



# Roughness and dynamics of a contact line on a disordered substrate

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## Introduction : Contact line on a disordered substrate

The shape of the CL is distorted as a result of a competition between its **stiffness** and the **defects** of the substrate.

Long-range elasticity of the CL:

$$K_{el}[\eta] = -\frac{1}{\pi} \gamma \sin^2 \theta \int dx' \frac{\eta(x')}{(x-x')^2}$$

Model:

$$\mu \left( v + \frac{\partial \eta}{\partial t} \right) = F_{app} + f(x, y) + K_{el}[\eta]$$

viscous dissipation

pulling force

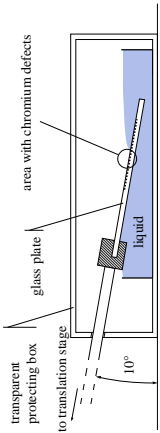
disorder

elasticity



Contact line (CL) on a disordered substrate

## Experimental setup

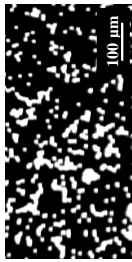


The mean velocity  $v$  of the CL is imposed by withdrawing the substrate from the liquid bath with a constant velocity.

Range of  $v$ :  $0.2 \mu\text{m/s} - 20 \mu\text{m/s}$

**Liquid:** water or water/glycerol mixture (20× more viscous than water)

**Substrate:** Glass plate covered, by photolithographic process, with  $10 \times 10 \mu\text{m}^2$  square defects of Chromium



receding angles:  $\theta_{\text{glass}} \approx 30^\circ$   
 $\theta_{\text{chromium}} \approx 40^\circ$   
well controlled disorder ( $\xi = 10 \mu\text{m}$ )

## Roughness of the contact line

Definition:

$$W(L) = \left\langle \left( \eta(x+L) - \eta(x) \right)^2 \right\rangle^{1/2}$$

Observation:

$W(L)$  depends neither on the velocity  $v$  nor on the viscosity.

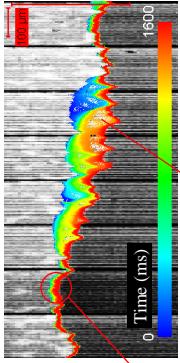
## Notations

- $v$ : mean velocity of the CL
- $\gamma$ : liquid-vapour surface tension
- $\theta$ : contact angle of the liquid on the substrate
- $\xi$ : correlation length of the disorder of the substrate
- $\zeta$ : roughness exponent
- $L_c$ : capillary length

For  $2\xi < L < Lc/2$ ,  $W(L) \propto L^\zeta$   
with  $0.48 < \zeta < 0.54$

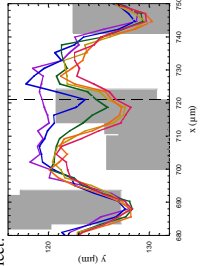
## Dynamics of the contact line

Studies with a fast camera (500 frames per second)  
Successive positions of the CL, time is represented by colour:



meeting with a chromium defect, fast jump forward: "avalanche"

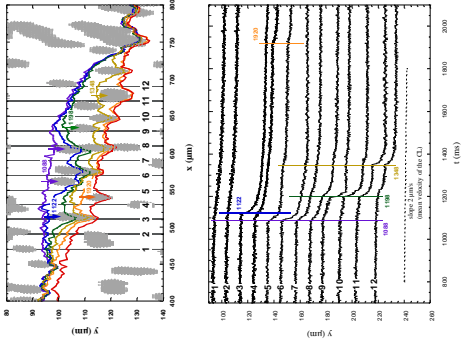
Meeting with a defect:



Observation:

- Maximum velocity  $\sim 2-3 \text{ mm/s}$ , independent of viscosity
- fast decrease of the velocity while the local pulling force has not vanished

For displacement of order of  $\xi$ , the CL motion can be considered as overdamped.



Position of the CL, just before meeting a new defect ( $\downarrow$ )

Temporal evolution of  $\eta(x)$  for fixed values of  $x$  (vertical lines in upper graph)

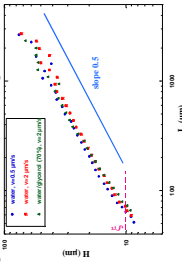
Observation:

"Simultaneous" acceleration of a large part of the CL around the defect  
Depinning from neighbouring defects occurs well after the shape of the meniscus has changed.

No retardation effect in the elastic restoring force

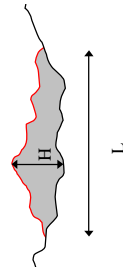
## Avalanches

Average height  $H$  of an avalanche of length  $L$ :



Studies with an ordinary CCD camera (25 frames per second)

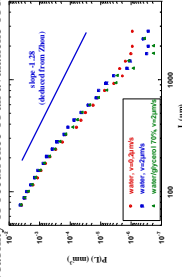
Black and red lines represent two successive "pinned" position of the CL.



$H(L)$  depends neither on  $v$  nor on the viscosity

Confirmation of the roughness exponent close to 0.5

Probability of occurrence of an avalanche of length  $L$ :



$P(L)$  depends neither on  $v$  nor on the viscosity

$P(L)$  decreases faster than a power law

## Discussion

What is missing?

Doubts still exist about:

- Dissipative term

$$\mu \left( v + \frac{\partial \eta}{\partial t} \right) = F_{app} + f(x, y) + K_{el}[\eta]$$

Is the dissipation due to viscosity?

Is this term linear in velocity?

Indications:

- The maximal local velocity during an avalanche does not depend on viscosity
- The contact angle hysteresis on bare glass (chromium) proves the existence of microscopic disorder ( $\ll \xi$ )

- Elastic force:

$$K_{el}[\eta] = -\frac{1}{\pi} \gamma \sin^2 \theta \int dx' \frac{\eta(x')}{(x-x')^2} + ???$$

It has been shown (Rosso & *al.*) that, for short-range elastic interaction, small non-harmonic correction can change the roughness exponent. What about long-range elasticity?

Future:

- study single defects to understand the effect of a non-linear dissipation term
- Investigate the dynamics of the system for higher velocities