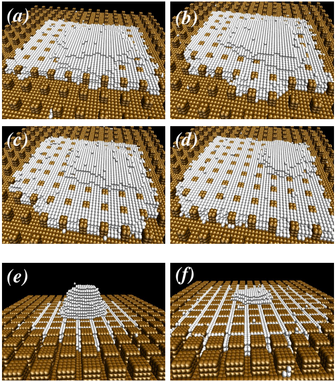


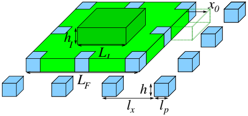


P. Gaillard, Y. Saito, OPL, Phys Rev Lett 2011

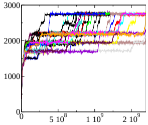
Nucleation-limited imbibition front motion

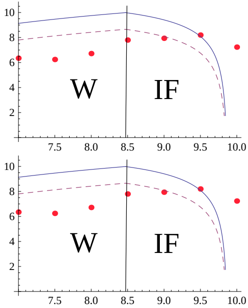
$\chi = 0.8,\ \ell_x = 6,\ h = 3,\ \ell_p = 2$





P. Gaillard, Y. Saito, OPL, Phys Rev Lett 2011





Summary

- Equilibrium and stability of isands and films
- Deweting of solid films: Rim facetting, Instability Coarsening and Ansitotropy
- Islands on nano-patterns: Multi-stability / Collapse / Elasticity
- Wetting of reactive islands

Other related issues and Perspectives

- Reactive wetting and nanowire growth
- Surface melting
- Non-equilibrium TL condition
- Link to complex fluids (polymers, etc)
- ... nucleation and growth