Persistence in Reactive-Wetting Interfaces

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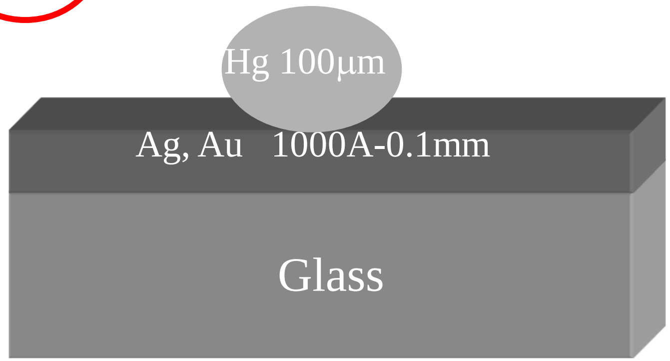
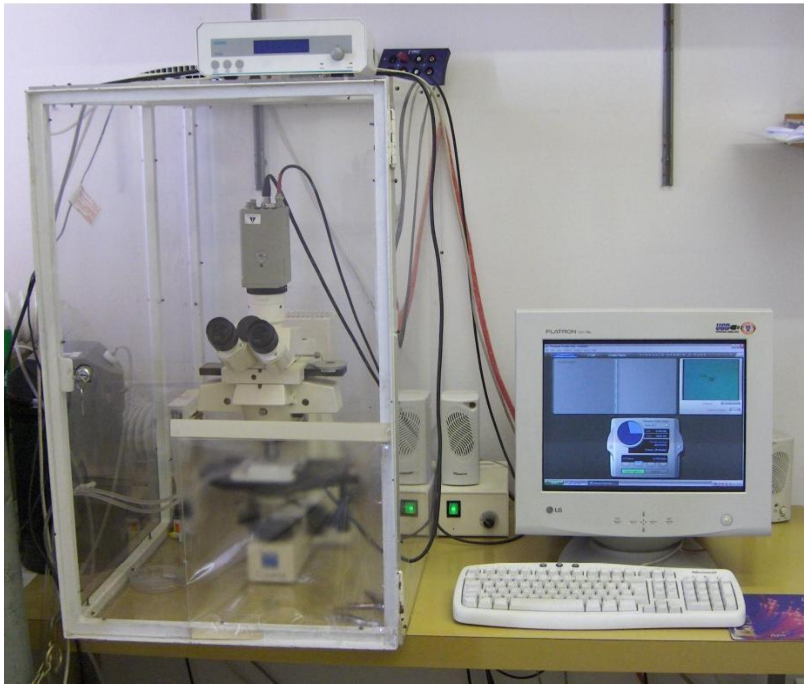
Hg-Ag (Au) Reactive-Wetting in Room Temperature



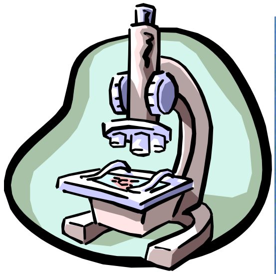
Side-view

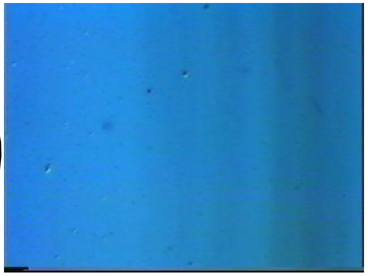
Top-view



Optical microscope + DIC

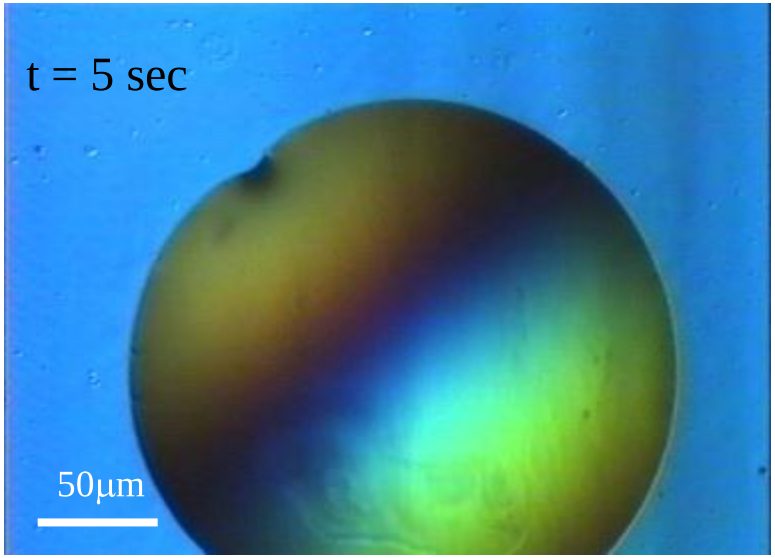
CCD Camera





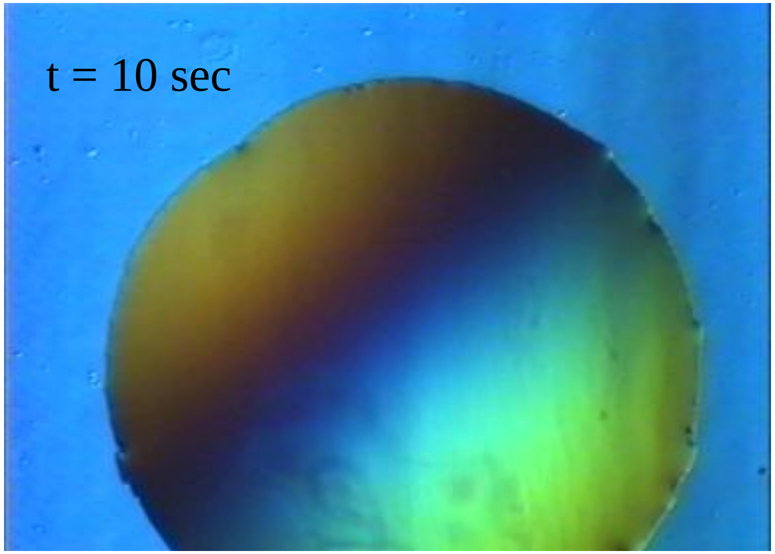
Silver 4200A

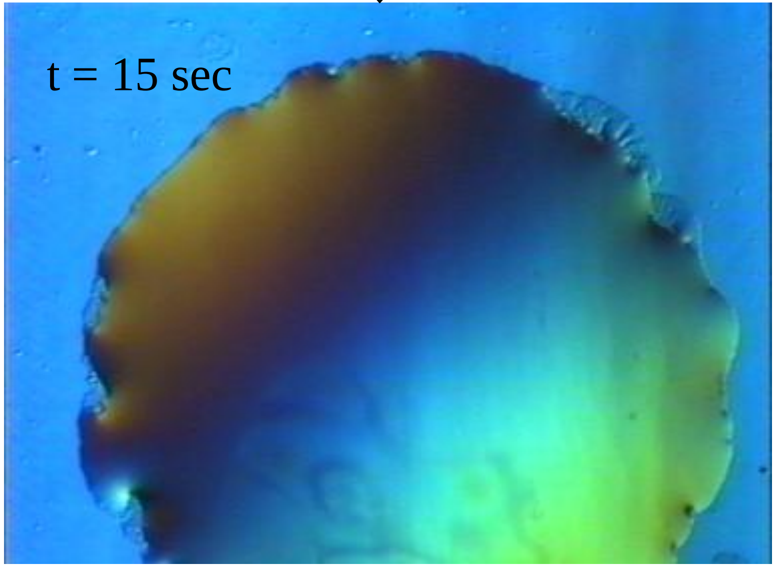
t = 5, 10, 15 sec



Bulk Spreading

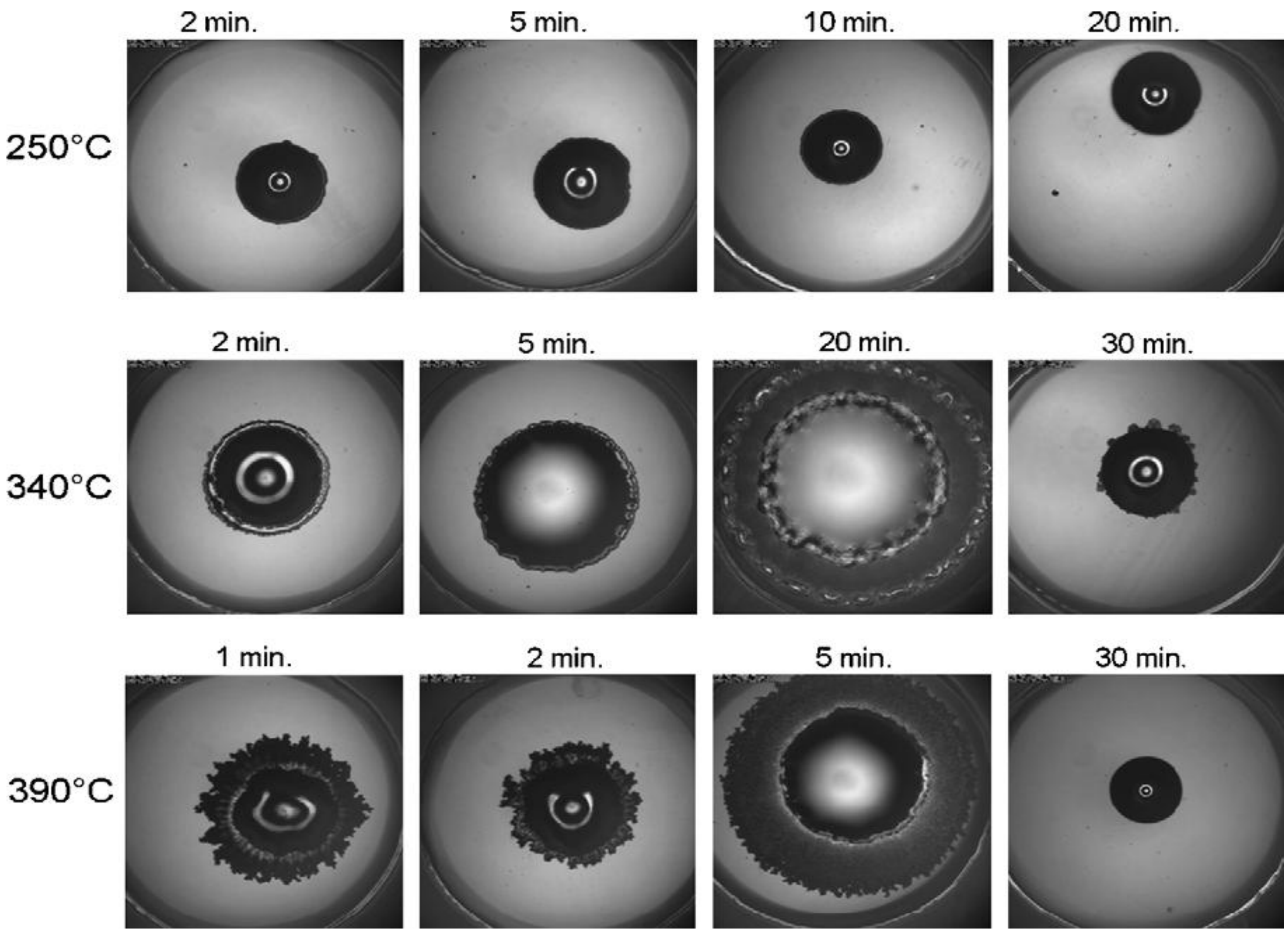
Kinetic Roughening



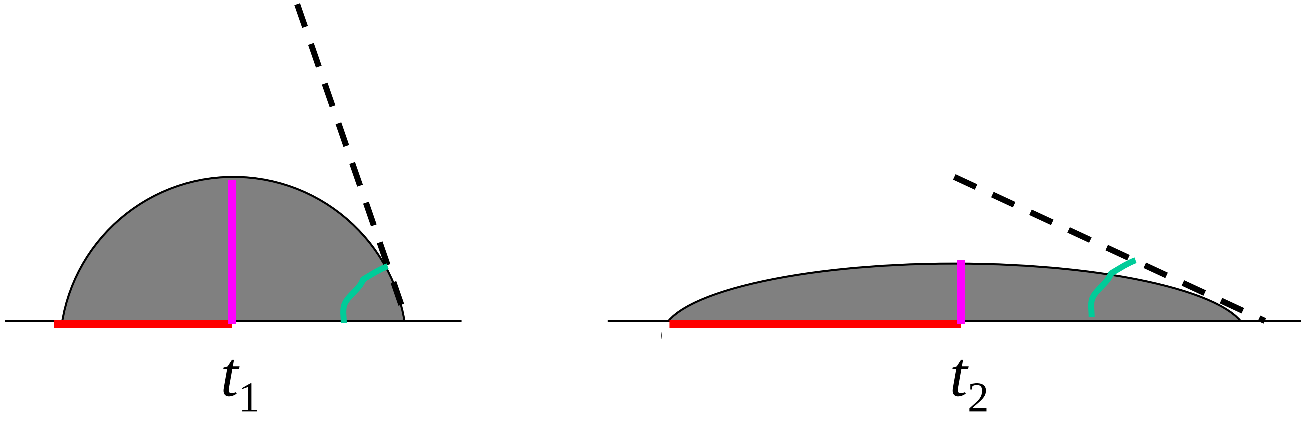


Kinetic Roughening in <u>High</u> Temperature

Sn spreading on 1μm Au-coated 12μm Cu (**Singler et al 2008**)



Dynamics of <u>Classical</u> Wetting

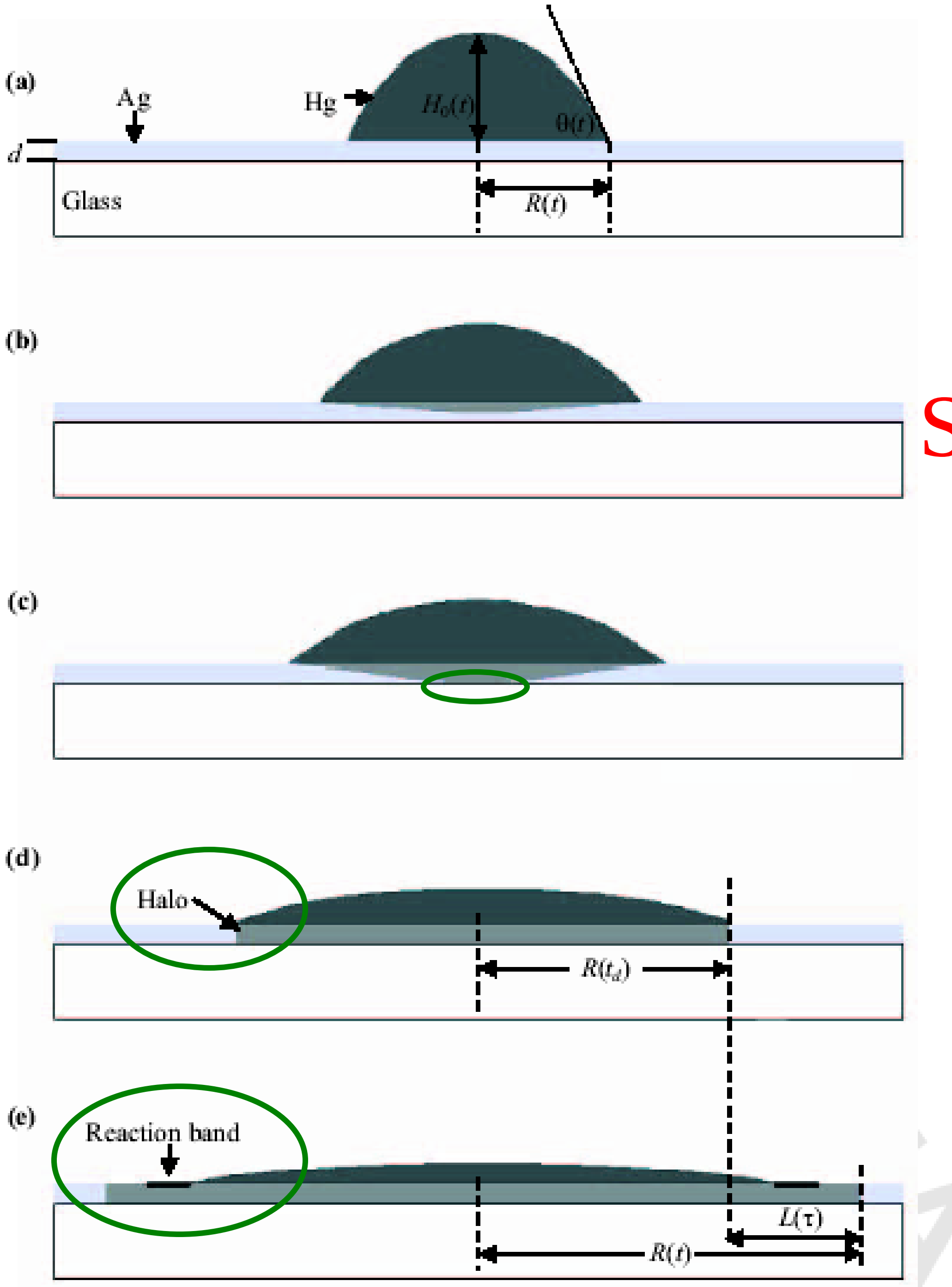


Side view

Tanner's Law

$\boldsymbol{\theta(t)}$	$t^{-3/10}$
$\boldsymbol{R(t)}$	$t^{1/10}$
$H(r=0,t)$	$\frac{1}{2}R(t)\theta(t)$

Reactive wetting ?



Droplet placement

Spreading & reaction

Touching the glass

Halo – fast flow

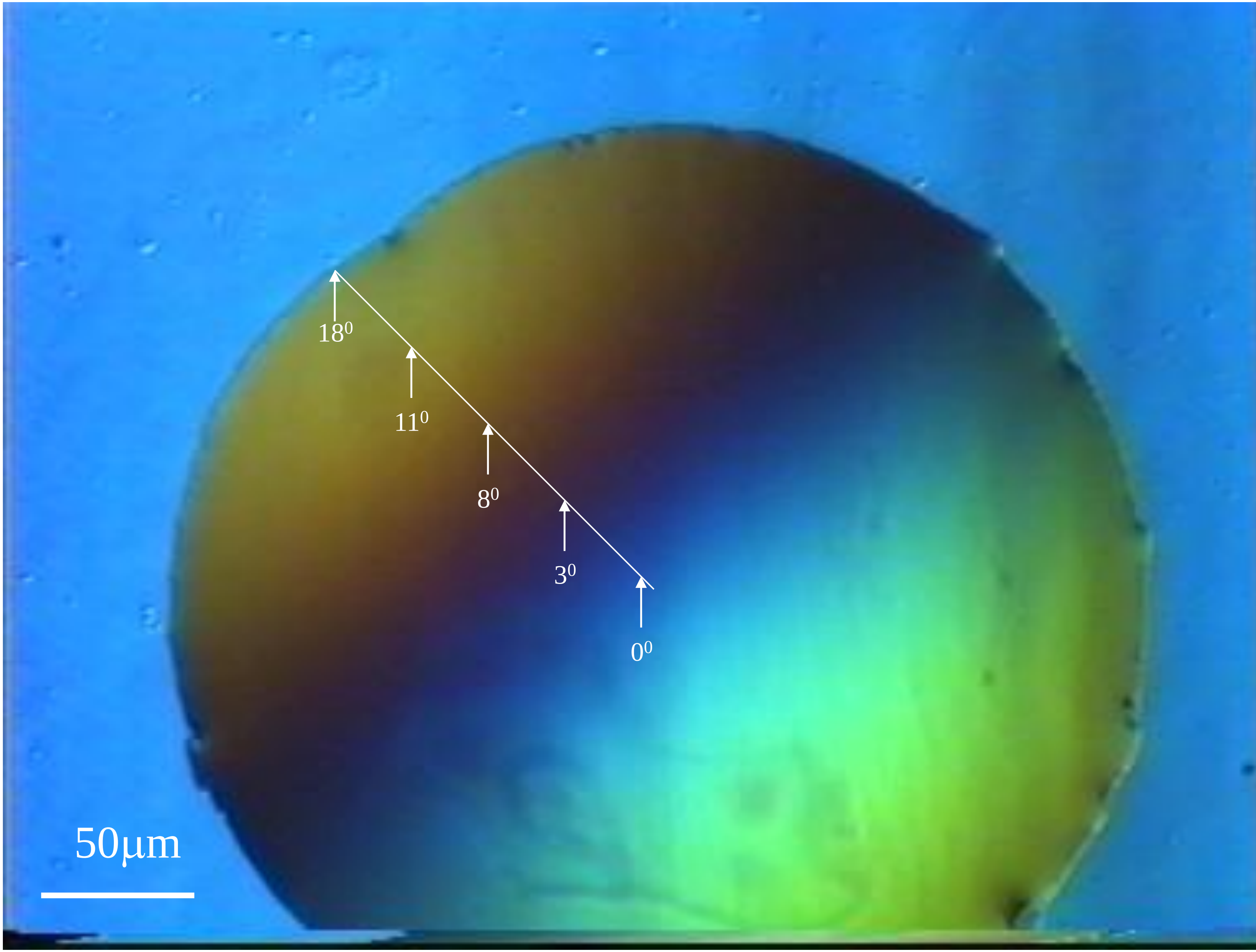
Final stage

Side-View ??

Dynamical 3-D Shape Reconstruction

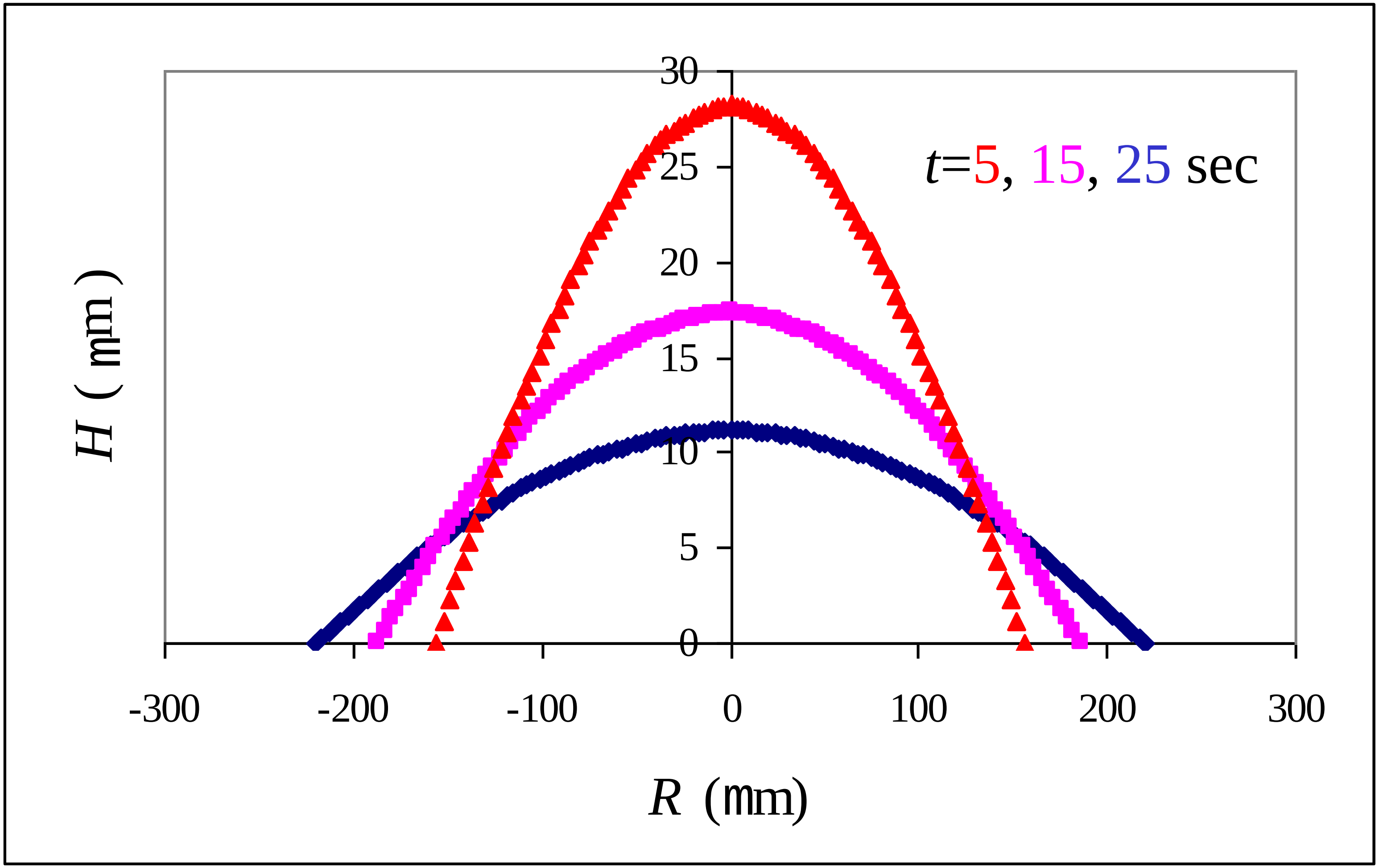
Side View from a Top View !

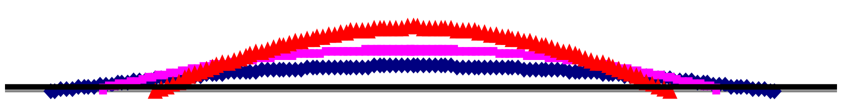
Be’er & Lereah, JOM 2002



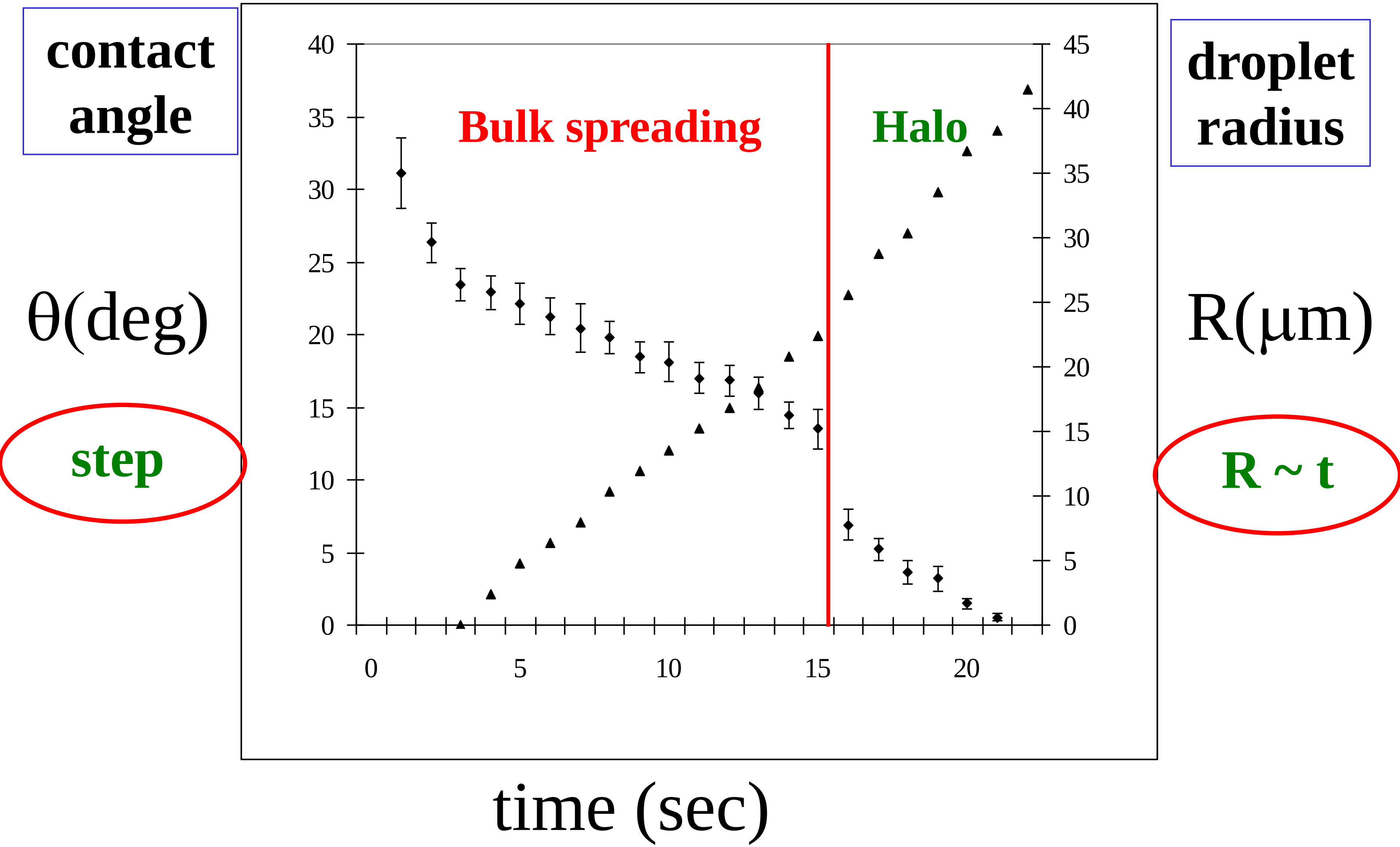
18⁰
11⁰
8⁰
3⁰
0⁰
50µm

Silver 4200 A

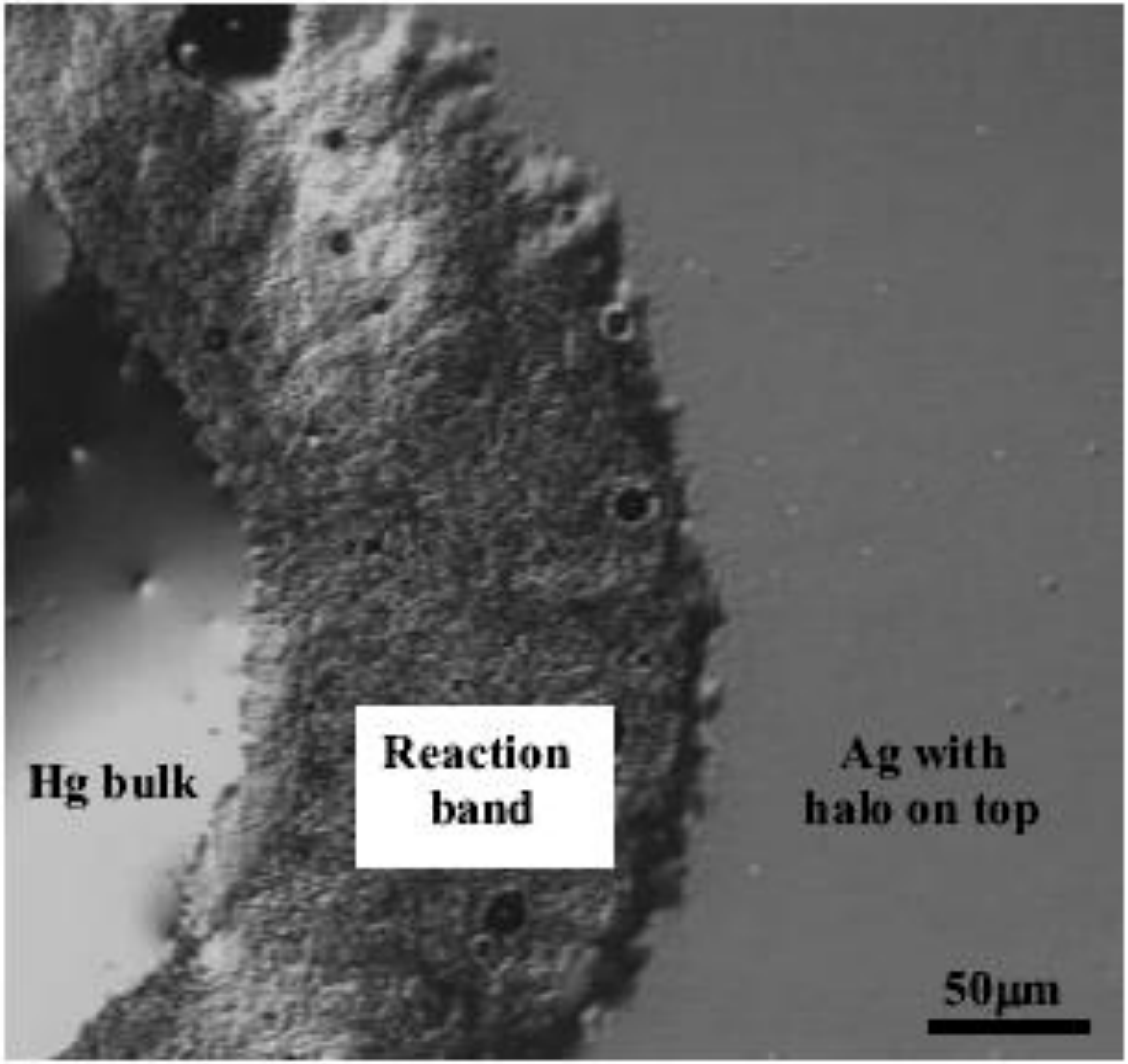




Silver 4200 A



Final stage – Top-view



SEM

Ag_3Hg_4

Ag_4Hg_3

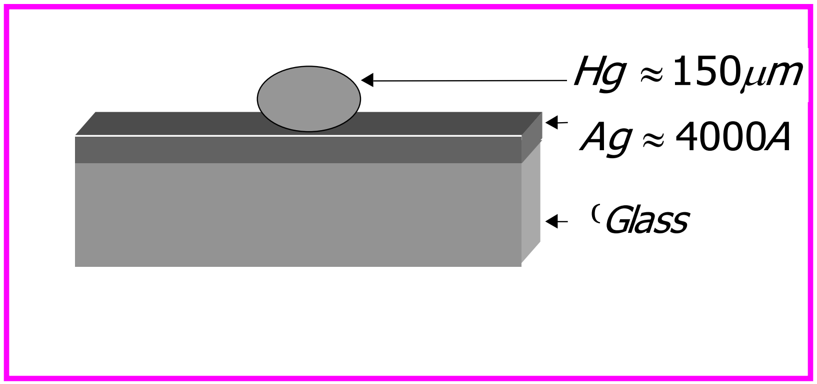
Kinetic Roughening of the Reaction Band

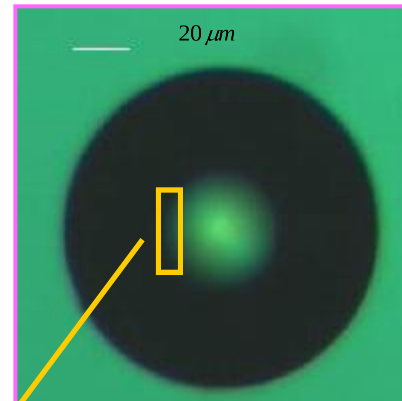
Screen height - about 100μm

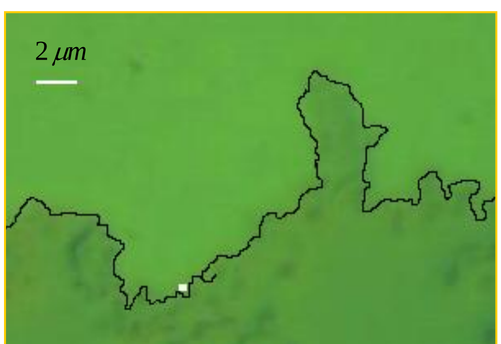
Ag thickness = 0.1 mm (foil)
Hg initial radius - about 150 μm.
Bulk height from surface - about 1 μm.

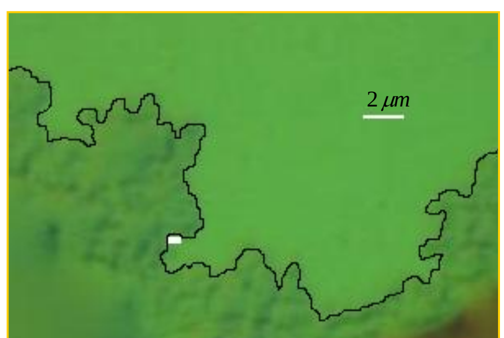
Initial time here is 15 sec
Total time of experiment = 5 min

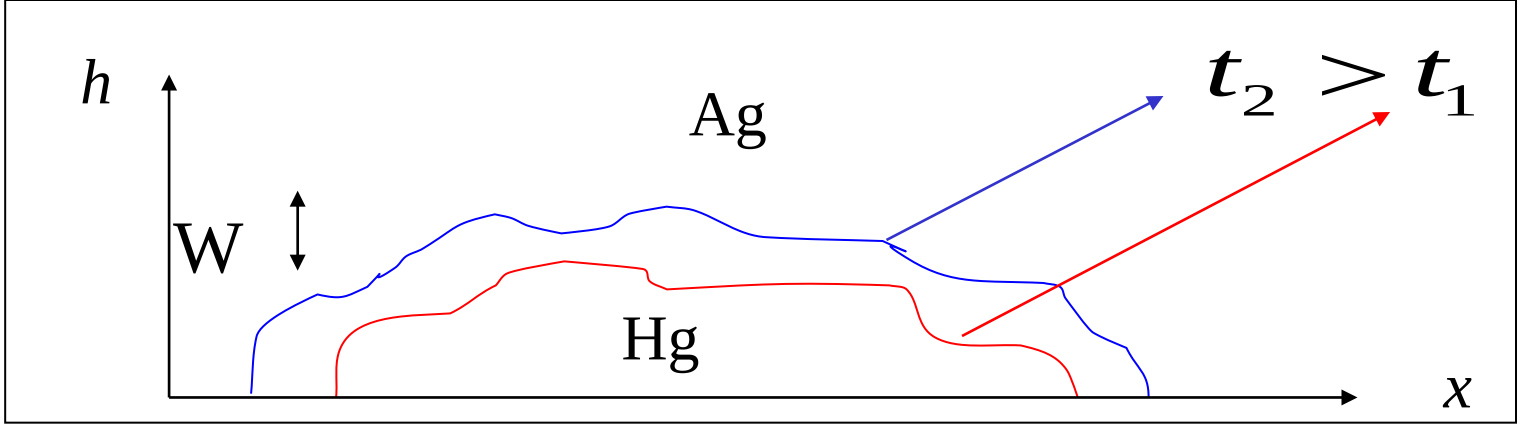
Complex Interface Patterns











$$W^2(L,t) = \langle h(x,t)^2 \rangle - \langle h(x,t) \rangle^2$$

Family-Vicsek scaling

$$W(L,t) \approx \begin{cases} t^{\beta} & t \ll t_0 \\ L^{\alpha} & t \gg t_0 \end{cases}$$

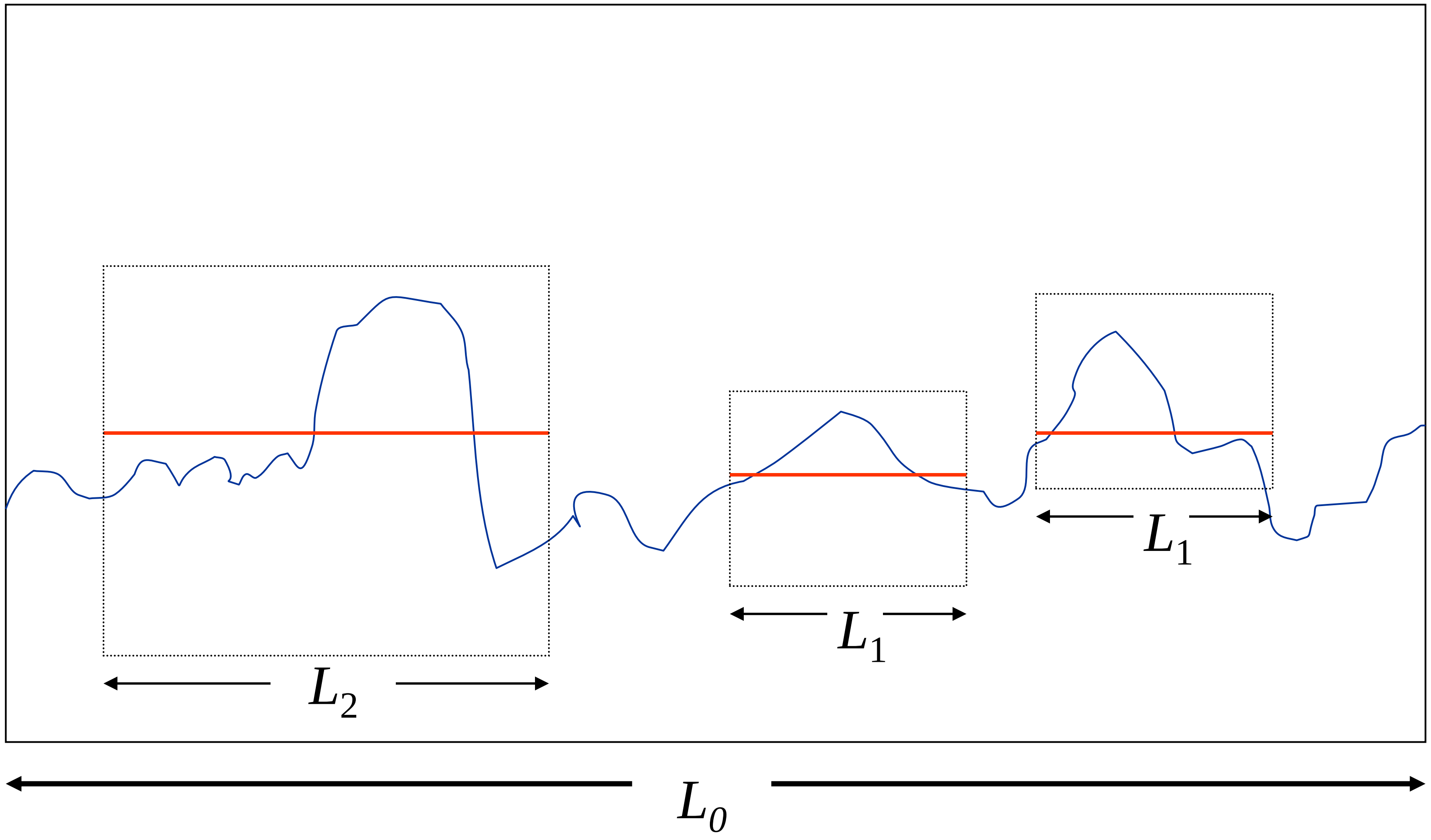
$$t_0 \propto L_0^{\alpha/\beta}$$

β - growth
α – roughness

In isotropic systems

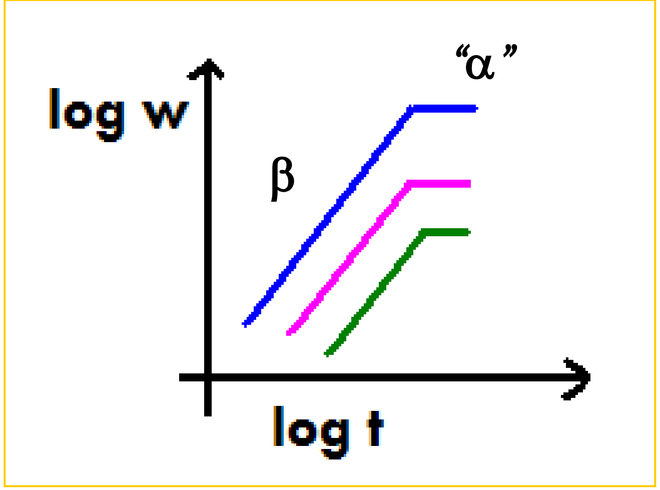
$$\alpha + \alpha/\beta = 2$$

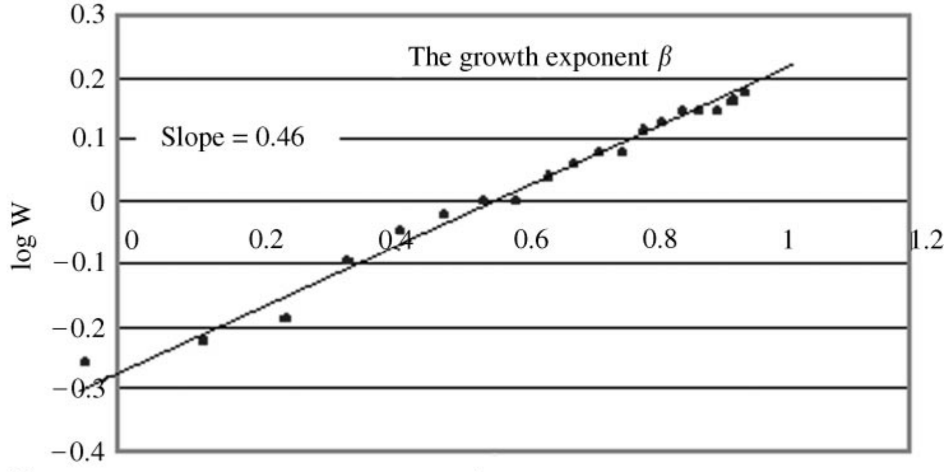
$$W^2(L,t) = \langle h(x,t)^2 \rangle - \langle h(x,t) \rangle^2$$



Scaling Exponents

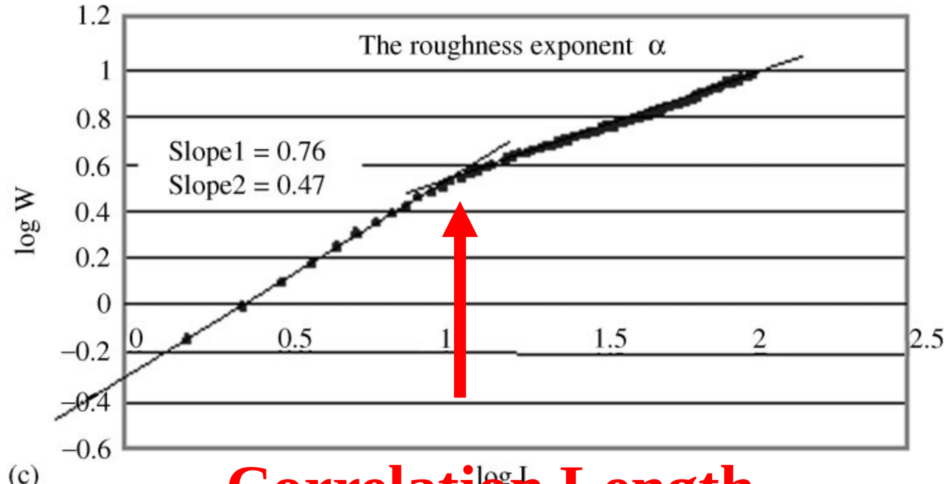
Silver 2000 A





(b)

$$\beta = 0.46 \pm 0.02$$



(c)

Correlation Length

$$\alpha = 0.76 \rightarrow 0.47$$

Crossover behavior

Summary of Results

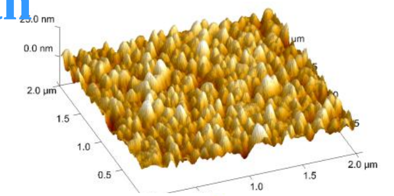
NOISE –

Substrate Roughnes

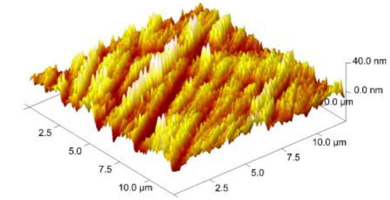
Material	Thickness	α	β
Silver	2000A	0.76 ± 0.03	0.46 ± 0.02
	0.1mm	0.82 ± 0.04	0.60 ± 0.02
Gold	1500A	0.85 ± 0.03	0.76 ± 0.03
	3000A	0.86 ± 0.04	1.00 ± 0.04

Correlation length

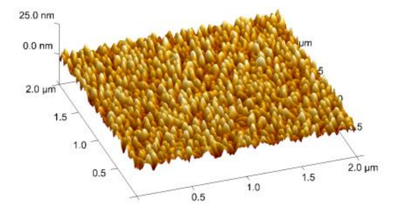
2μm



8μm



7μm

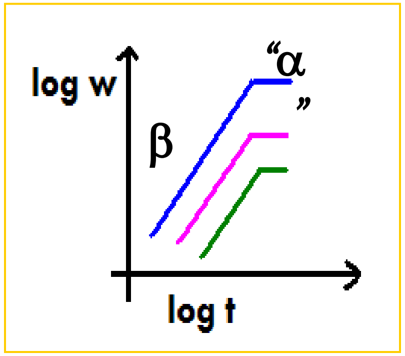


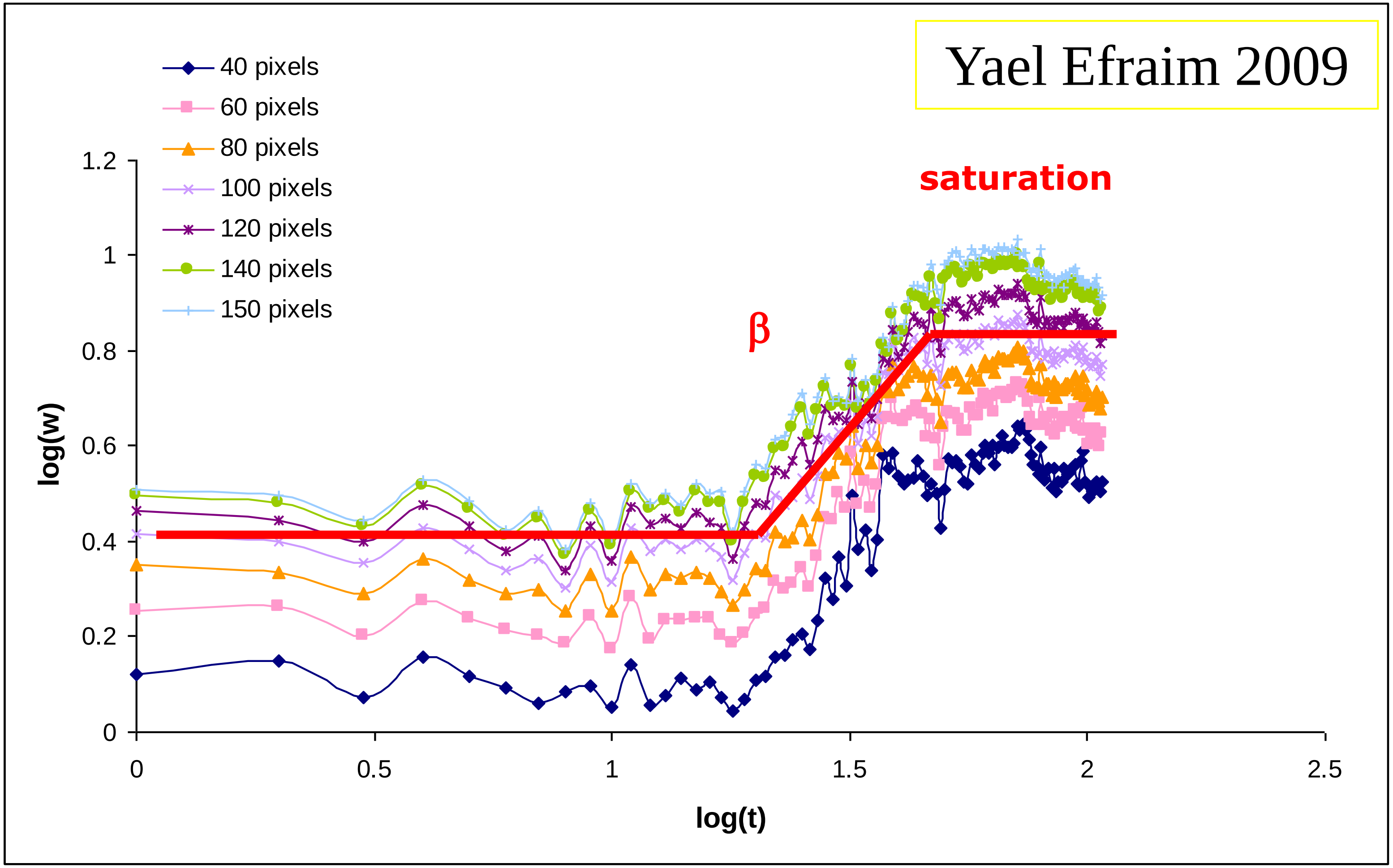
14μm

Universality Class ??

$\alpha + \alpha/\beta = 2$?

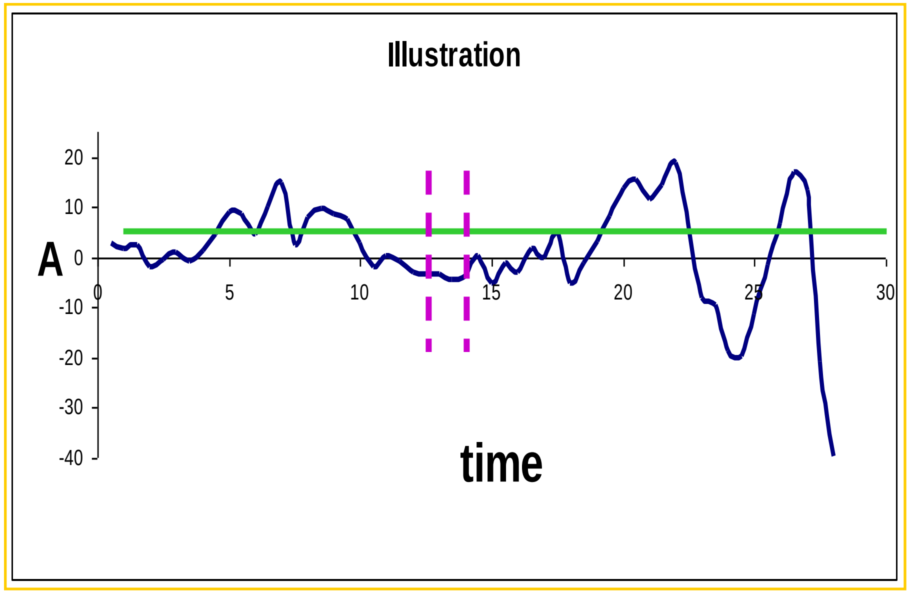
What really happens in the growth regime ???





The persistence measure

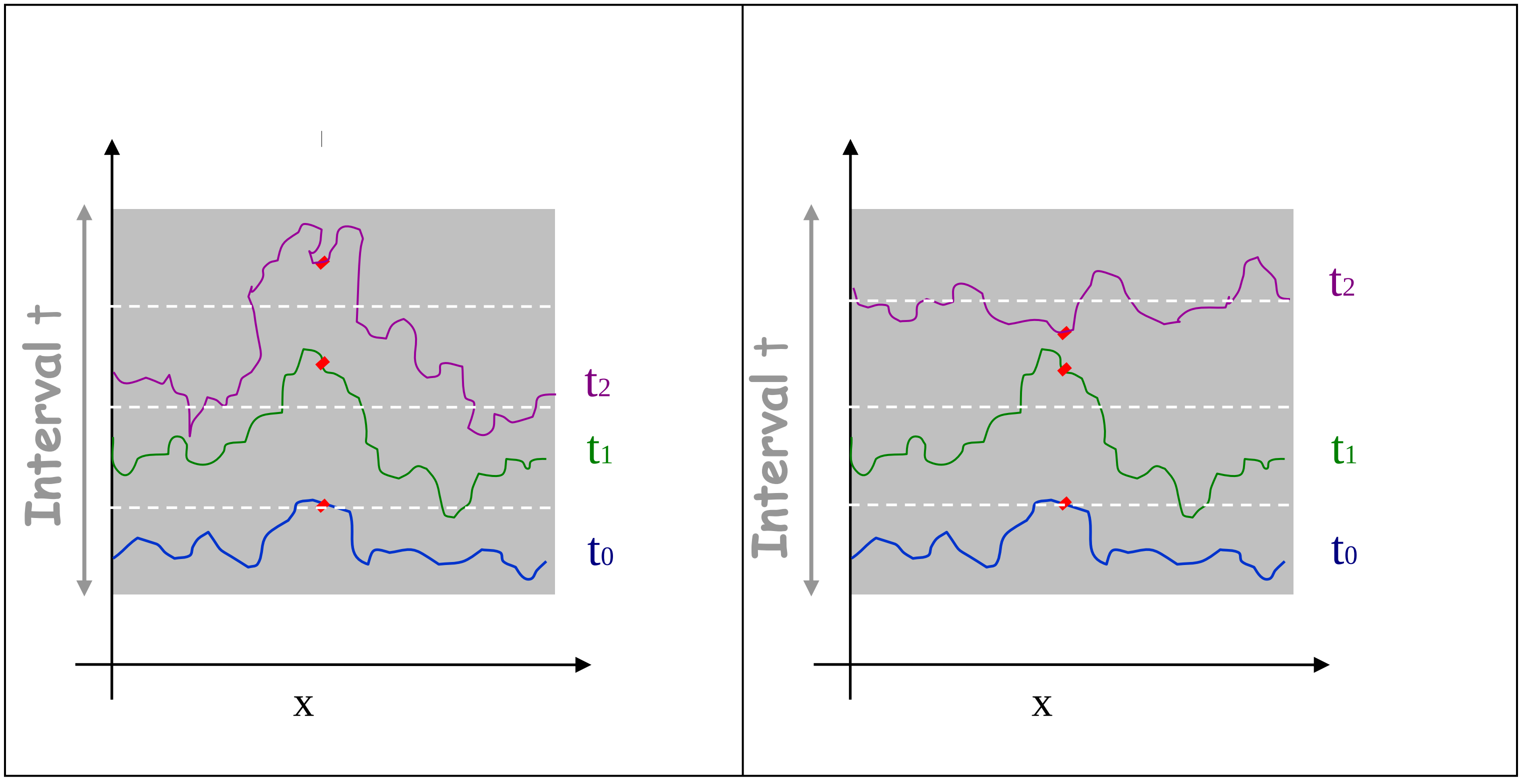
- **Persistence probability P(t) is the probability that a certain flactuative variable never crosses a chosen reference level within time interval t.**



Universal scaling form: $\boxed{P(t) \propto t^{-\theta}}$

Derrida *et al.* PRL (1994)

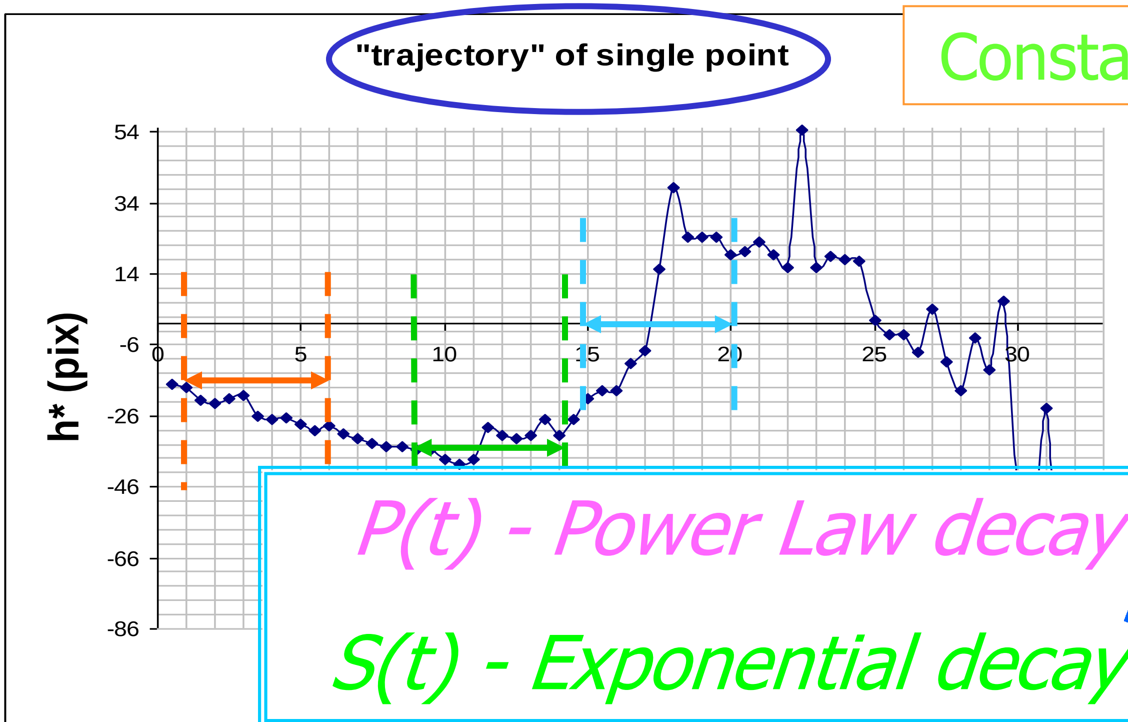
Persistence in Reactive-Wetting Interface



- Flactuative variable- “location” of points on interface
- Reference level- height at time t_0

Survival - the algorithm

- Single point – distance from <h> vs. t
- Divide t axis to intervals in length t′ where t′=1,2…T_{max} sec
- Count "persistent" intervals for each t.



Constant reference level - h*=0

$S(x,t_0,t_0+t)$ *is prob. that* $sign[h(x,t_0+t')]$ *remains the same for all* $0 \le t' \le t$

- Average over t_0 & x:

$S(x,t_0,t_0+t) \to S(t)$

C. Dasgupta et. al.

P(t) - Power Law decay

S(t) - Exponential decay

Persistence Exponent Results

- Ising model (PRL 1996) $\theta = 0.37, 0.22, 0.26$ (1d, 2d, 3d)
- Potts model (Physica 1996) $\theta = 0.86$ (2d- large q)
- Random walk (PRE 1997) $\theta = 0.5$
- Linear Langevin equations (PRE 1997) $\theta_c = 1 - \beta$
- KPZ equation (Europhys. Lett. 1999) $\theta_+ = 1.18$ $\theta_- = 1.64$

Experimental results

- 2d Liquid crystal (PRE

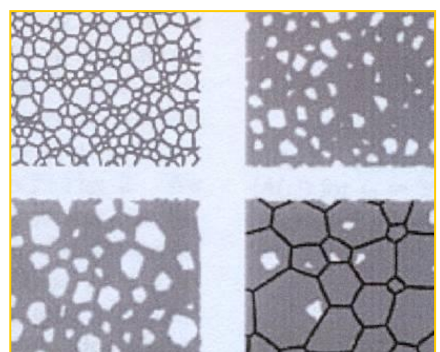
Relation θ=1-β is valid
even though system is non-linear

- Fluctuating monatomi

$$\theta = 0.77 \pm 0.03$$

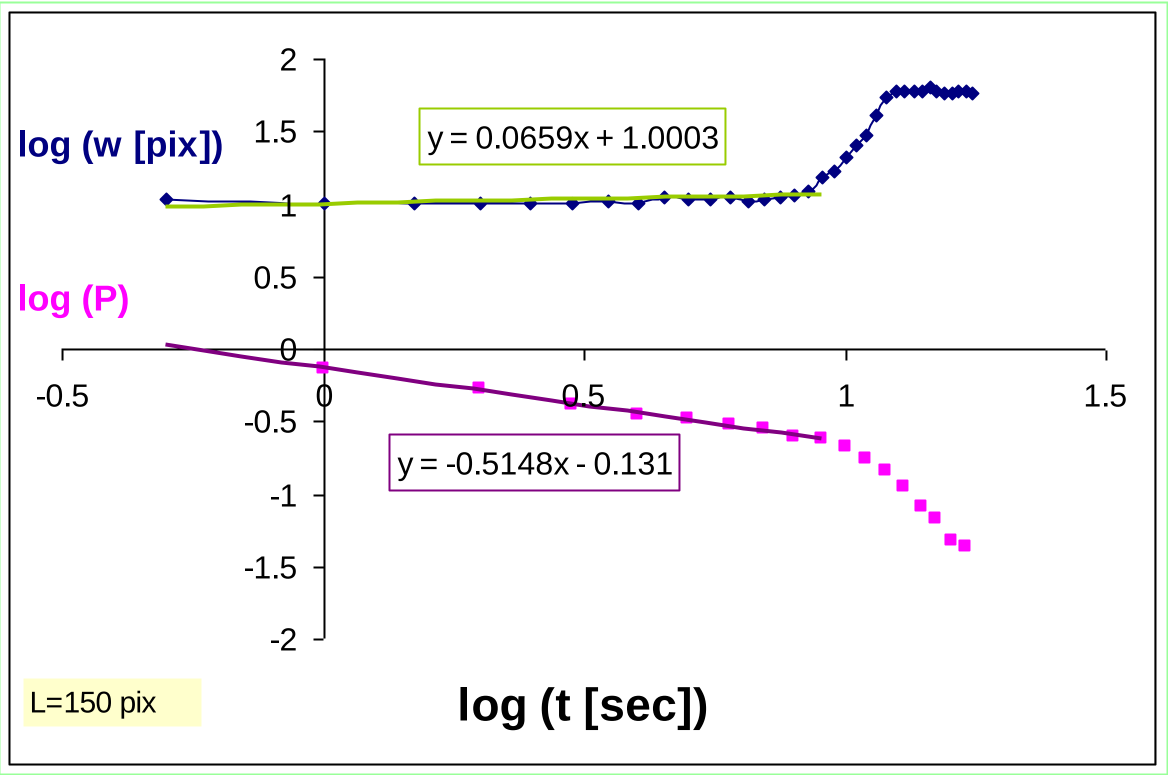
- Combustion fronts in paper (PRL 2003) $\theta = 0.66 \pm 0.03$

- 2d Soap froth (PRL 1997)



$$\theta = 0.88 \pm 0.02$$

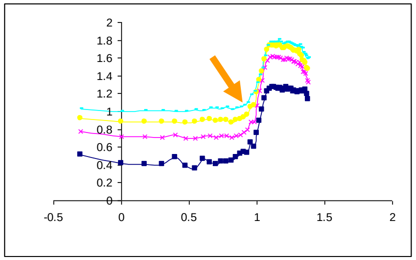
Results for Reactive-Wetting

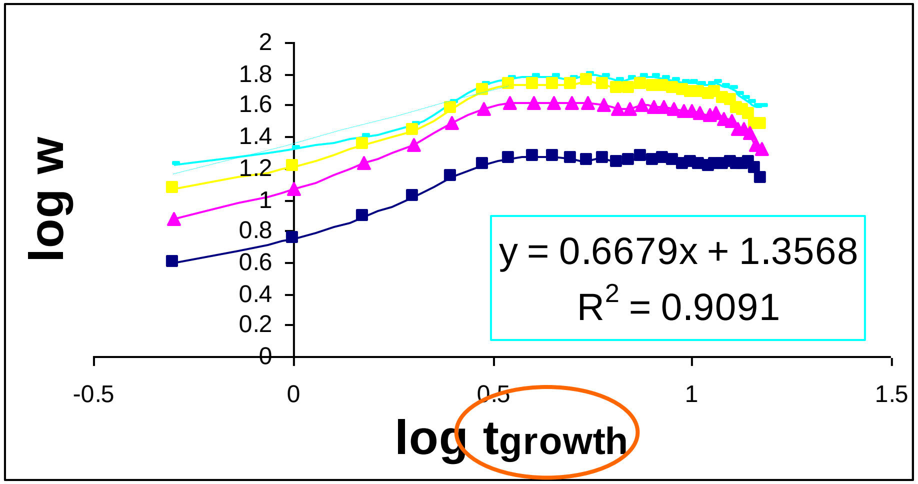


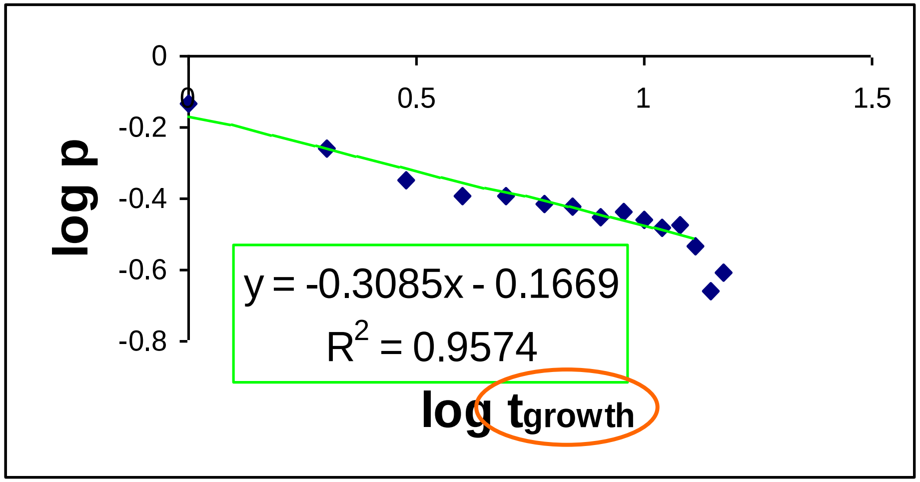
- First time regime:
- $W(t) \approx const$
- $\theta = 0.55 \pm 0.05$
- Random walk

- Persistence in growth regime → **new calculation !**

Persistence – growth regime

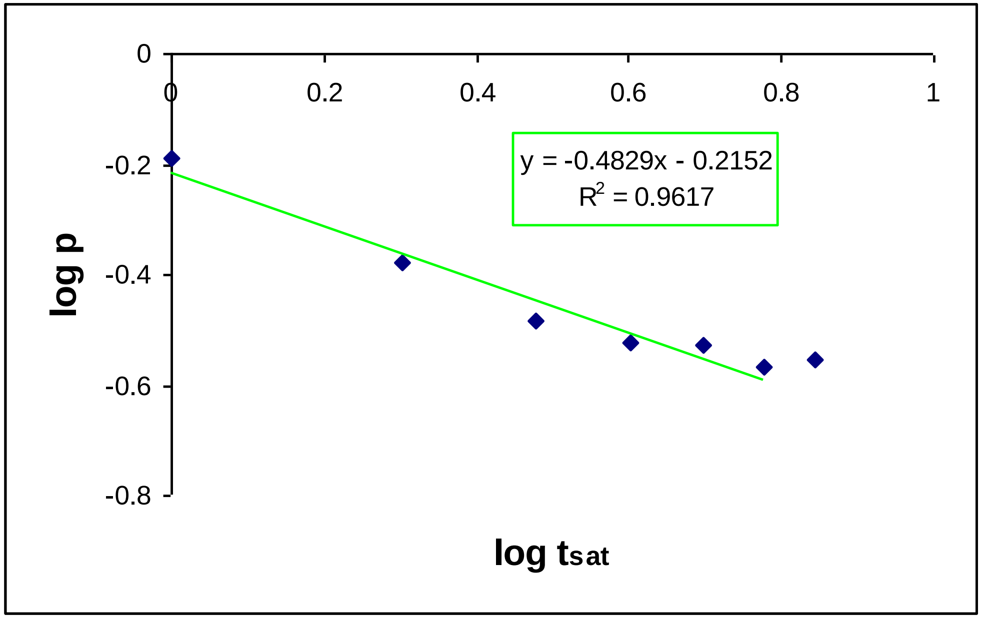


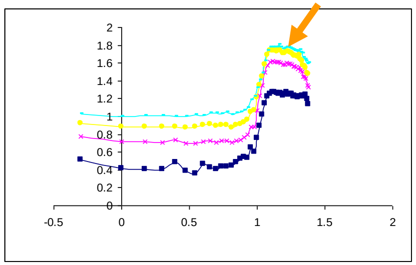




- $\beta = 0.68 \pm 0.07$, $\theta = 0.37 \pm 0.05$
- Relation $\theta = 1 - \beta$ is valid: $\theta + \beta = 1.04 \pm 0.08$

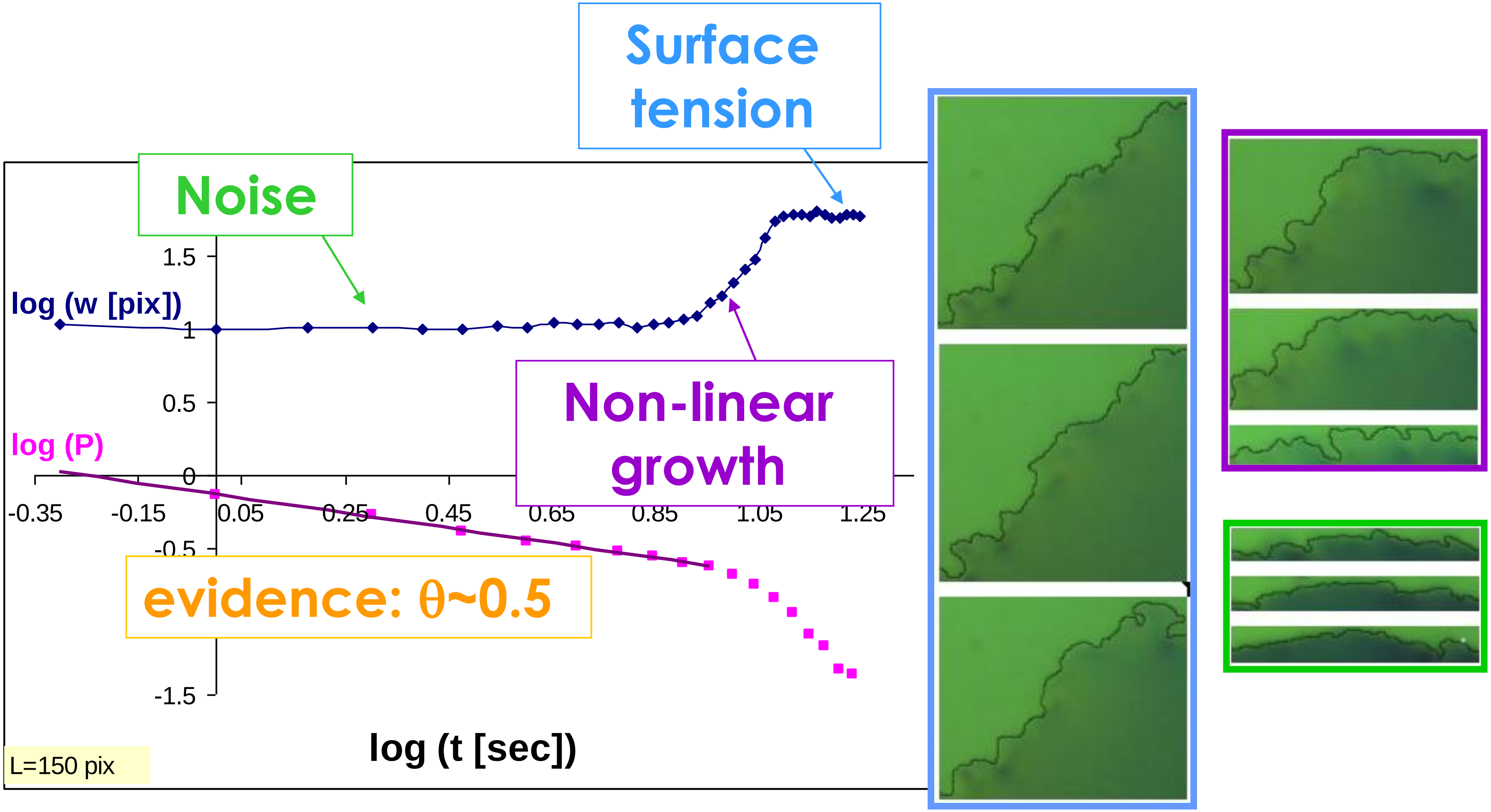
Persistence – saturation regime





- Random walk again: $\theta = 0.47 \pm 0.01$

Global interpretation



Persistence Summary

- ☺ Three kinetic regimes in experiment:
  - ☺ Transient regime - random walk mechanism
  - ☺ Growth regime - $\boxed{\theta + \beta = 1}$
  - ☺ Saturation regime - random walk again

- ☺ Growth: $\boxed{\beta = 0.68 \pm 0.07}$
- ☺ Persistence: $\boxed{\theta = 0.37 \pm 0.05}$

Validity of "Linear" relation in a non-linear system

Summary

- **Reactive-Wetting - Room Temperature**

  Side view from Top View
  Bulk Spreading – θ(t), R(t)

- **Interface Kinetic Roughening**

  Spatio - Roughness Exponent , Lateral Correlation Length
  Temporal - Growth Exponent, The Persistence Measure

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