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Main Scientific Interests

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SCIENTIFIC INTERESTS

KINETICS OF SPREADING

MEMBRANE SEPARATION

KINETICS OF REVERSIBLE COAGULATION

RHEOLOGY OF CONCENTRATED SUSPENSIONS

PUBLICATIONS	**259**
PRESENTATIONS AT SCIENTIFIC MEETINGS	**200**
h-index	**29**
Sitations	**2816**

PHD STUDENTS SUPERVISED

More than	**35**
DSc SUPERVISED	**3**

OUTLINE

SURFACE FORCES ACTION

SPREADING OVER POROUS SUBSTRATES: SATURATED AND DRY, SURFACTANT SOLUTIONS

SPREADING OVER SURFACES COVERED WITH FATTY ACID OR LIPID LAYERS

SPREADING OVER HYDROPHOBIC SURFACES

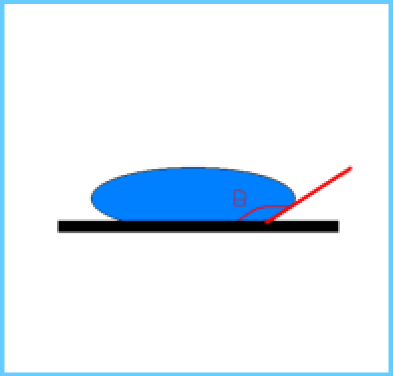
SUSFACTANTS ON THIN WATER LAYERS

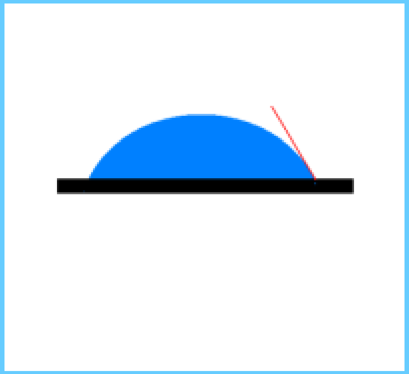
IMBIBITION INTO POROUS MEDIA

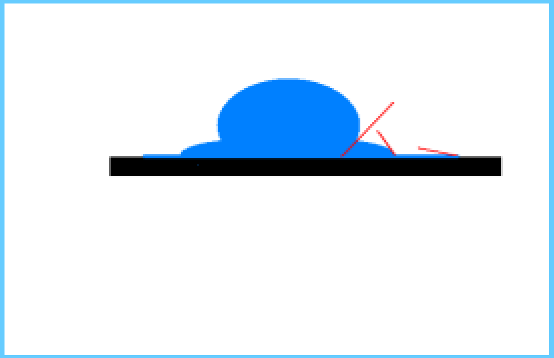
Rheology of concentrated suspensions/emulsions

A water droplet on three different substrates

θ contact angle







Teflon

Non-wetting,

$\theta > \pi/2$

Glass or mica

Partial wetting,

$0 < \theta < \pi/2$

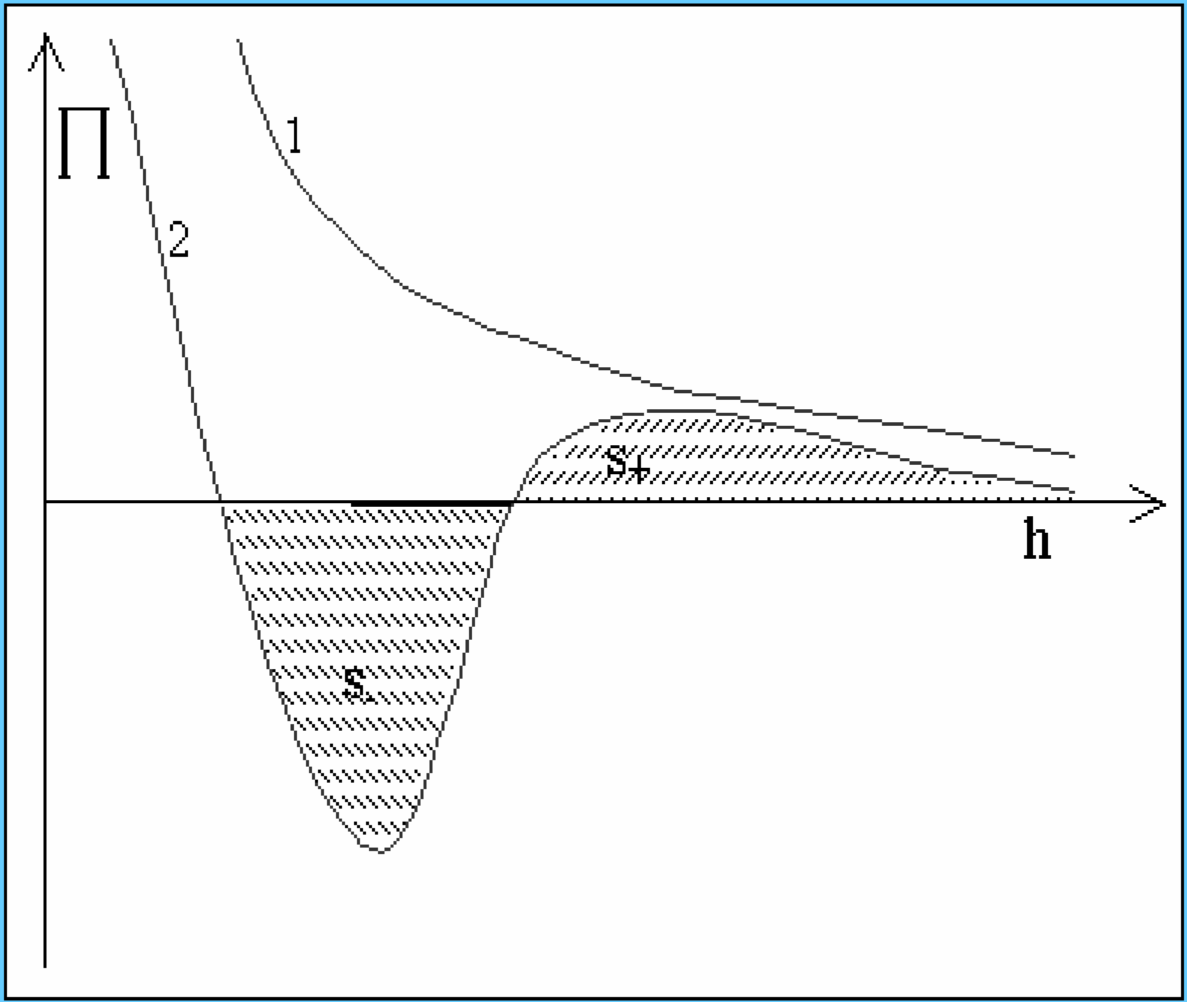
Complete wetting

Silicone wafer,

water spreads out completely

$\theta(t)$ dynamic contact angle

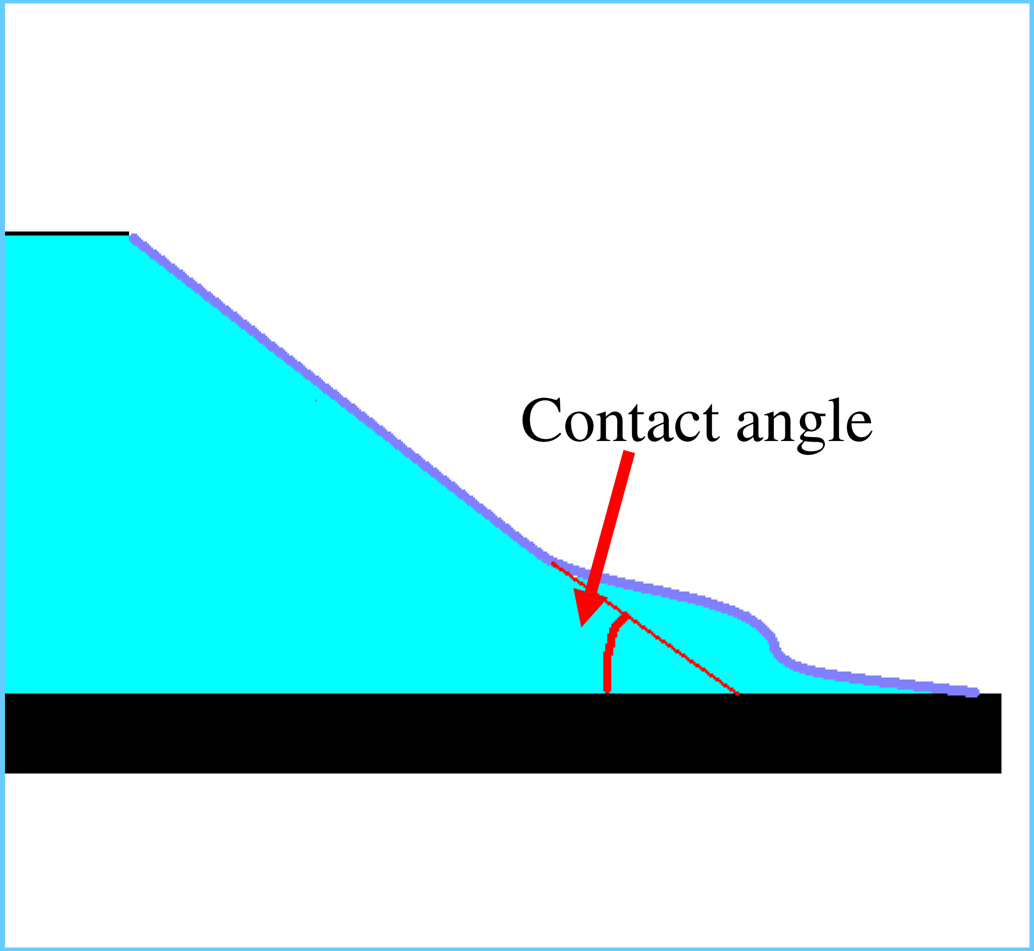
WHAT IS THE REASON?



Disjoining pressure:
1 Complete wetting
2 Partial wetting

$$\cos\theta = 1 - \frac{S_- - S_+}{\gamma}$$

Disjoining pressure determines the liquid shape in the transition zone



Static advances and receding contact angles on smooth homogeneous substrates

Deformation of soft solids in contact with transition zone

Non-flat liquid layers

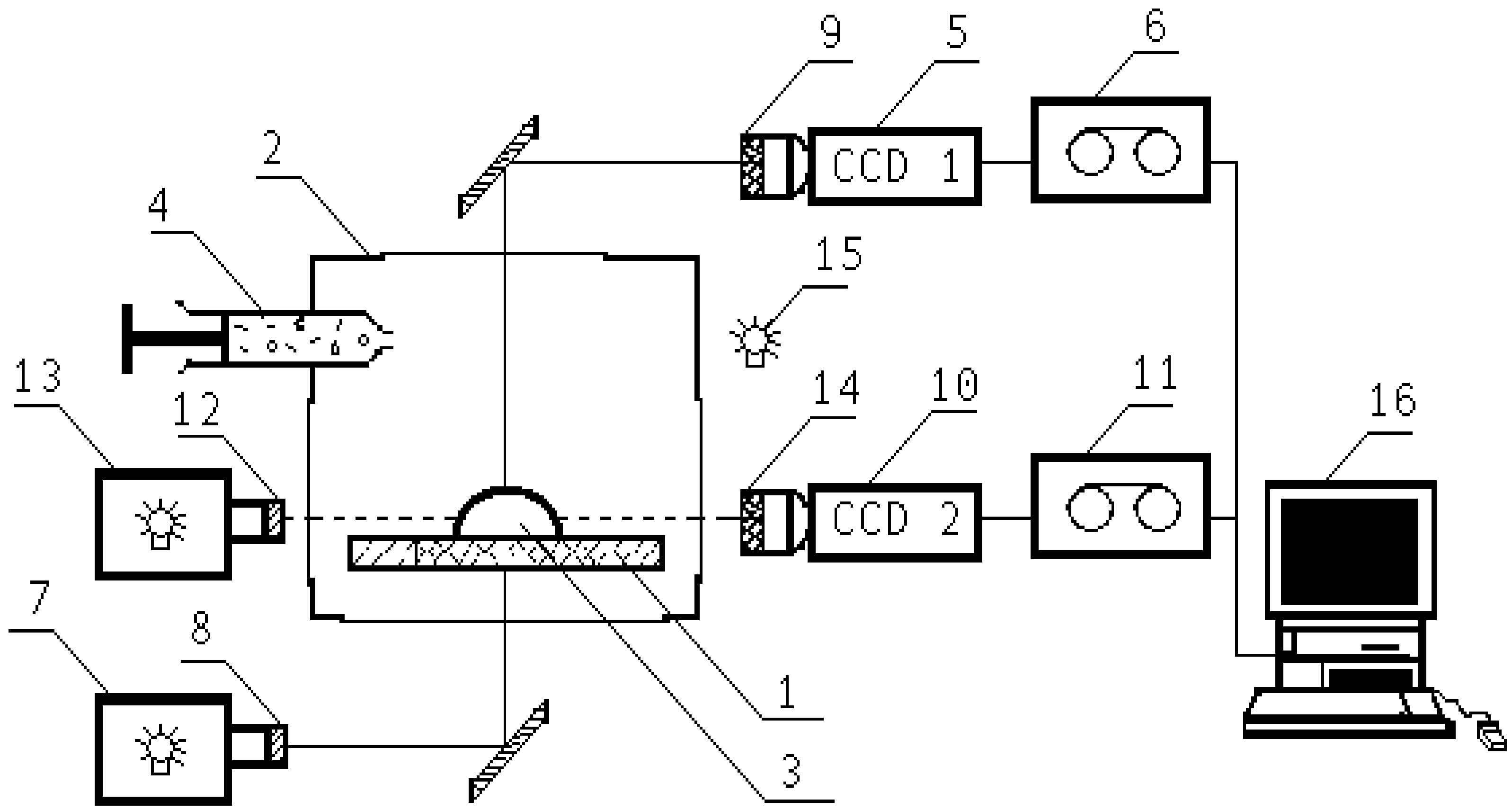
Line tension

Influence of roughness

Motion of drops/bubbles in thin capillaries

Kinetics of spreading in the case of complete wetting

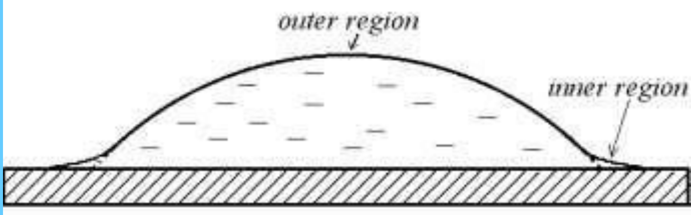
Experimental set-up



1-substrate, 2-hermetically closed, thermo stated chamber, 3-liquid drop, 4-syringe, 5, 14- front view and view from above CCD cameras, 6, 11-VCRs, 7, 13- light sources, 8, 12 collimating lenses, 9,14-tele-photo objectives, 15-flash gun, 16-PC.

SPREADING OVER SATURATED POROUS LAYERS

Spreading over saturated porous layers



"Outer" solution **spherical cap**

Matching of outer and inner solutions results in

$$L(t) = L_0\left(1+\frac{t}{\tau}\right)^{0.1}, \quad \tau = \frac{\mu L_0}{10\gamma\omega}\left(\frac{\pi L_0^3}{4V}\right)^3$$

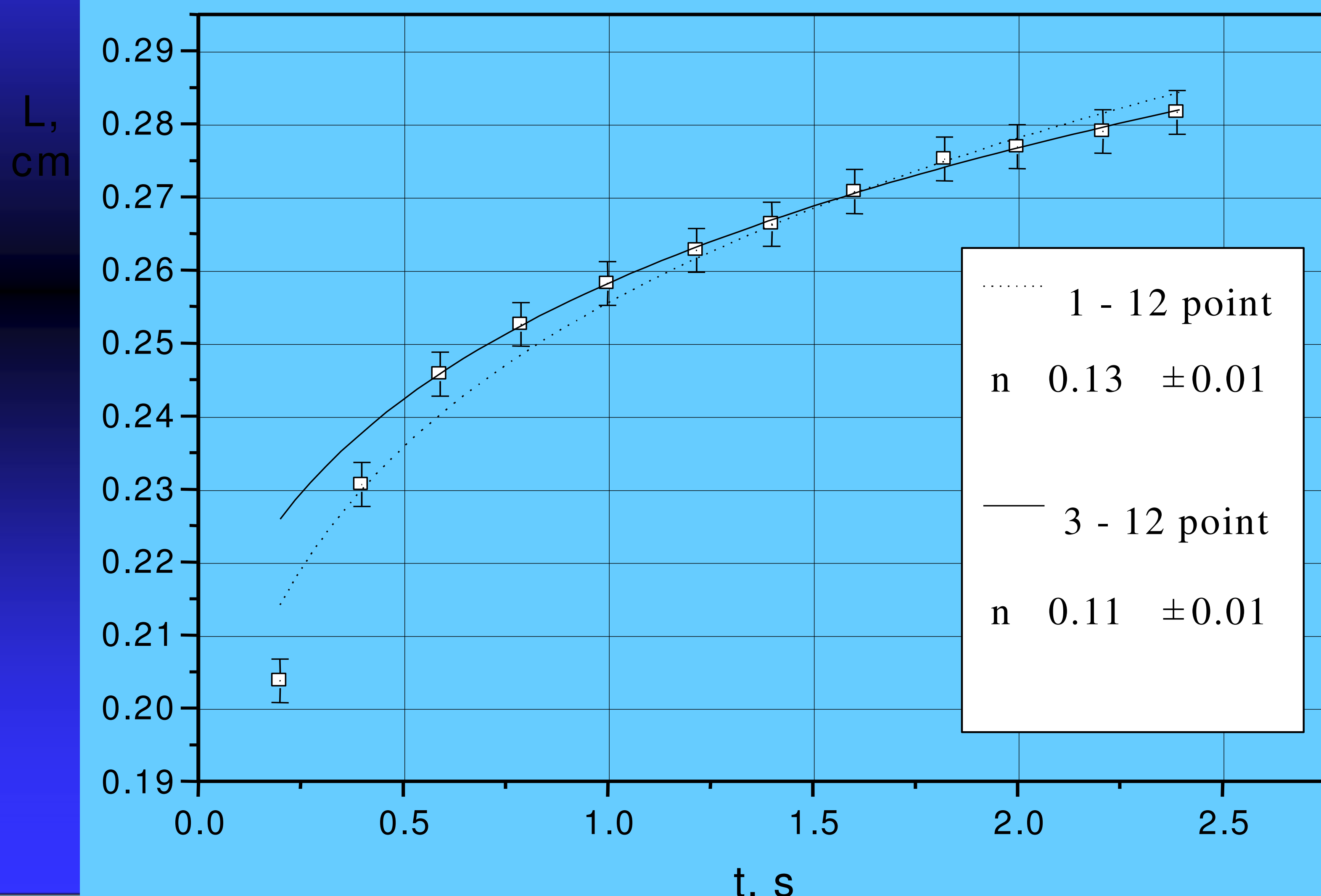
Spreading law

$$\frac{dL}{dt} = \omega\frac{\gamma\theta^3}{\mu}$$

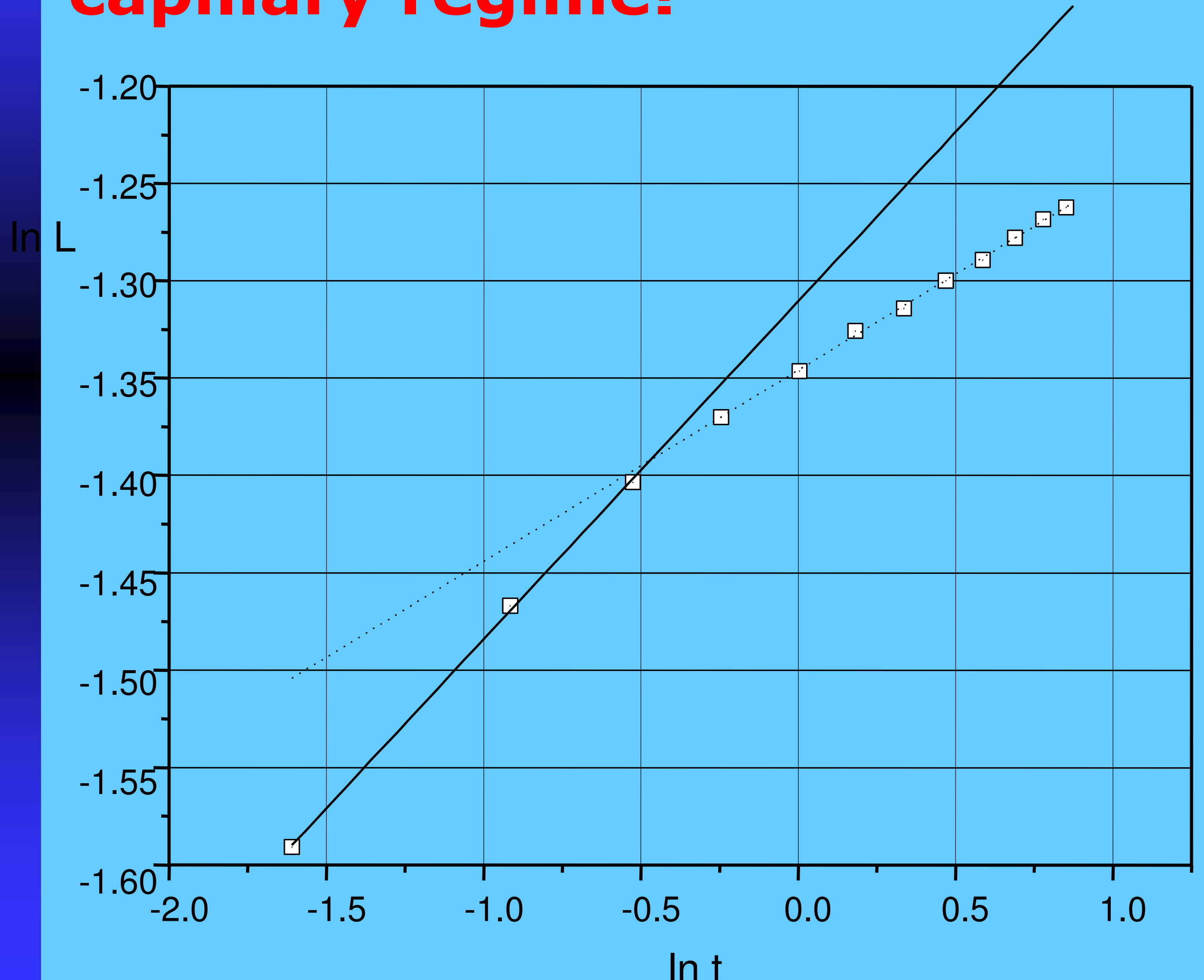
Effective lubrication coefficient ω **can be both experimentally determined** and calculated

SILICONE OILS ON NITROCELLULOSE MEMBRANES

Fitted as: $$L = L_0 (1 + t/\tau)^n$$ $$L = L_0 \left(1 + 10 \left(\frac{4}{\pi} \right)^3 \frac{V^3 \gamma}{L_0^{10} \mu} \omega t \right)^{0.1}$$



Initial stage differs from the capillary regime!



EXPERIMENTAL VALUES OF EFFECTIVE LUBRICATION COEFFICIENT ω

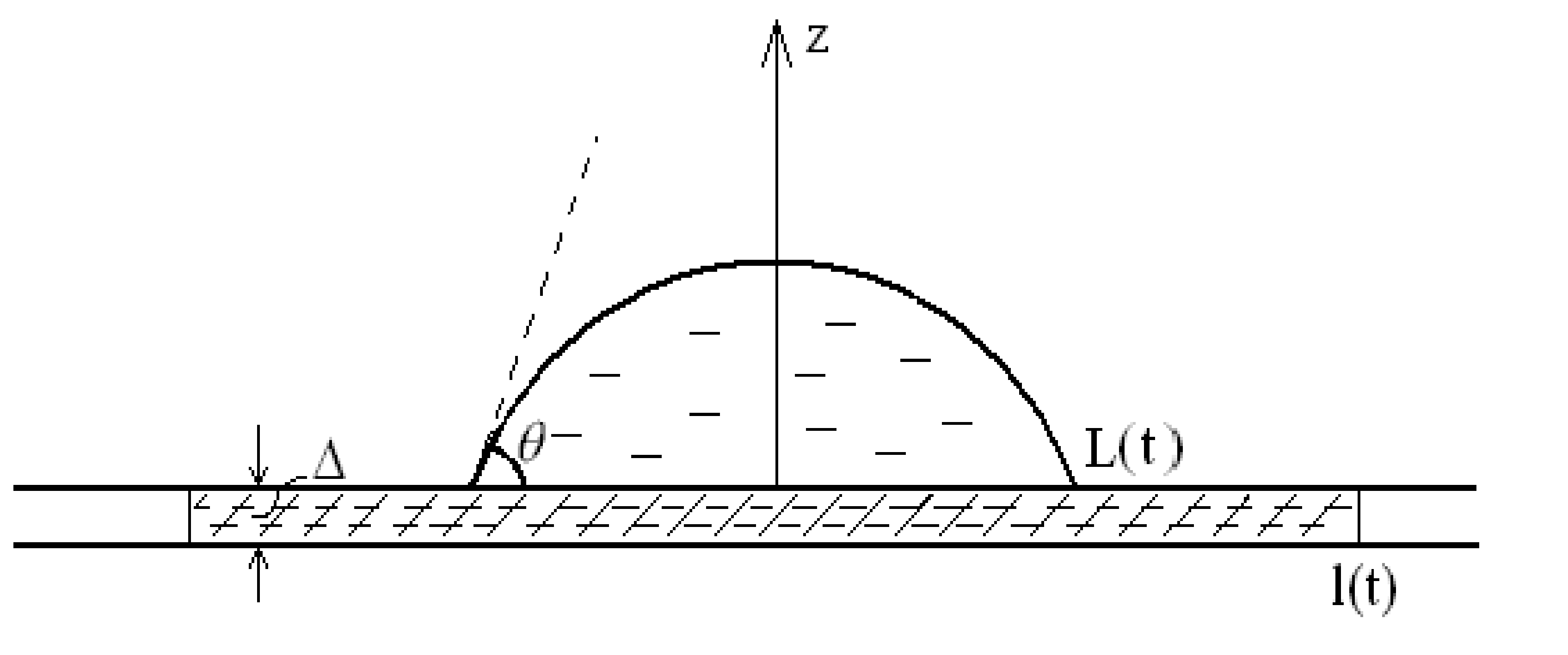
Membrane pore size	μ, P	τ, sec	V, mm^3	ω
0.2 μm	5.58	0.3330	3.9	0.017 ± 0.004
0.2 μm	0.558	0.0592	4.0	0.018 ± 0.004
0.2 μm	1.18	0.00163	3.0	0.014 ± 0.005
0.2 μm	1.18	0.0026	3.4	0.014 ± 0.003
0.2 μm 3 μm	1.18 1.18	0.0086 0.0546	3.0 5.5	0.016 ± 0.005 0.015 ± 0.009
3 μm	1.18	0.4610	5.0	0.016 ± 0.009
3 μm	0.558	0.6090	5.0	0.018 ± 0.008
Optical glass	0.558	0.0378	6.8	0.012 ± 0.003
Optical glass	1.18	0.0103	2.0	0.010 ± 0.005

SPREADING OVER DRY POROUS LAYERS

SIMULTENEOUS SPREADING AND IMBIBITION INTO THE POROUS SUBSTRATE

COMPLETE WETTING

Spreading over dry porous substrates



L(t) **radius of the drop base,**

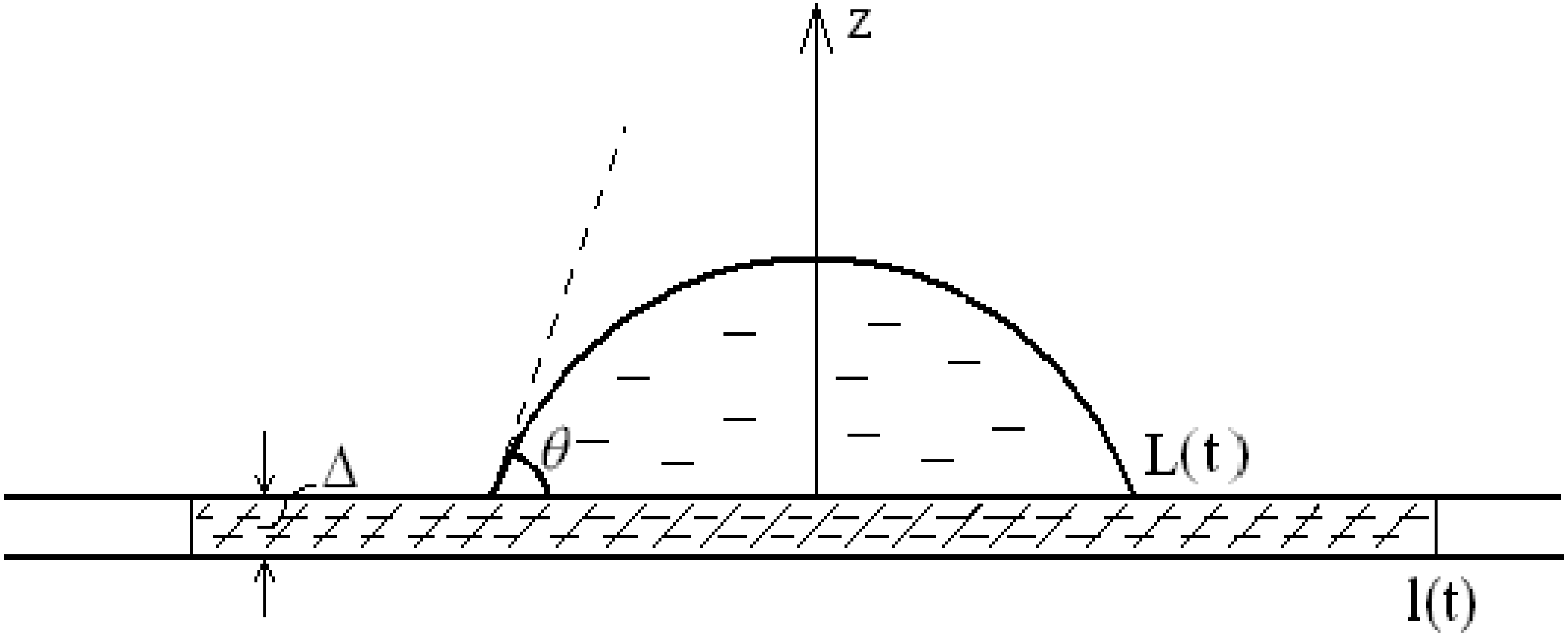
l(t) **radius of the wetted region inside the porous layer,**

θ(t) **dynamic contact angle**

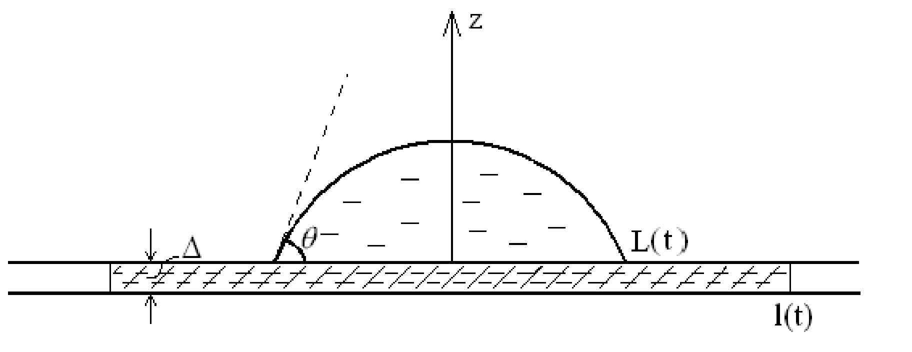
DRY POROUS SUBSTRATE

Drop volume

$$V(t) = V_0 - \pi m \Delta l(t)^2$$



SPREADING
SHRINKAGE

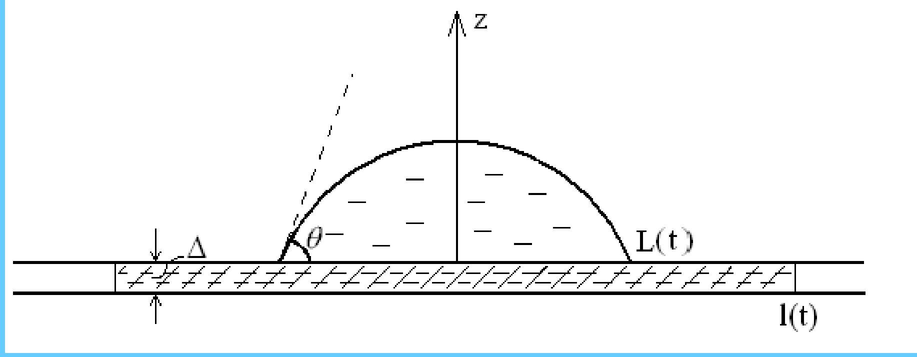


$$\frac{dL}{dt} = v_+ - v_-$$

v_+ → velocity of spreading

v_- → velocity of shrinkage

SPREADING OF LIQUID DROPS OVER DRY POROUS LAYERS: COMPLETE WETTING CASE



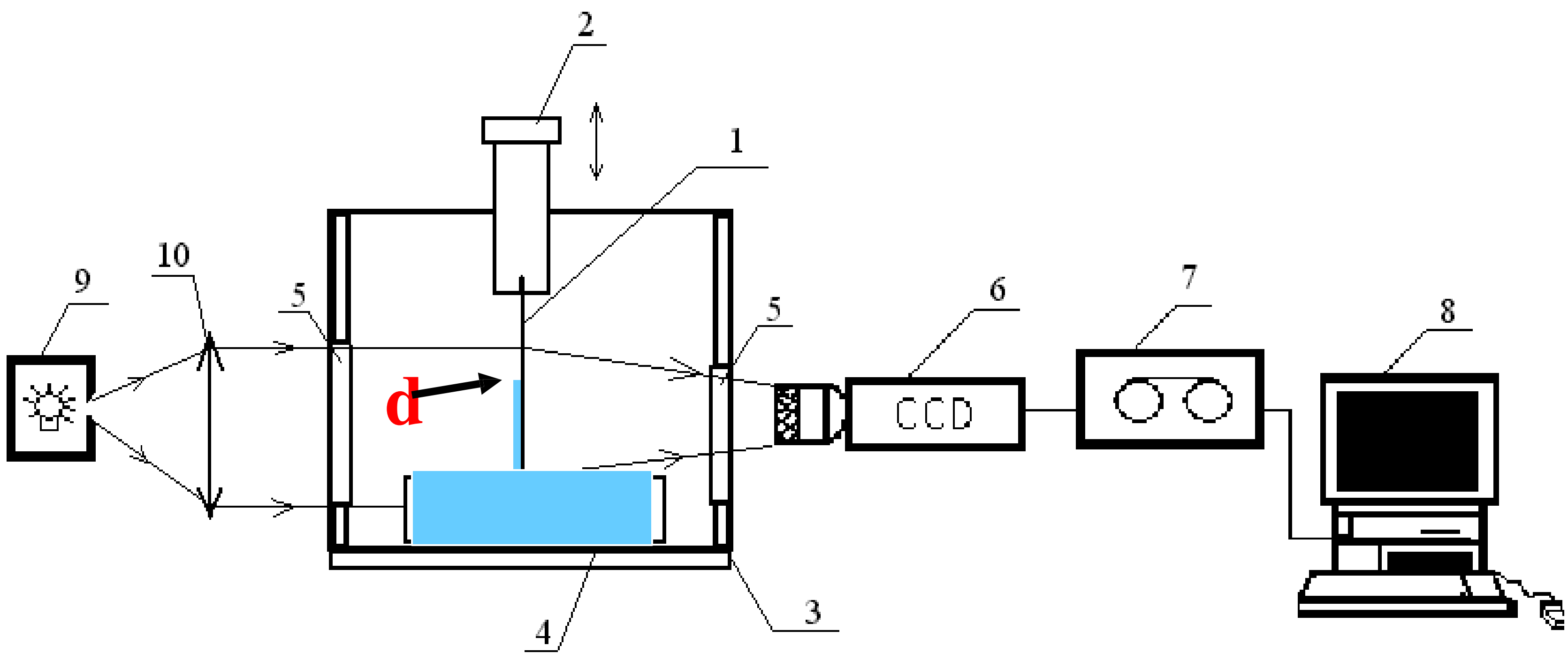
$$\frac{dL}{dt}=0.1\left(\frac{4V}{\pi}\right)^{0.3}\left(\frac{10\gamma\omega}{\mu}\right)^{0.1}\frac{1}{(t+t_0)^{0.9}}-\frac{2\pi^{2/3}m\Delta K_p p_c}{3\mu}\left(\frac{4}{\left(V_0-\pi m\Delta l^2\right)\theta}\right)^{1/3}\frac{1}{\ln\frac{l}{L}}$$

$$\frac{dl}{dt}=\frac{K_p p_c/\mu}{l\ln\frac{l}{L}}$$

$K_p p_c$ is determined independently

NO FITTING PARAMETERS

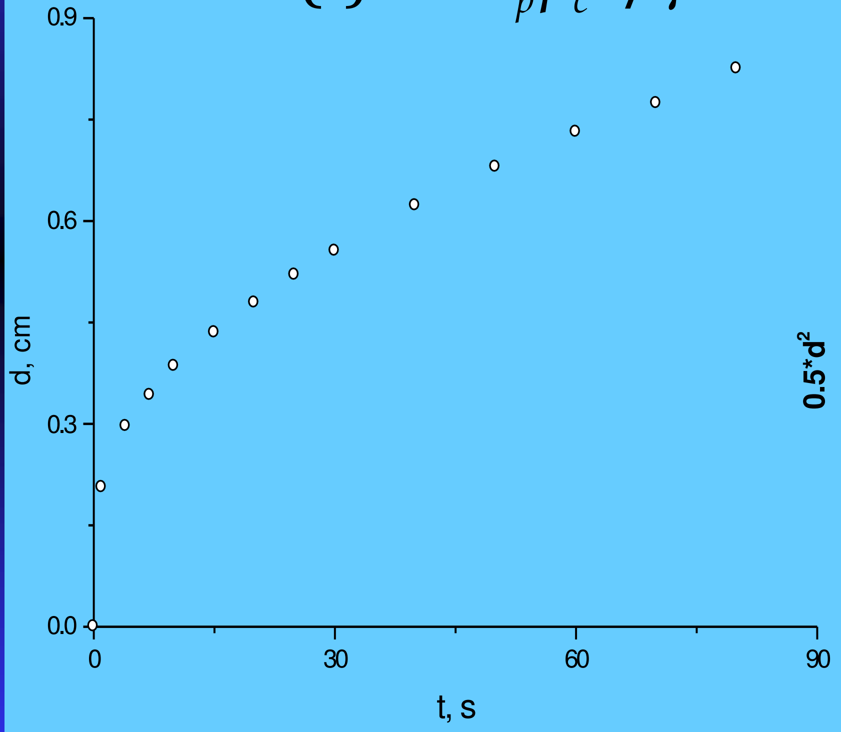
CAPILLARY IMBIBITION: DETERMINATION OF K_p p_c

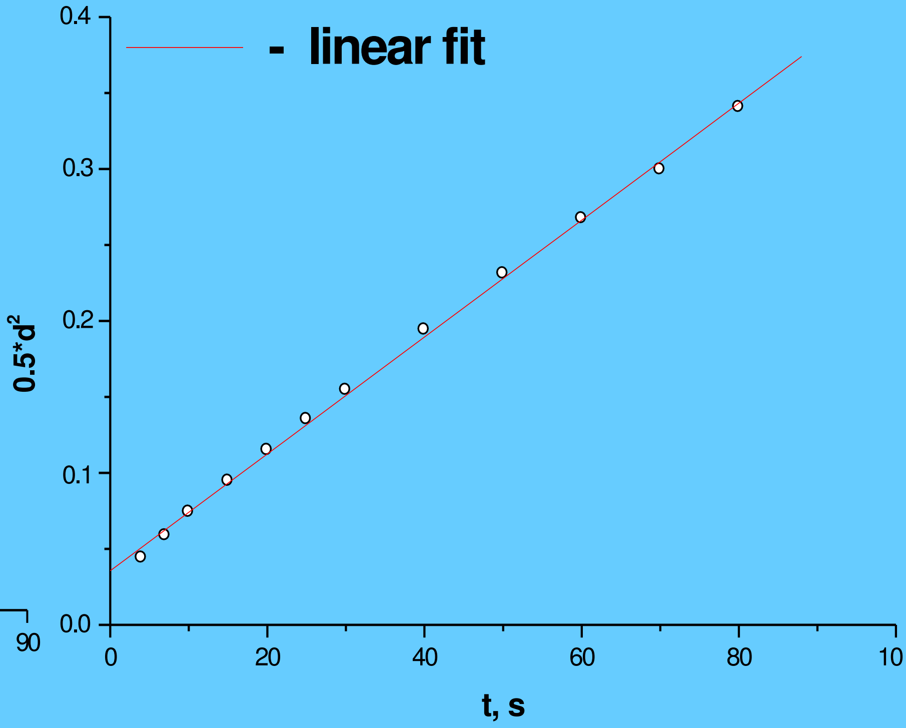


Experimental set-up
1-membrane, 2-lifting up/down device, 3-thermo stated chamber, 4-Petri dish with liquid, 5-optical glass windows, 6-CCD camera, 7-video tape-recorder, 8- PC

Capillary imbibition of silicone oils: independent determination of $K_p\, p_c$

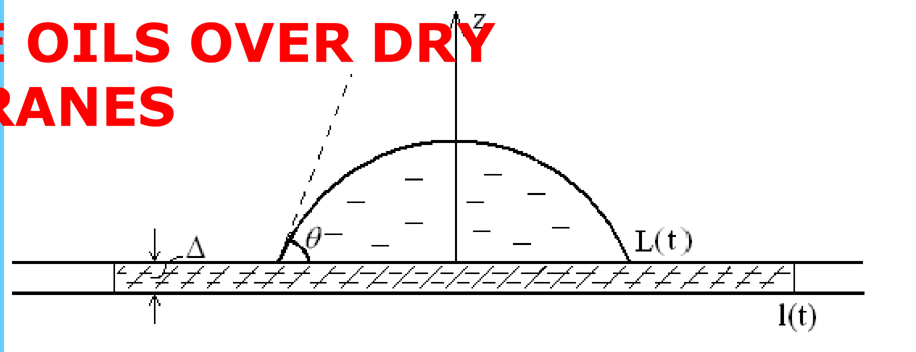
$$d^2(t) = 2K_p p_c t / \mu$$

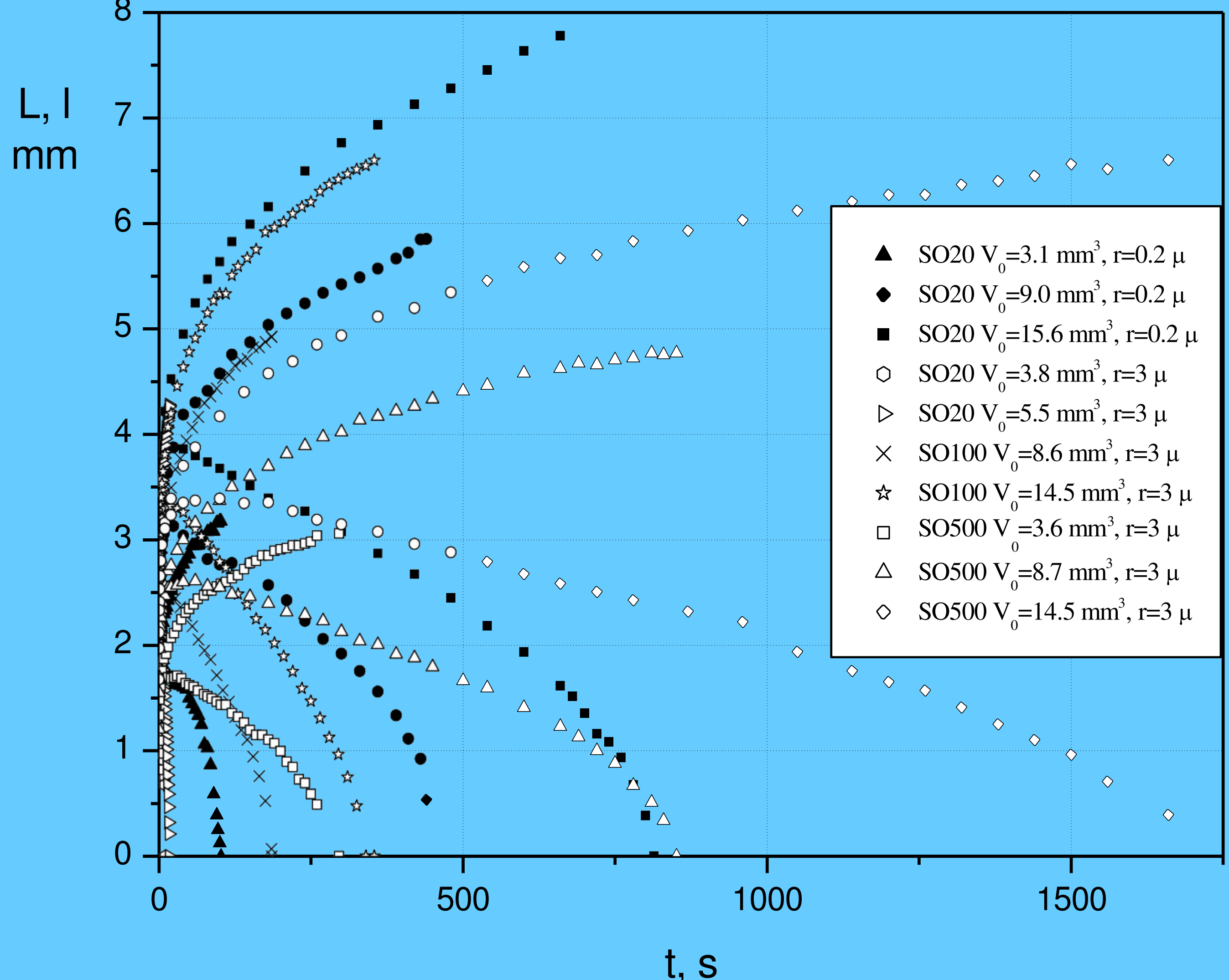




Nitrocellulose membrane 0.22 μm

SPREADING OF SILICONE OILS OVER DRY NITROCELLULOSE MEMBRANES



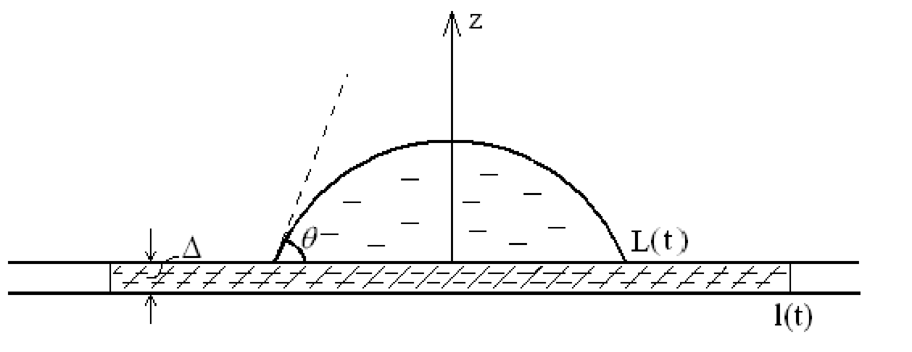


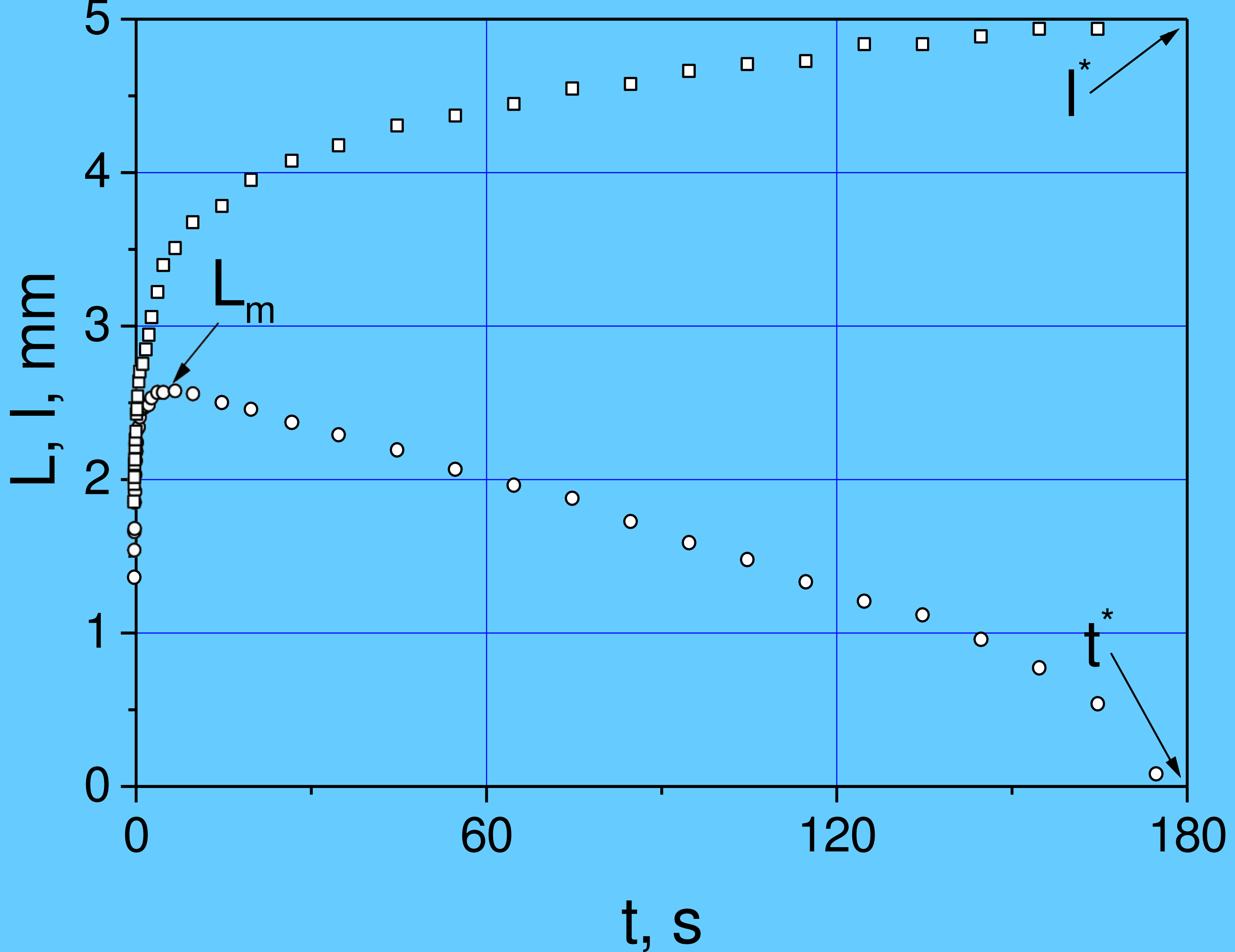
l upper parts

L lower parts

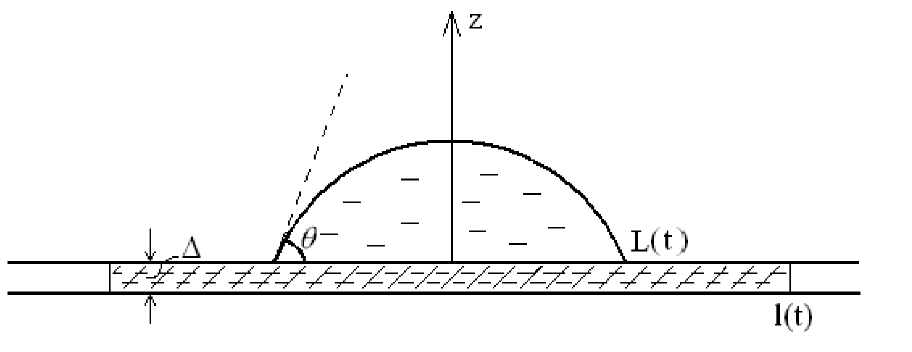
Dimensionless values

$$\bar{L} = L / L_m , \bar{l} = l / l^* , \bar{t} = t / t^*$$

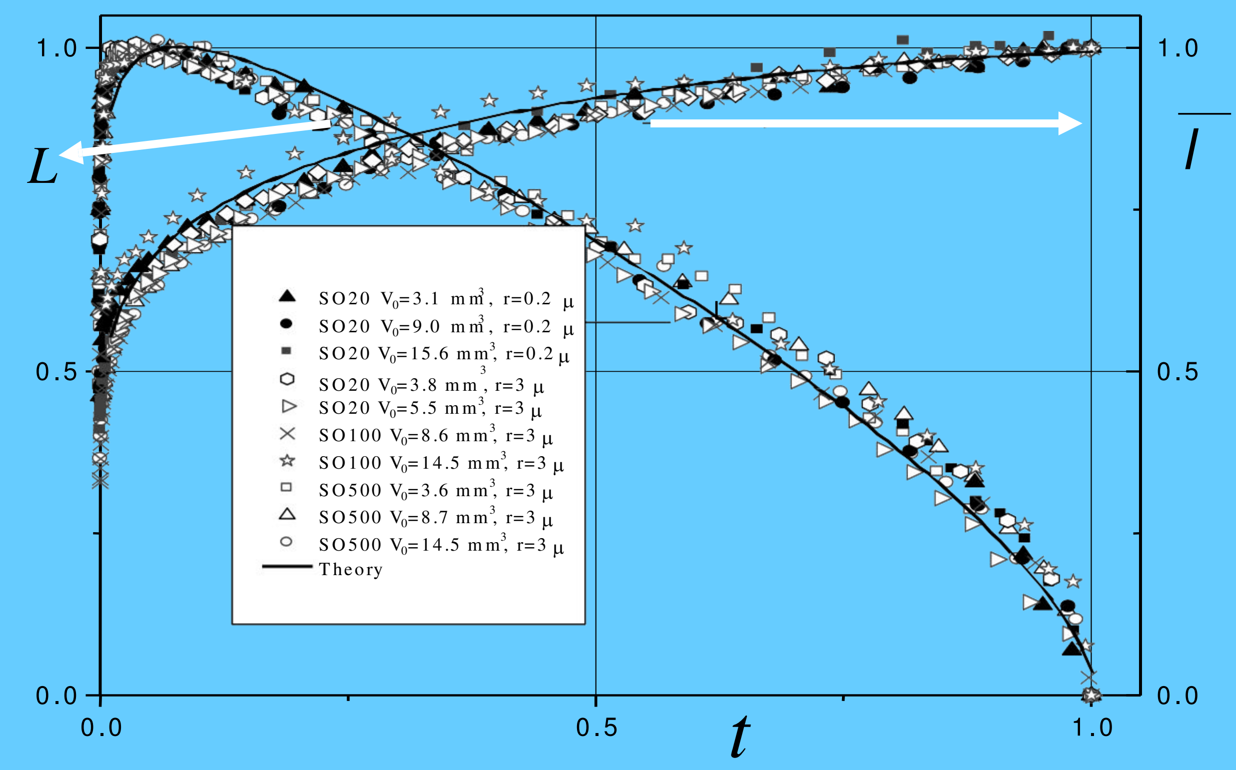




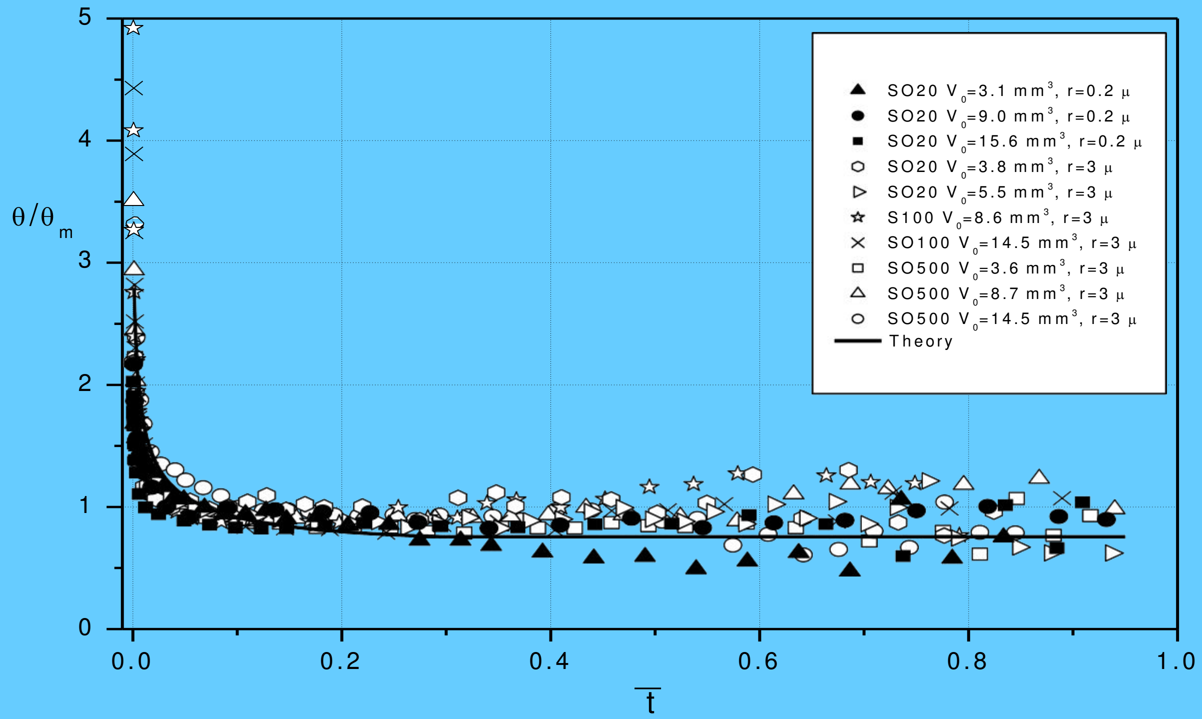
Universal behaviour: solid lines according to our theory predictions



$$\bar{L} = L / L_m, \bar{l} = l / l^*, \bar{t} = t / t^*$$



Universal behaviour: θ / θ_m
solid line according to our theory predictions



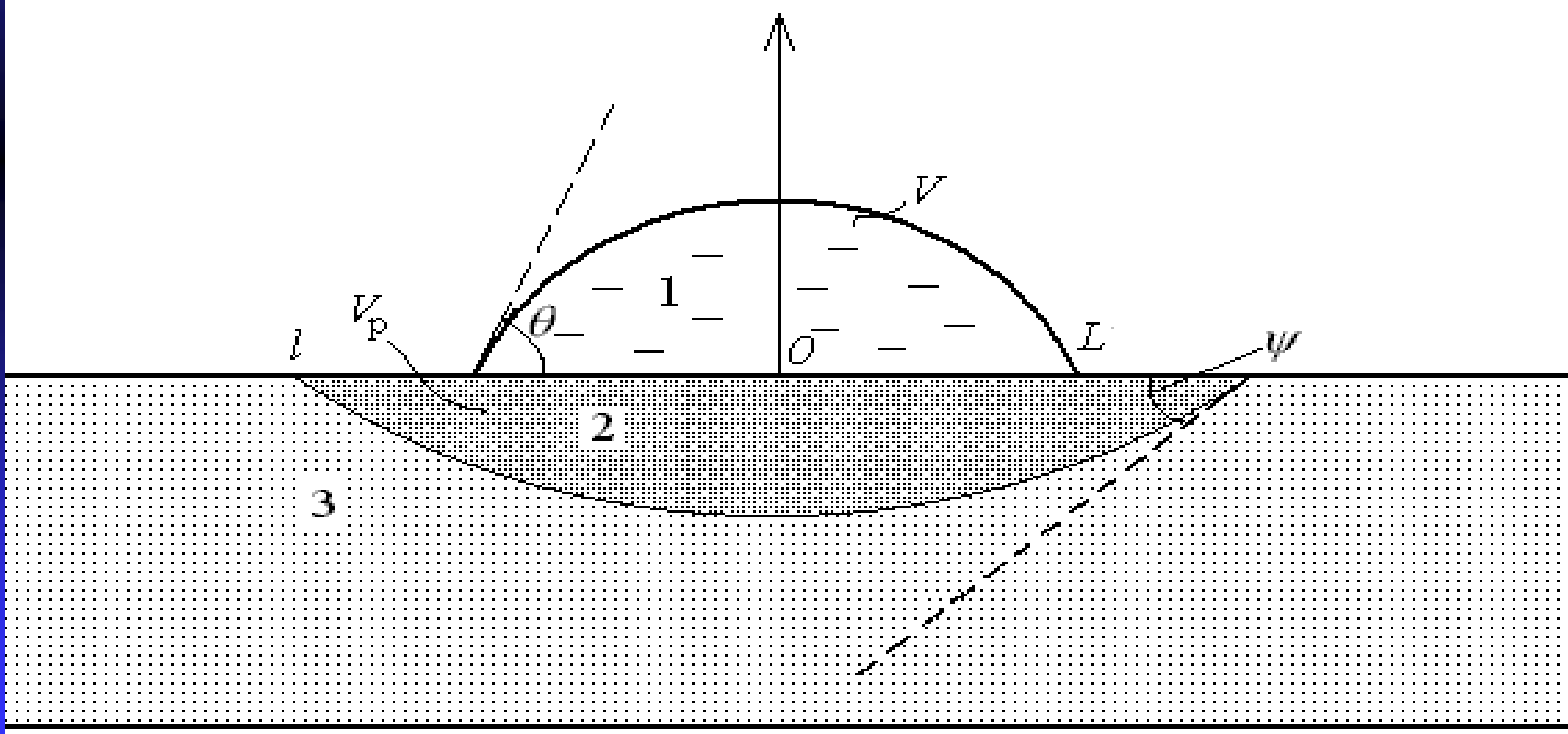
θ_e constant over the second stage!

SPREADING OF LIQUID DROPS OVER THICK POROUS LAYERS

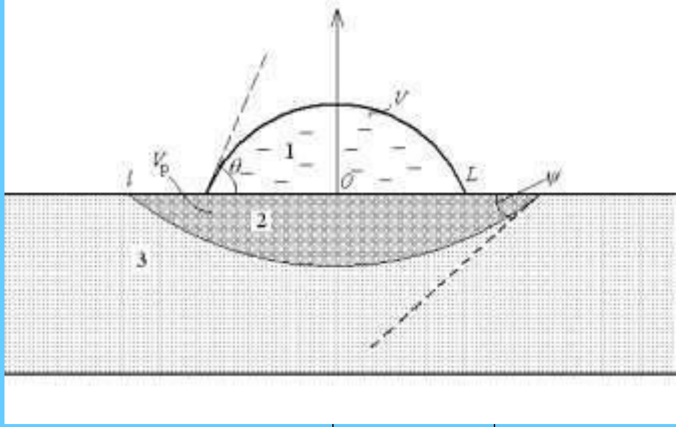
COMPLETE WETTING CASE

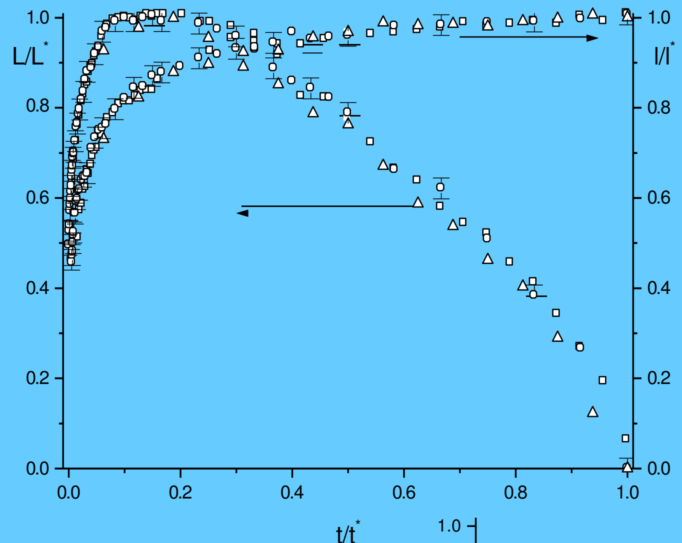
SPREADING OF LIQUID DROPS OVER THICK POROUS LAYERS: COMPLETE WETTING CASE

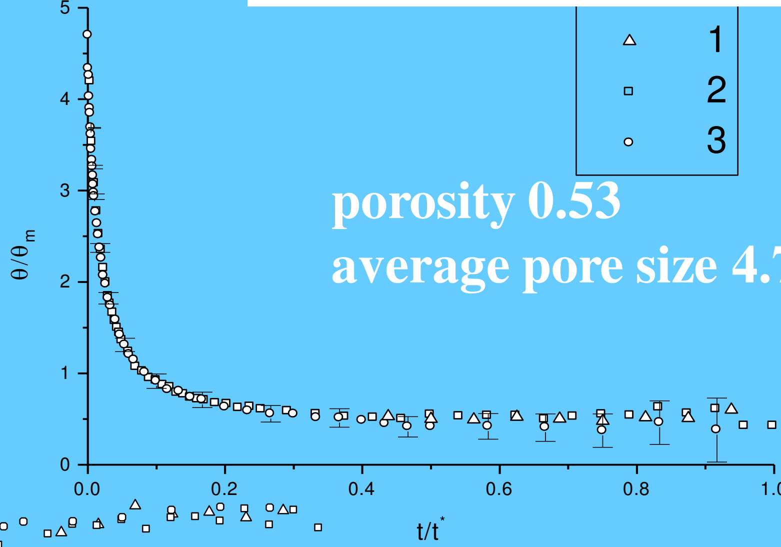
$\psi(t)$ effective contact angle



Different viscosities, the same glass filter



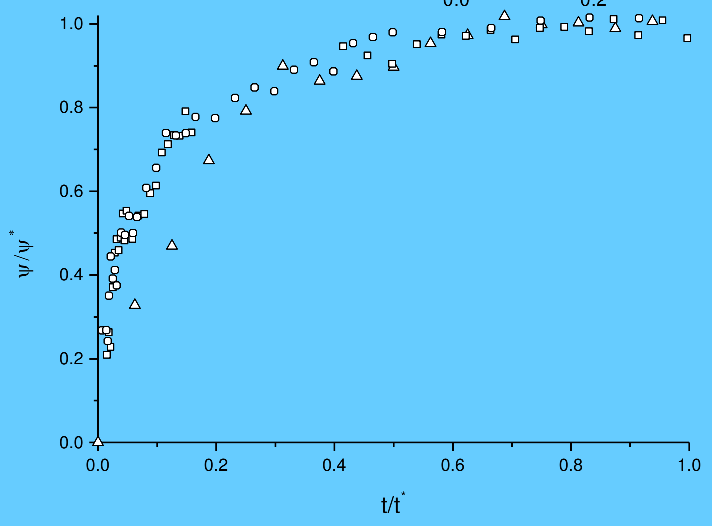




porosity 0.53

average pore size 4.7 μm

UNIVERSAL BEHAVIOUR

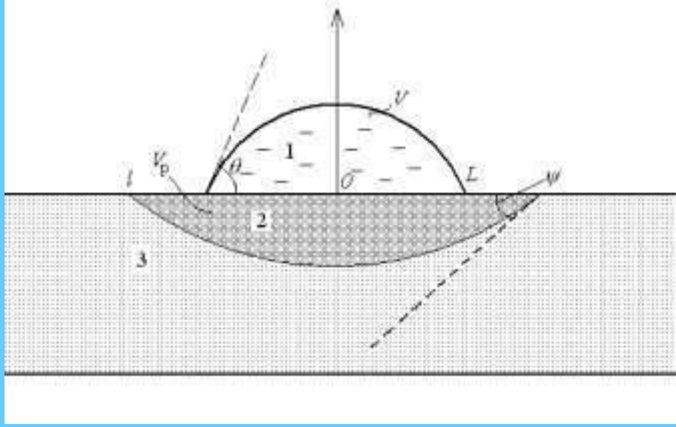


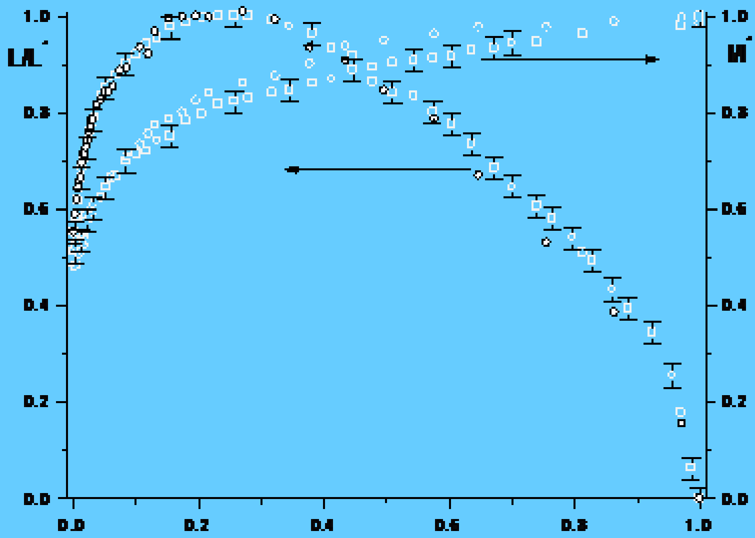
1 μ=5 c P

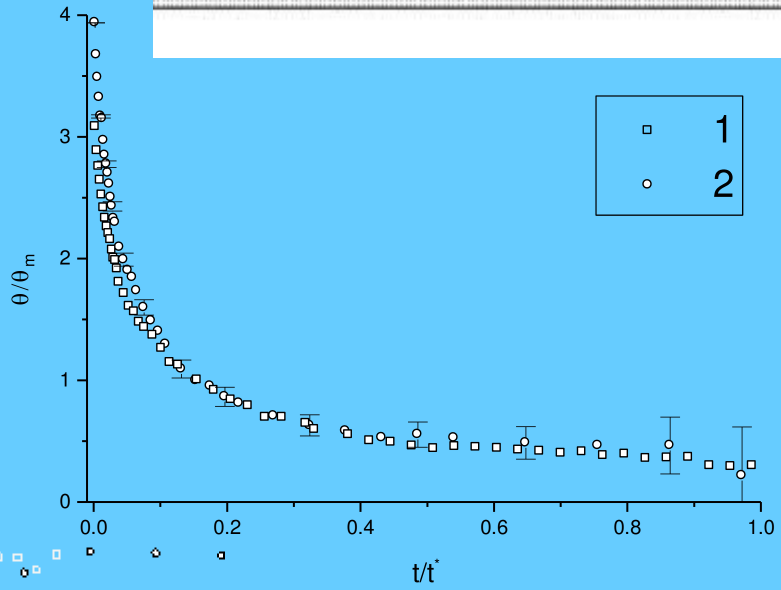
2 μ=100 cP

3 μ=500 cP

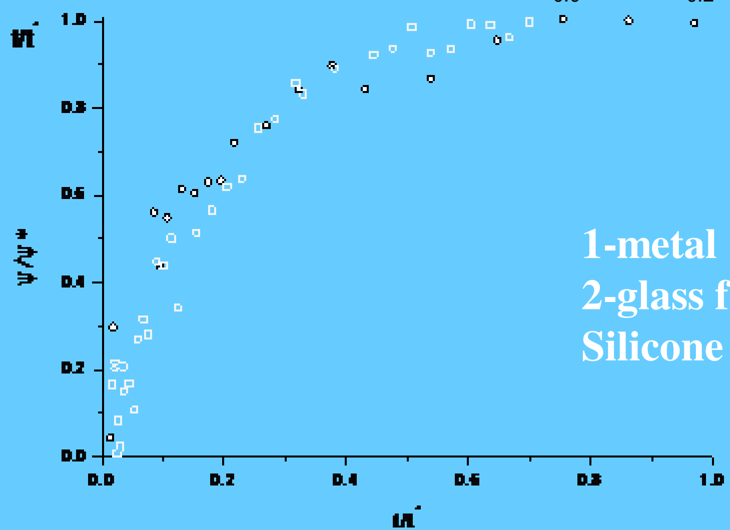
Glass and metal filters with similar properties





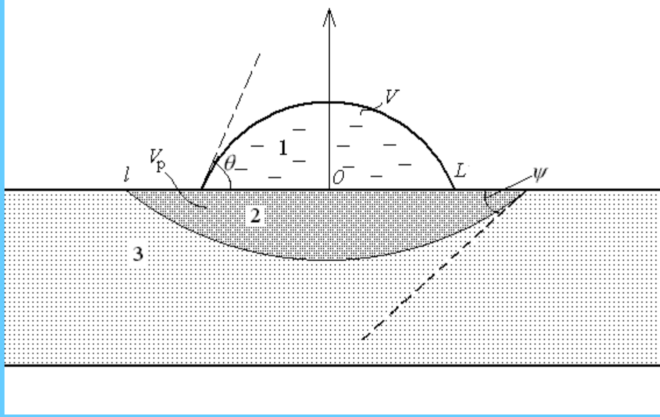


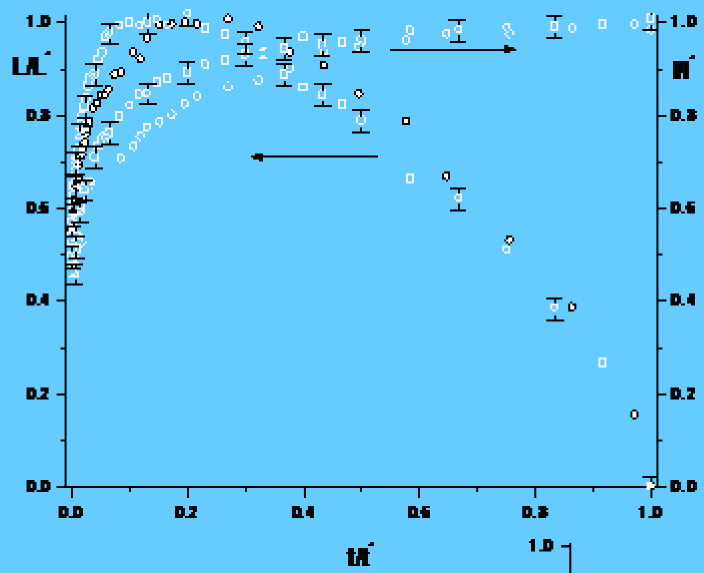
UNIVERSAL BEHAVIOUR

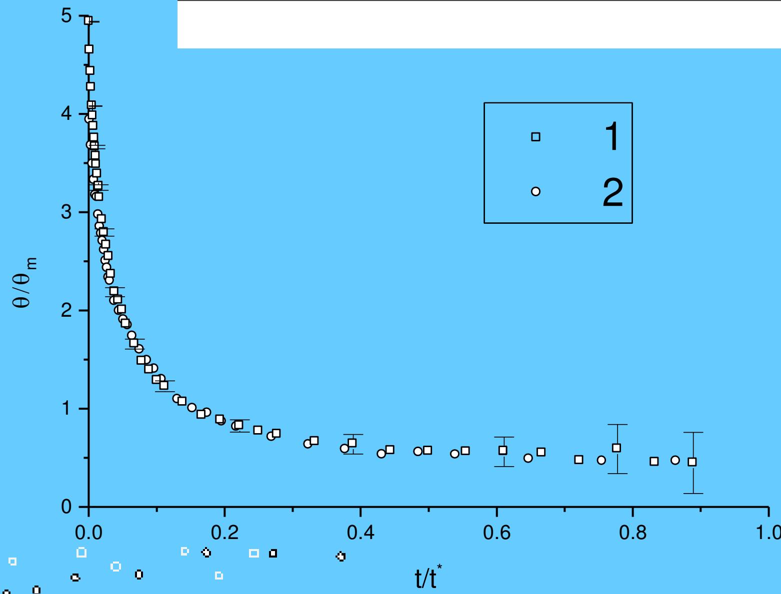


1-metal filter: m=0.32, r=26.1 μm.
2-glass filter: m=0.31, r=26.8 μm
Silicone oil μ=5 c P

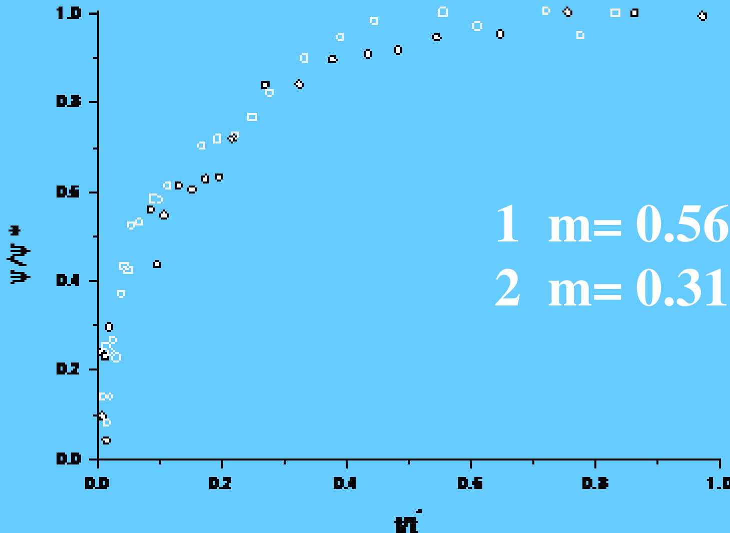
Glass filters: different porosity and averaged pore sizes, μ=500 cP







Stage 1 difference
Stage 2 universal behaviour



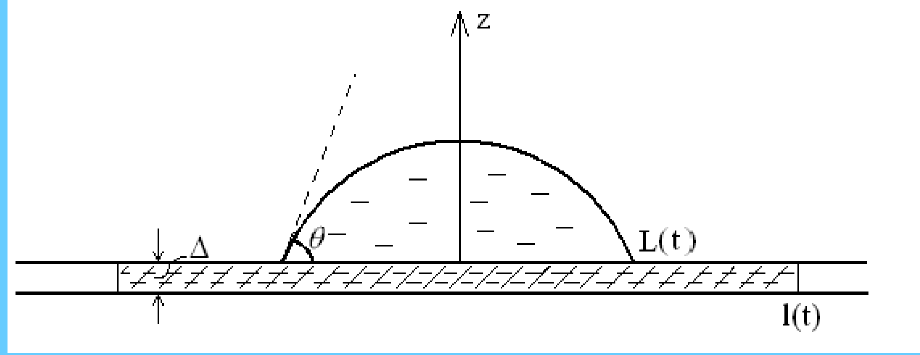
1 m= 0.56; r= 3.7 μm
2 m= 0.31; r=26.8 μm

SPREADING OF SDS SOLUTIONS

INFLUENCE OF HYSTERESIS

PARTIAL WETTING

SPREADING OF SDS SOLUTIONS OVER NITROCELLULOSE MEMBRANES: influence of hysteresis

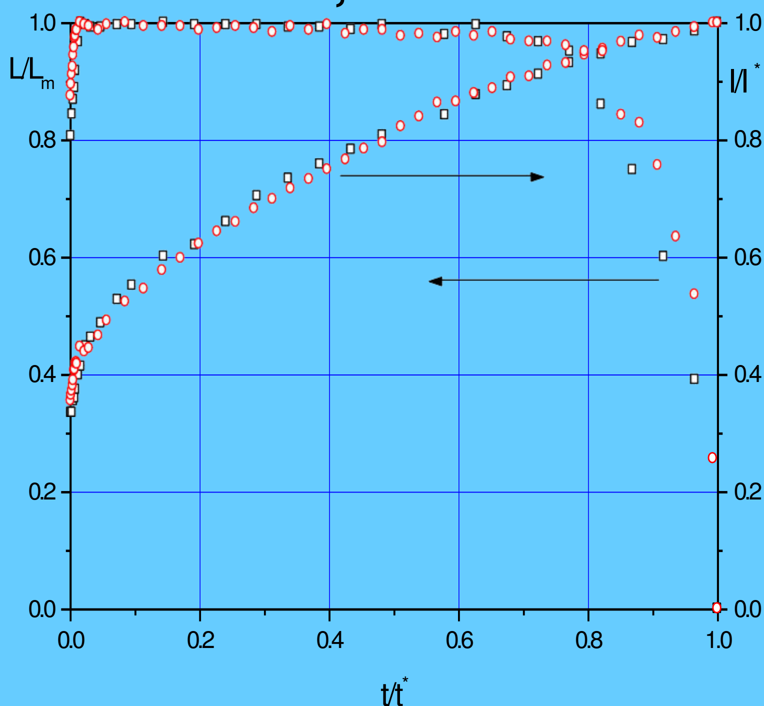


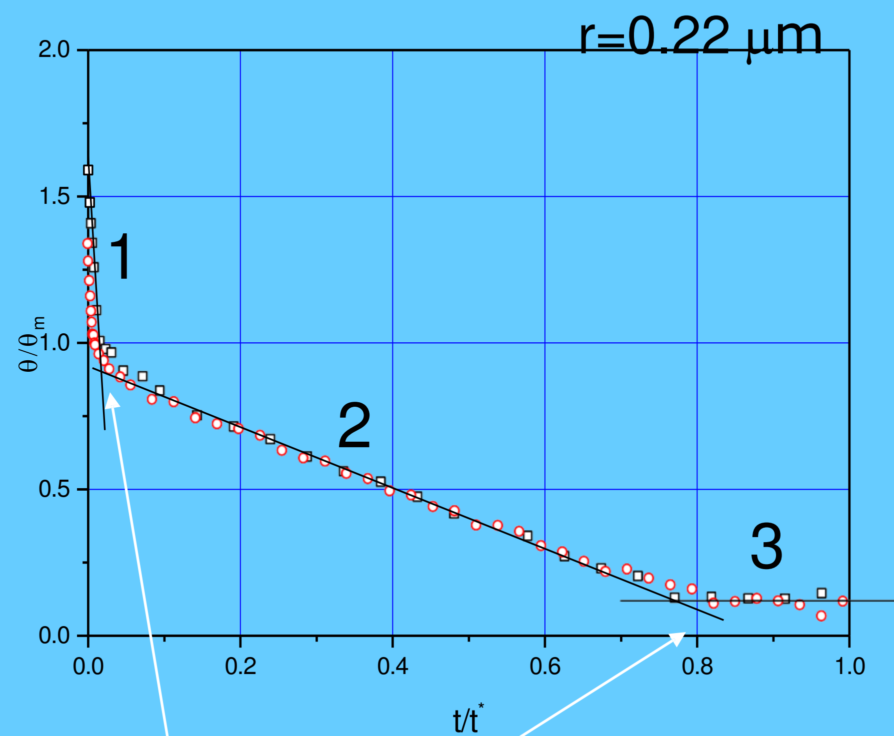
THREE STAGES OF SPREADING

1 θ decreases, *L*, increases until the maximum value

2 *L* constant, θ decreases linearly

3 *L* decreases, θ constant

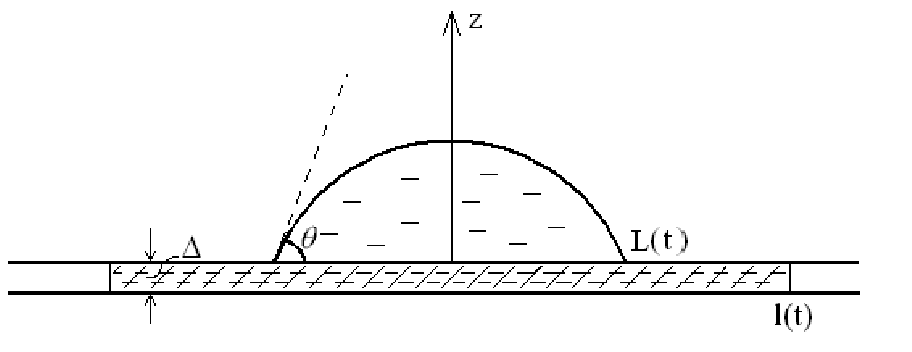


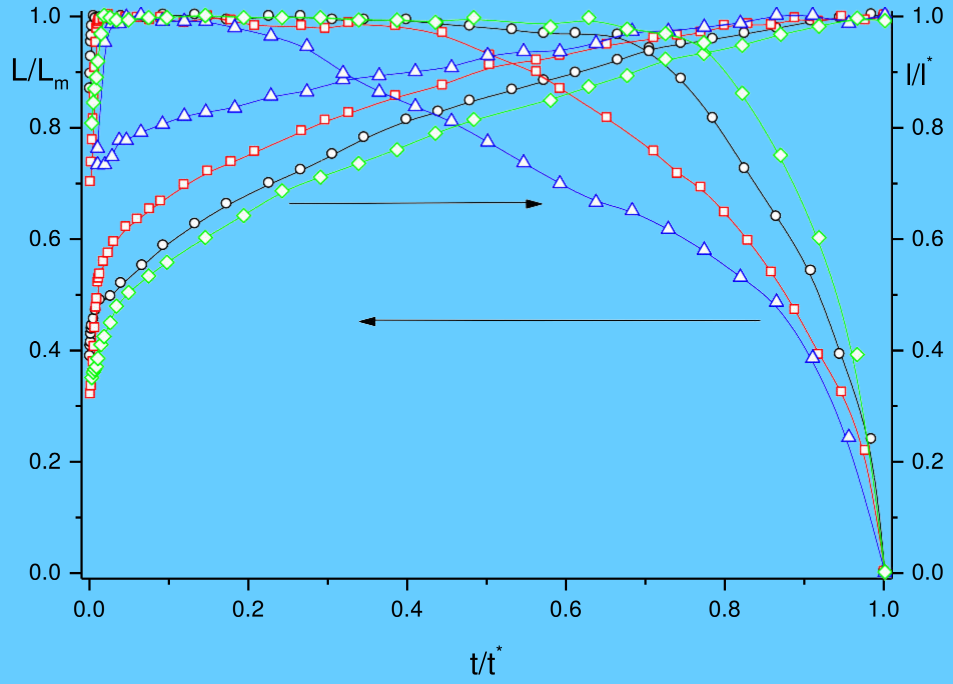


θ_a advancing contact angle

θ_e constant contact angle

Contact angle hysteresis: influence SDS concentration

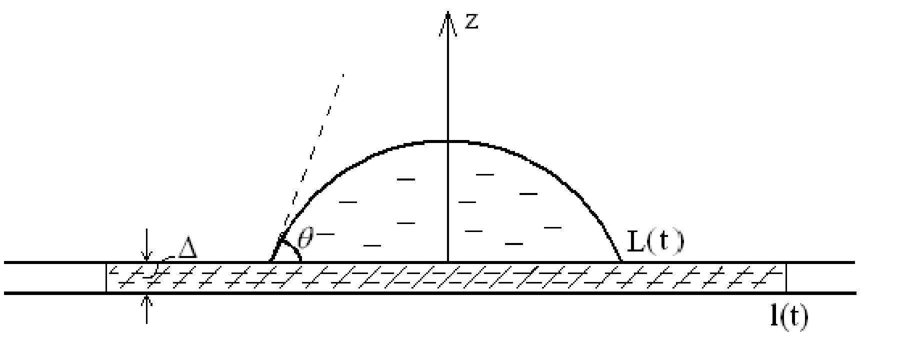


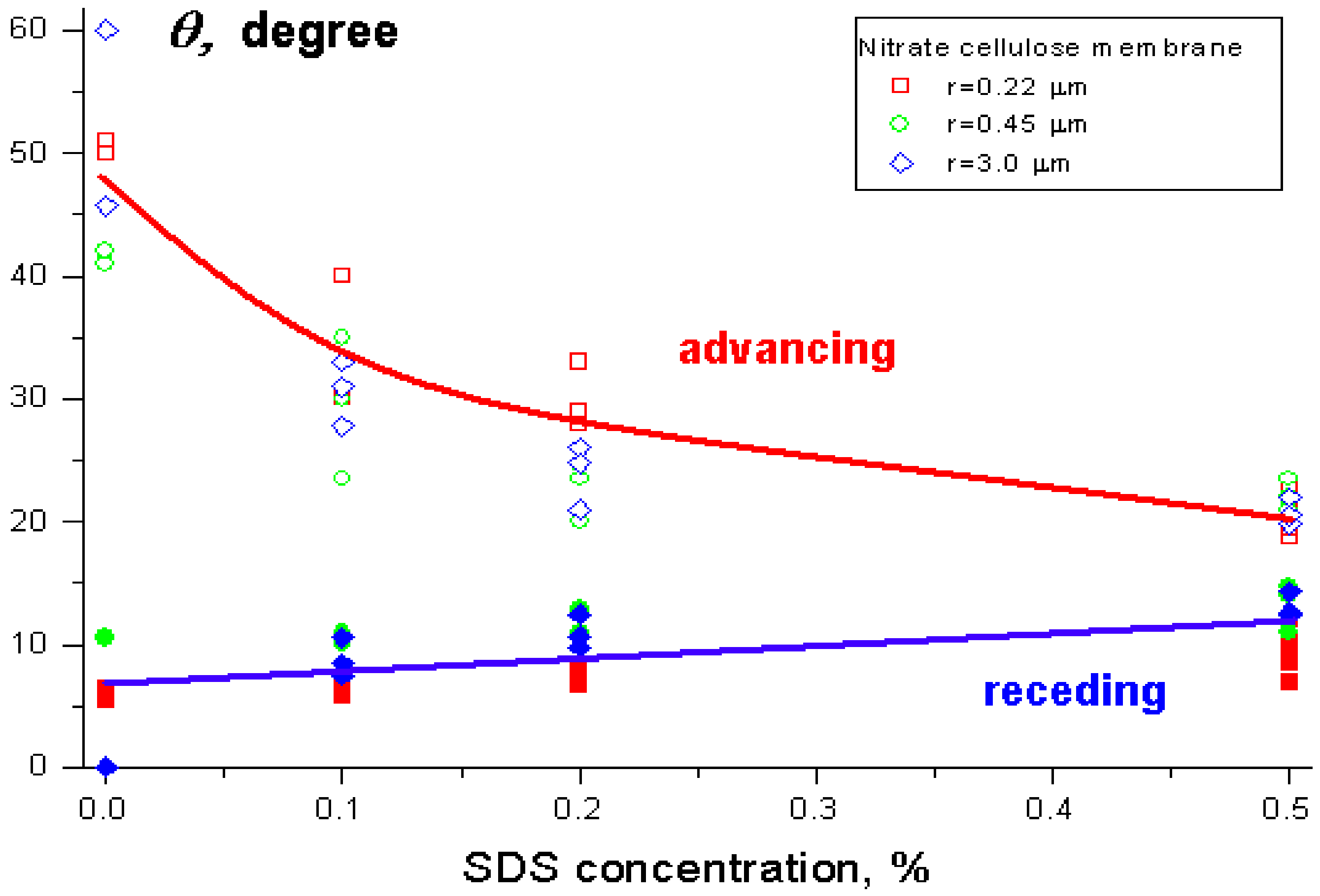


r=0.22 μm
SDS 0%
0.1%
0.2%
0.5%

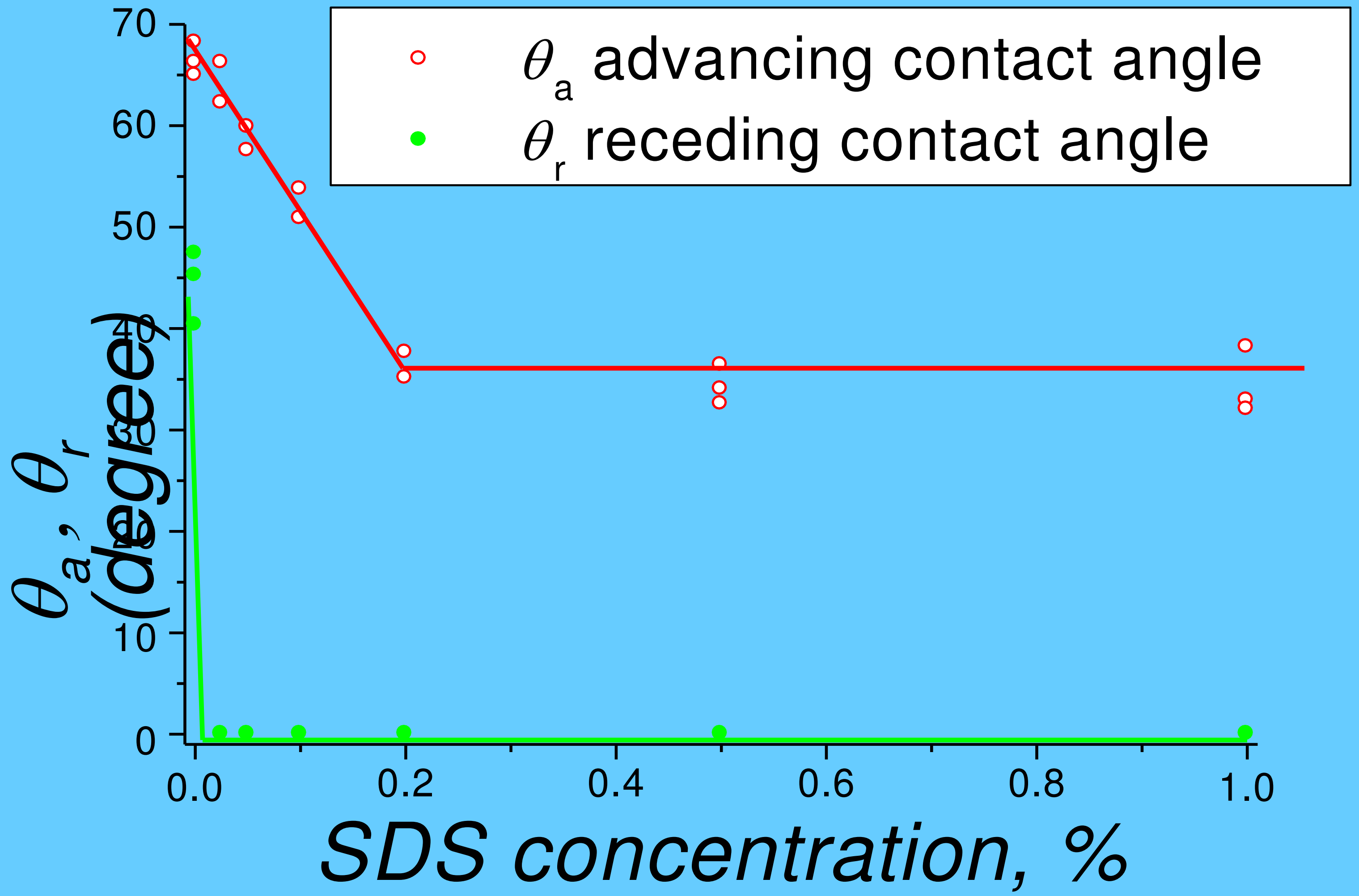
HYSTERESIS DECREASES WITH SDS CONCENTRATION

Contact angle hysteresis: influence of SDS concentration

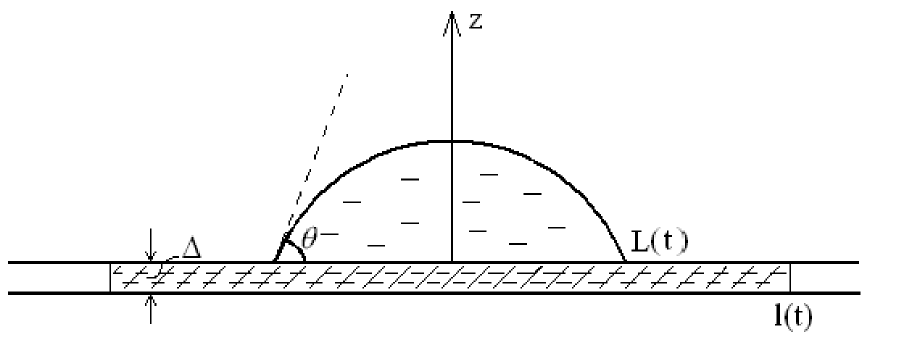


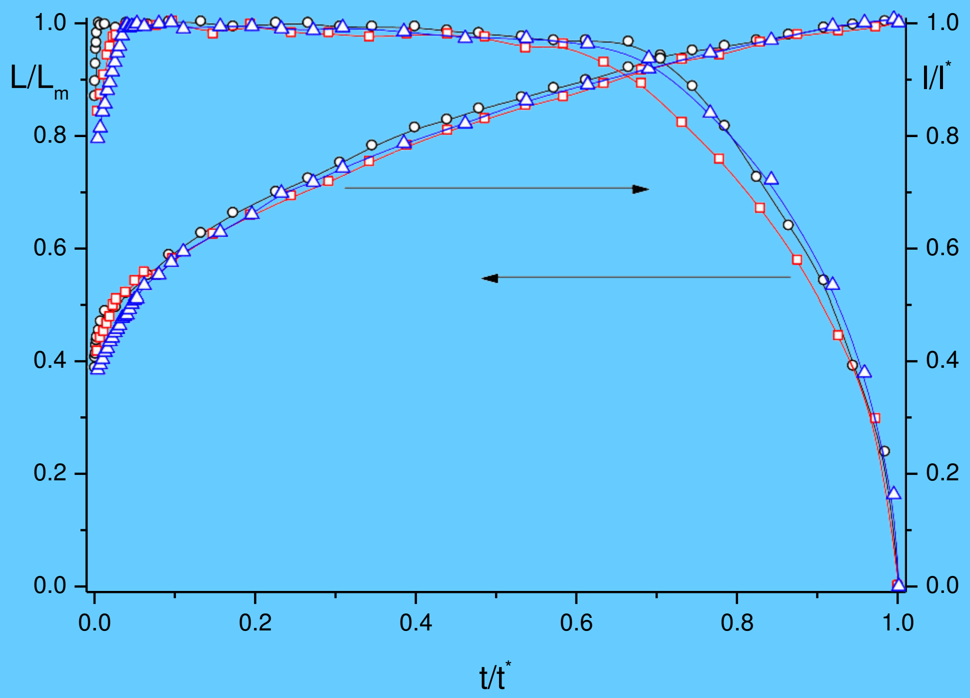


HYSTERESIS ON NON-POROUS NITROCELLULOSE SUBSTRATE



Pore size influence: WEAK DEPENDENCY





SDS 0.1%

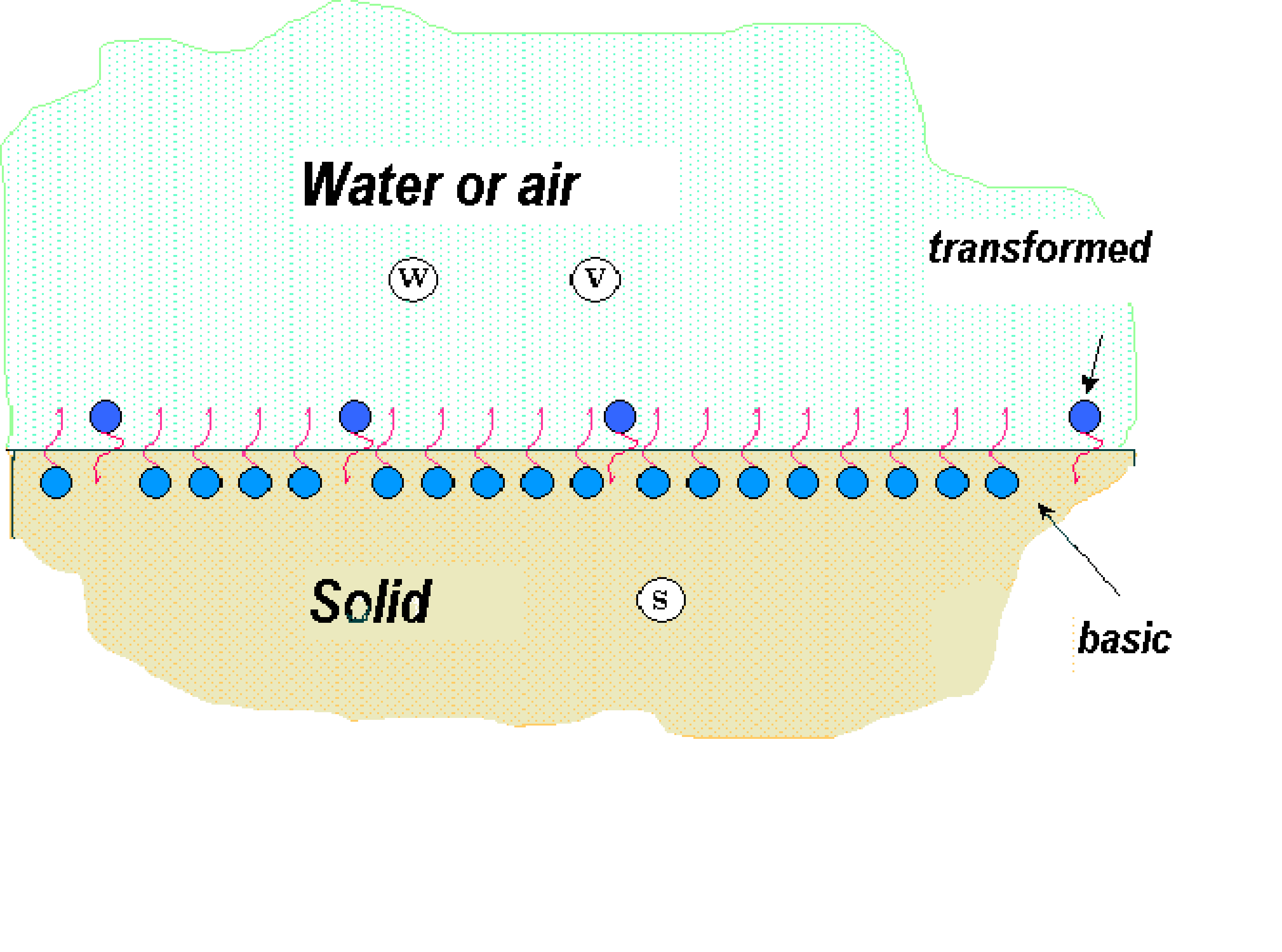
r1=0.22μm

r2=0.45μm

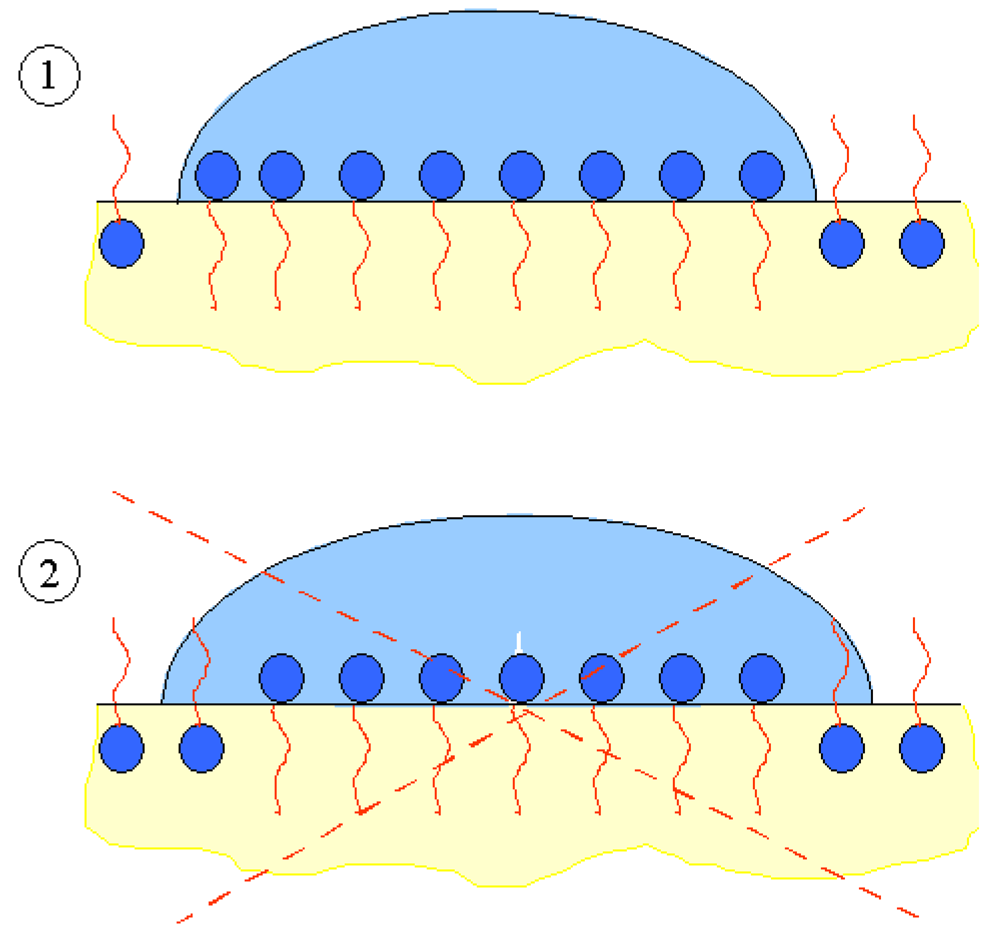
r3=3.0μm

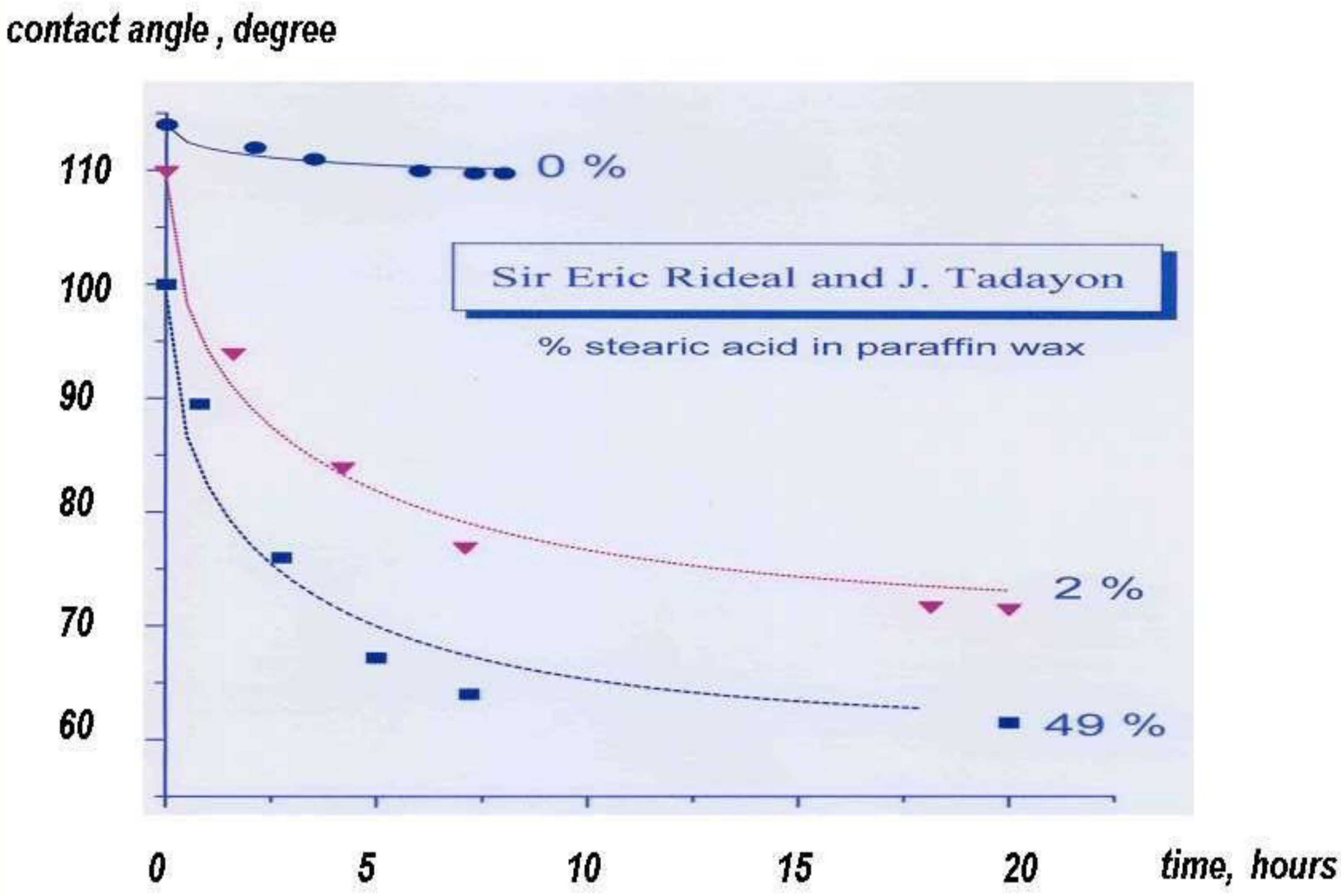
SPREDING OVER FATTY ACID SURFACES OR LIPID LAYERS

SOLID SUBSTRATE WITH ROTATIONALLY MOBILE CHAINS OF FATTY ACID



NO LATERAL INTERACTION – NO SPREADING

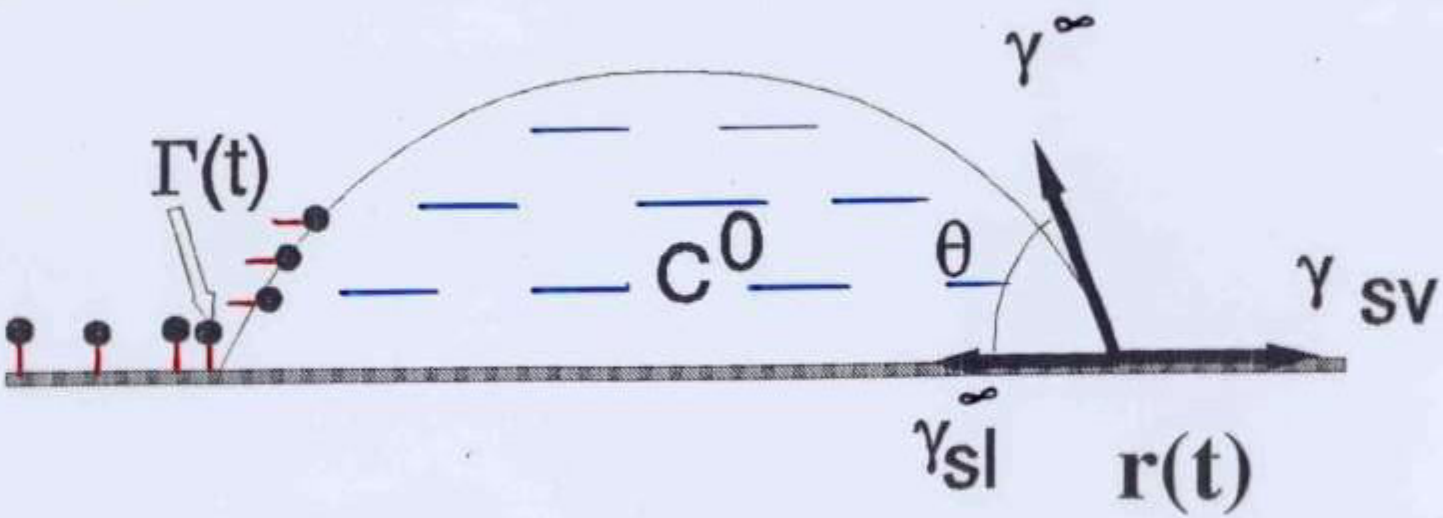




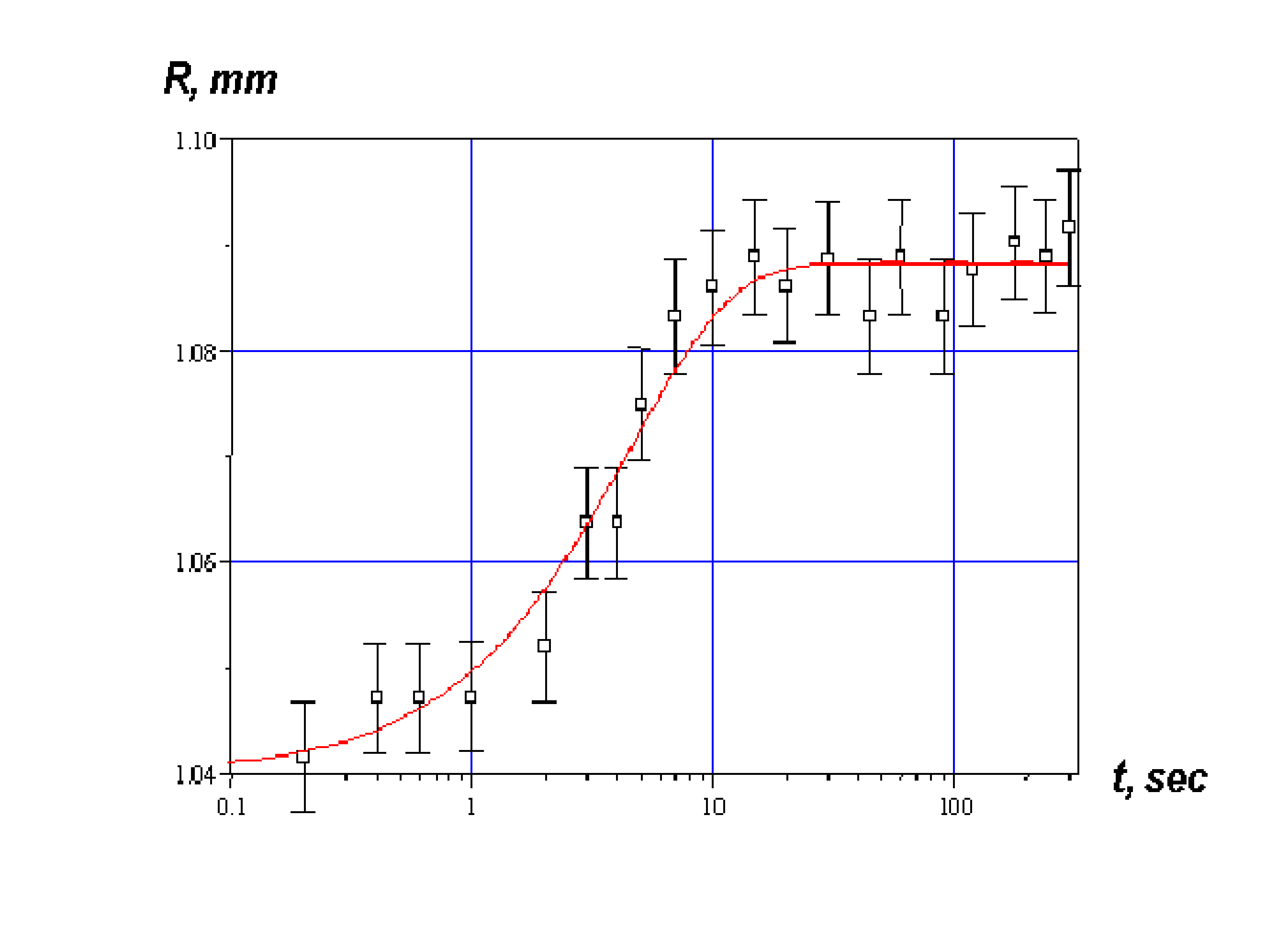
contact angle , degree
110
100
90
80
70
60
0 %
Sir Eric Rideal and J. Tadayon
% stearic acid in paraffin wax
2 %
49 %
0
5
10
15
20
time, hours

SPREADING OVER HYDROPHOBIC SUBSTRATES

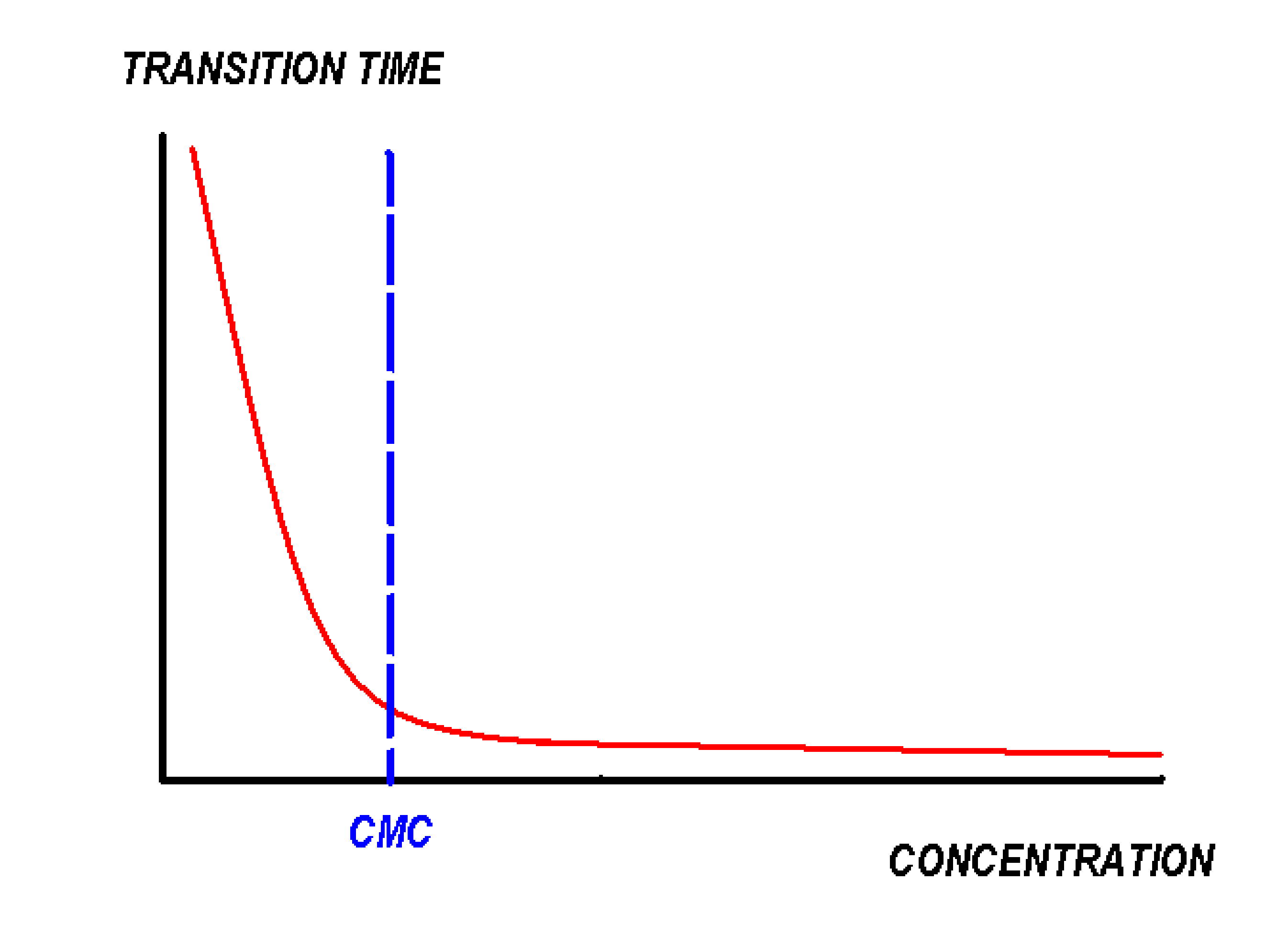
Kinetics of drops spreading over hydrophobic surfaces



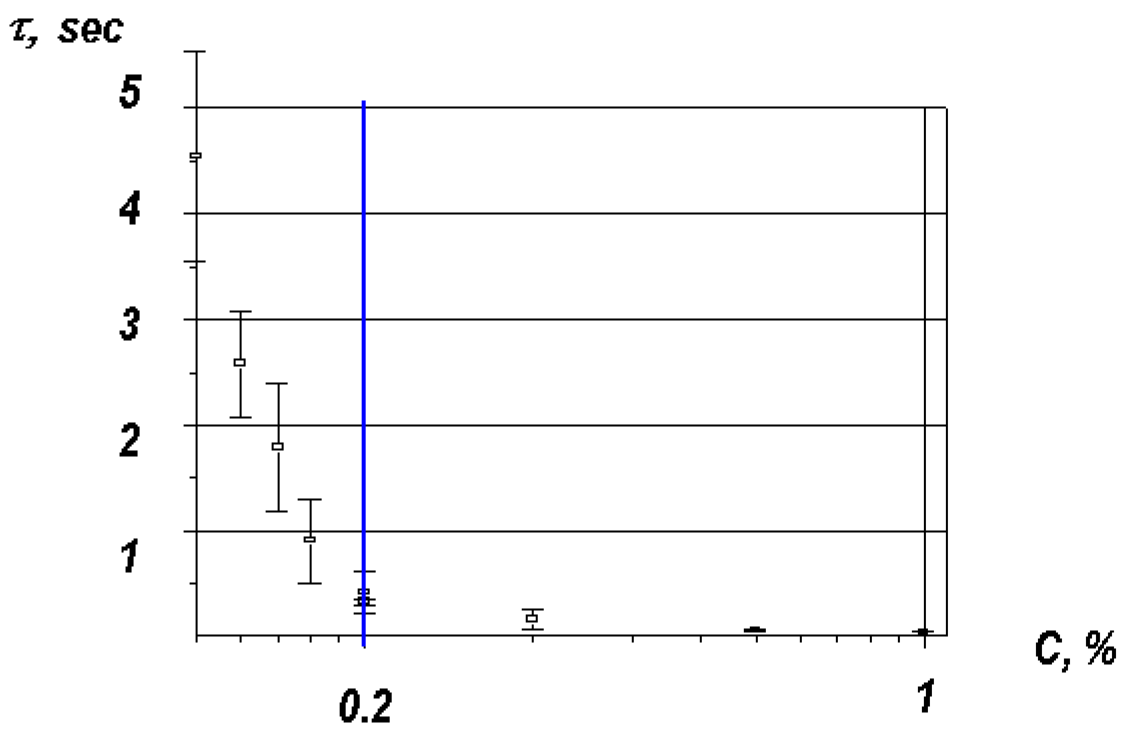
SPREADING OF DROPS (2.5±0.2 μl) OF 0.05% SDS SOLUTION OVER PTFE WAFER



THEORY PREDICTION



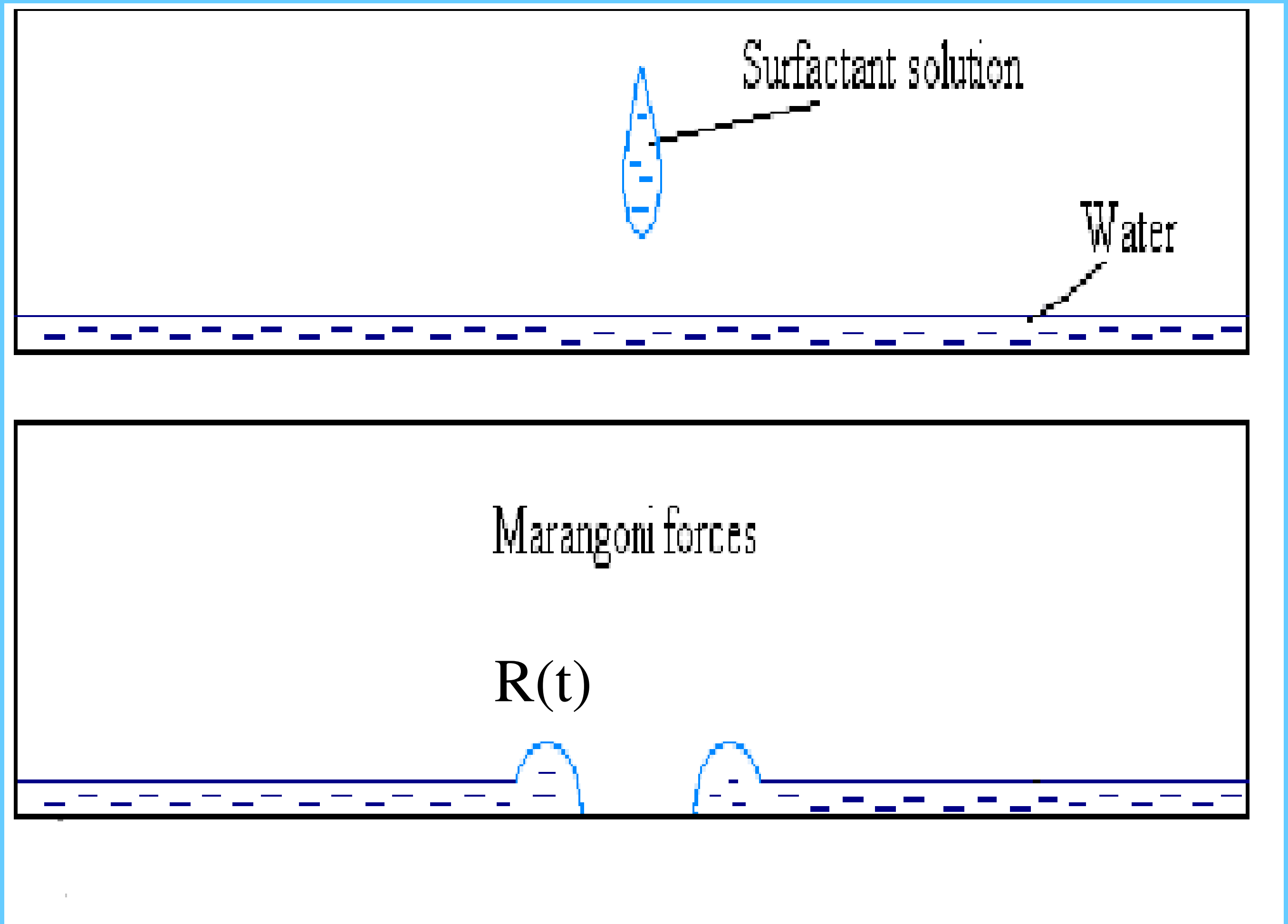
TRANSITION TIME, τ, ON CONCENTRATION SPREADING OF SDS SOLUTIONS OVER PTMF

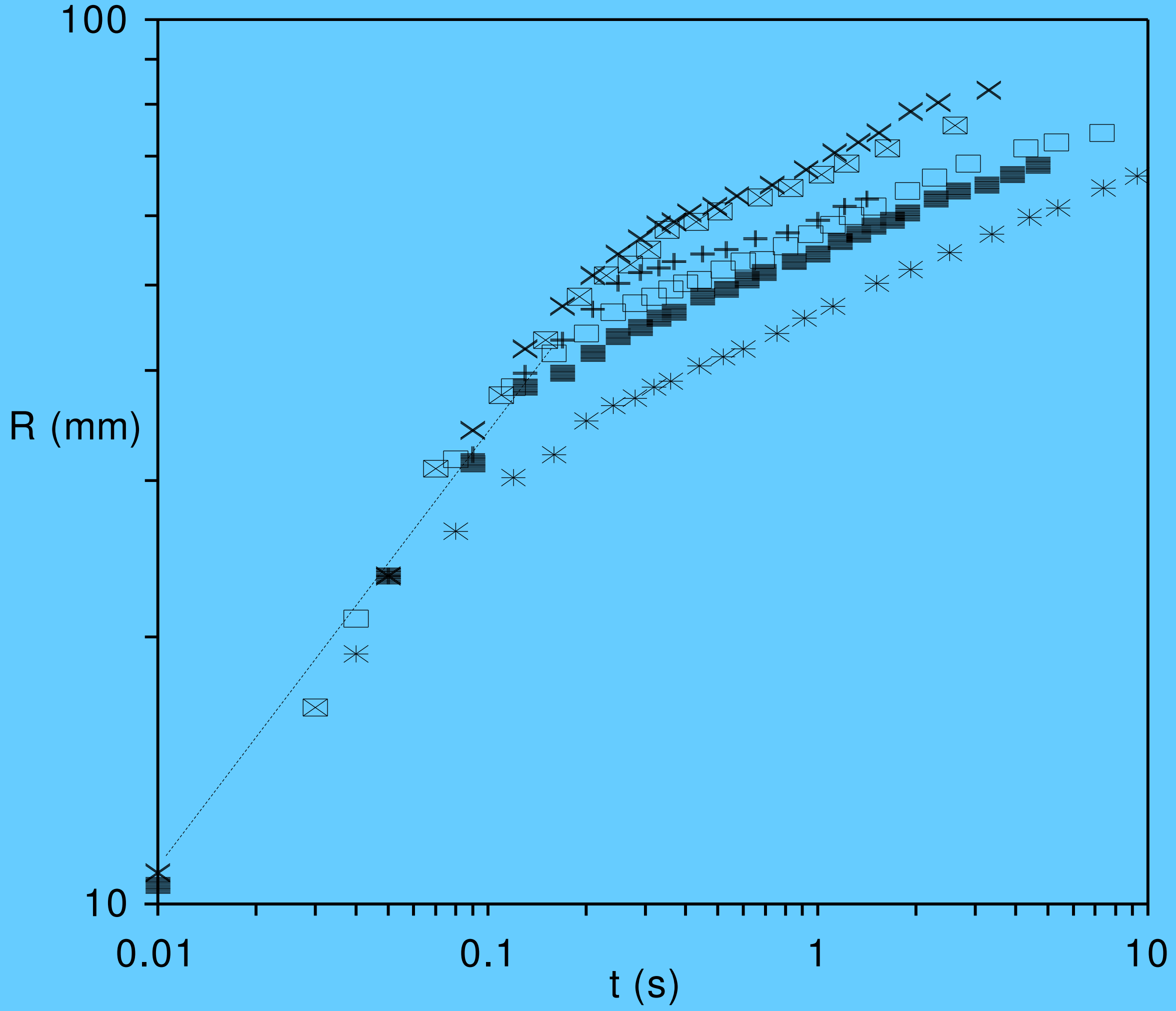


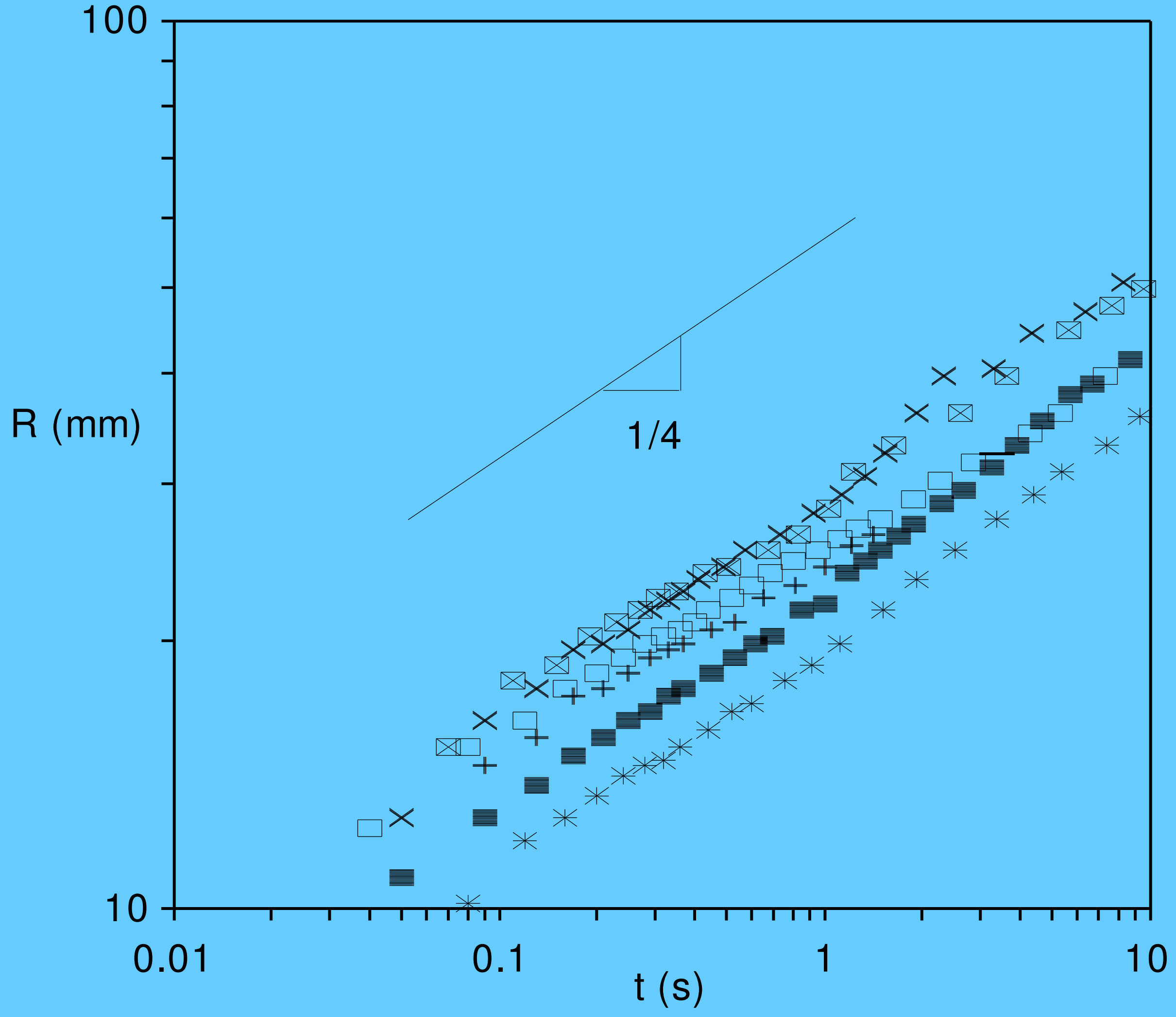
SURFACTANTS ON THIN WATER LAYERS:

MARANGONI FLOW

SURFACTANT ON THIN WATER LAYER



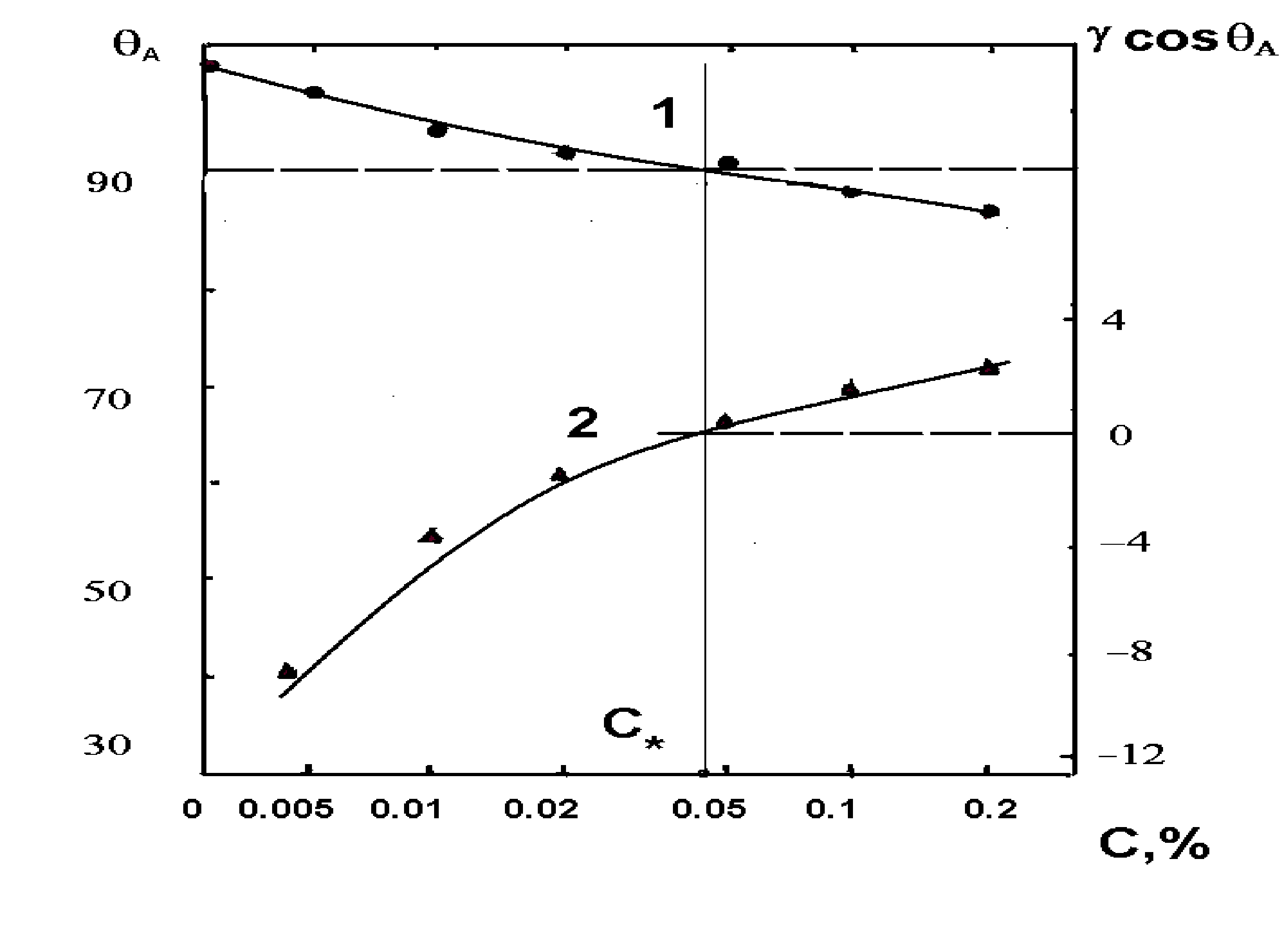

100
R (mm)
10
0.01
0.1
1
10
t (s)


100
R (mm)
1/4
10
0.01
0.1
1
10
t (s)

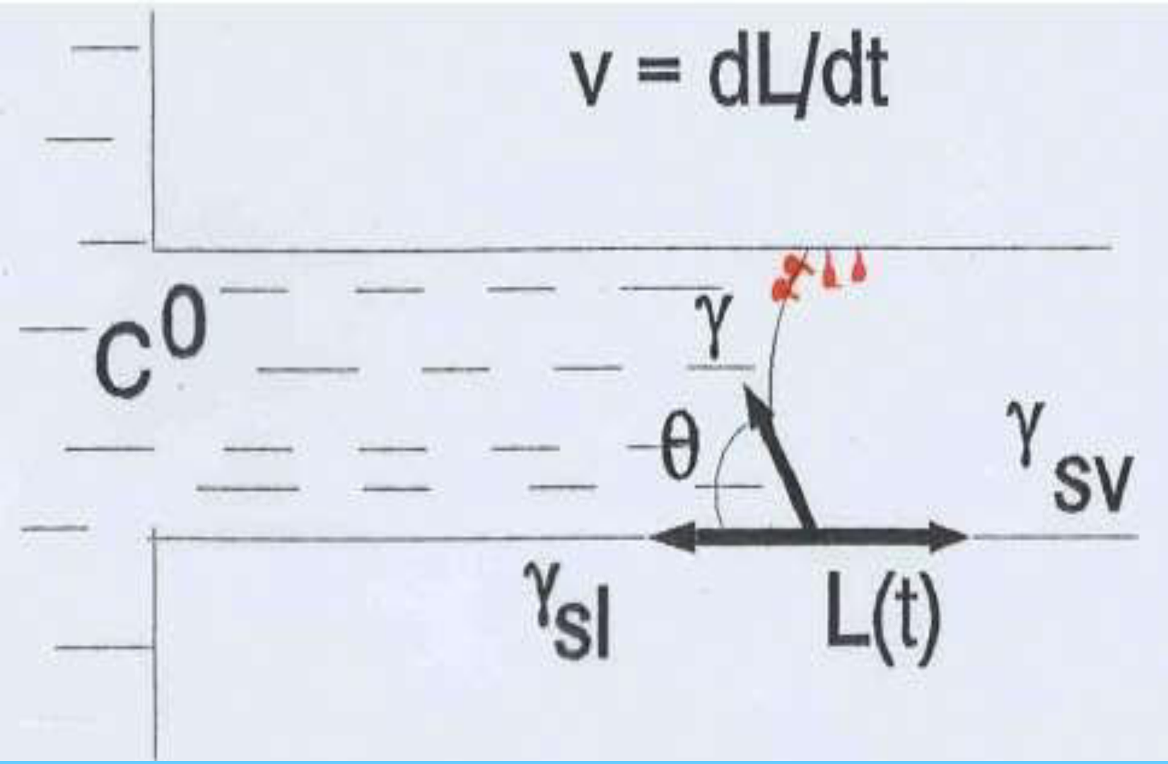
Capillary imbibition of surfactant solutions

NON-WETTING

SYNTAMID-5 ON HYDROPHOBISED QUARTZ SURFACE



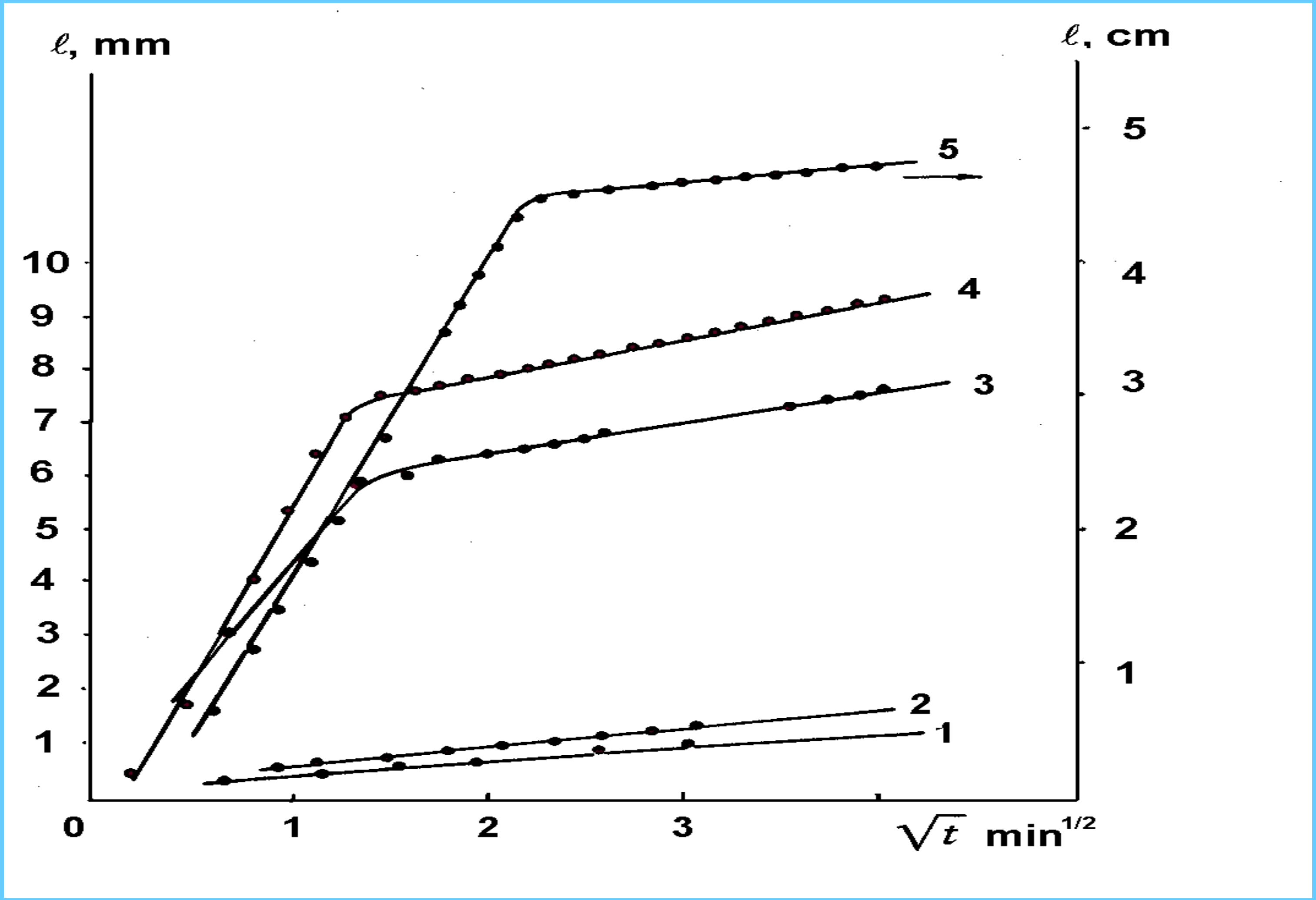
IMBIBITION OF SURFACTANT SOLUTIONS INTO HYDROPHOBISED QUARTZ CAPILLARIES



SPONTANEOUS PROCESS!

Imbibition length, *l*, on time, *t* , Syntamide-5 horizontal hydrophobized quartz capillary, r = 16 μm.

1 1 0.05%; 2 0.1%; 3 0.4%; 4 0.5%; 5 1%.

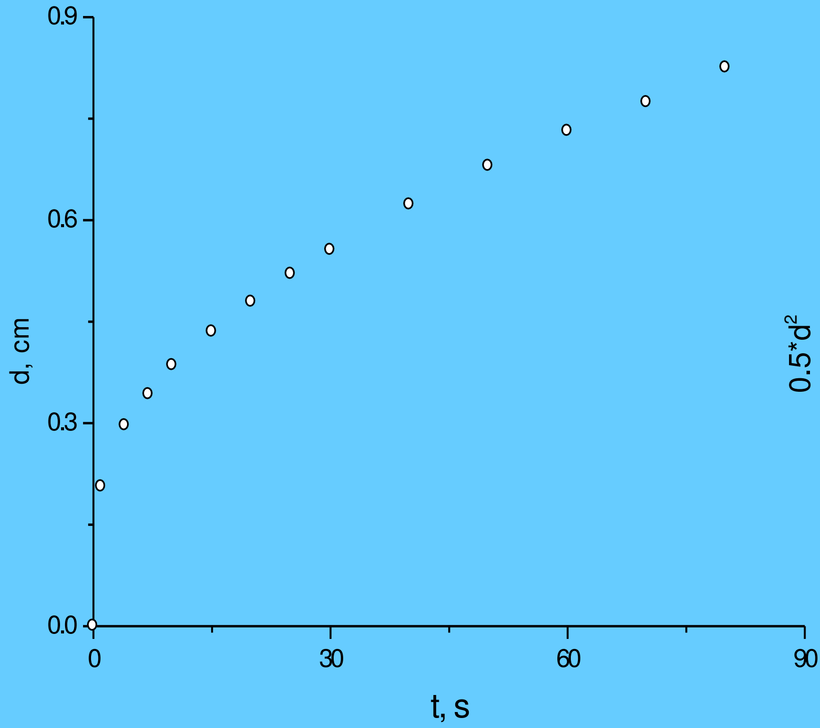


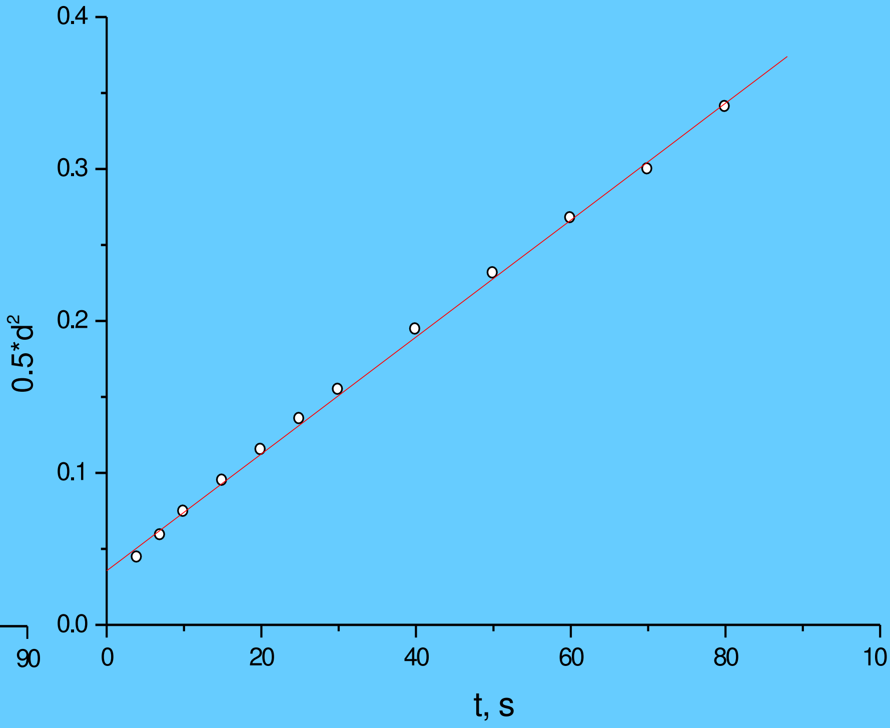
CAPILLARY IMBIBITION OF SURFACTANT SOLUTIONS

PARTIAL WETTING

Capillary imbibition of surfactant solutions: partial wetting

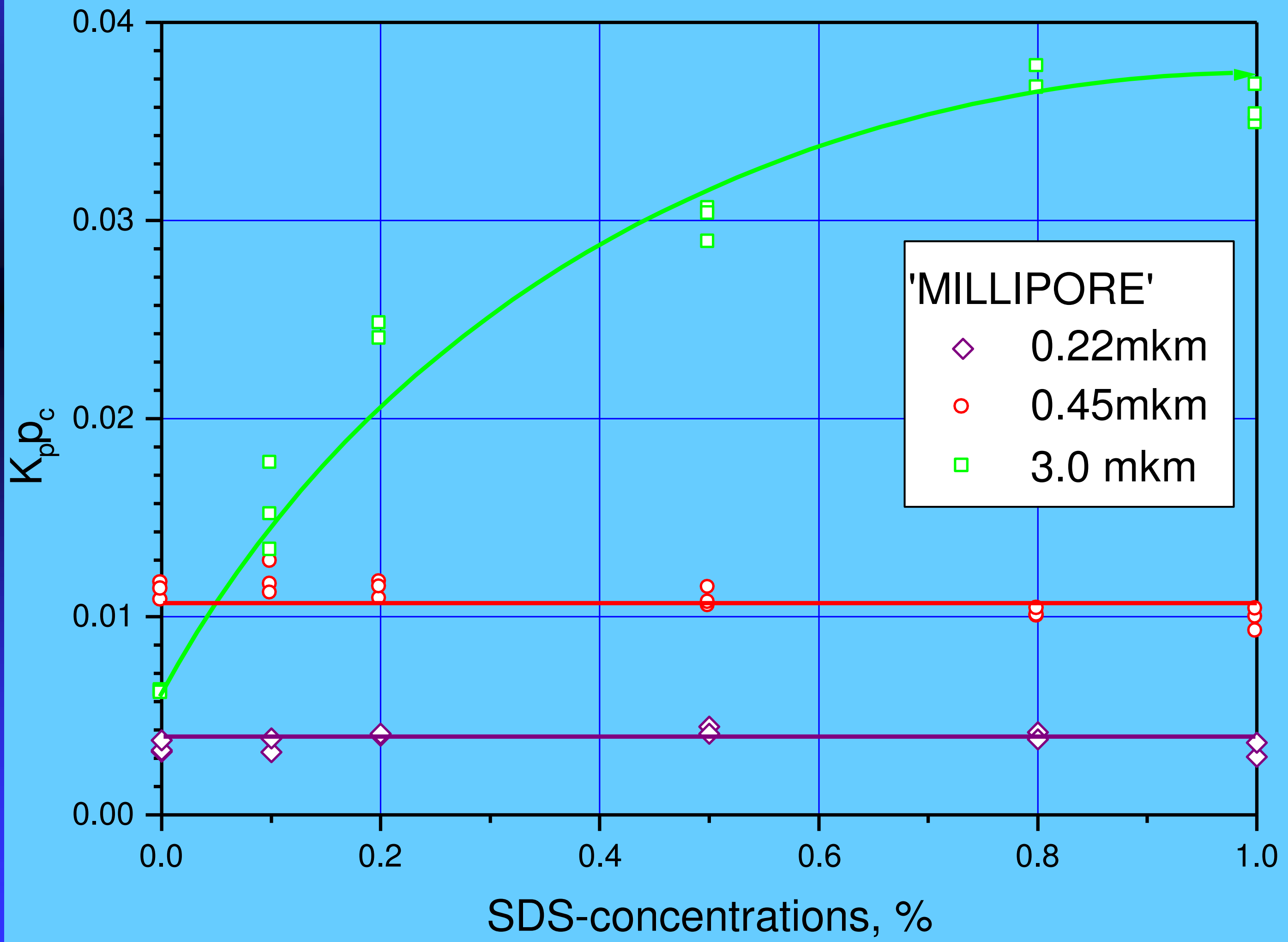
$$d^2(t) = 2K_p p_c t / \mu$$





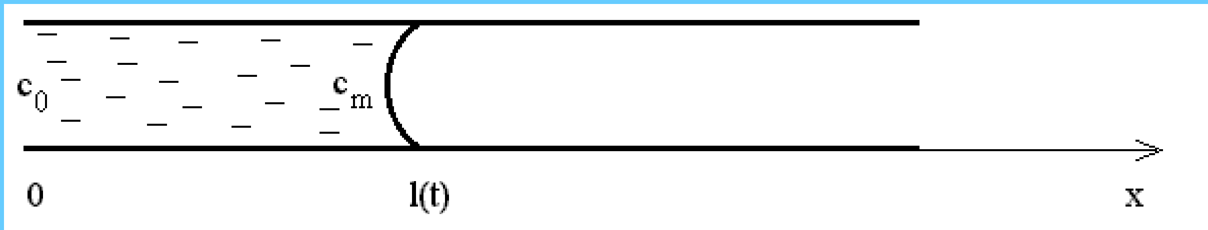
Nitrocellulose membrane
SDS concentration 0.1%
Average pore size 0.22 μm.

Capillary imbibition of SDS solutions: nitrocellulose membranes



Capillary imbibition of surfactant solutions

Theory



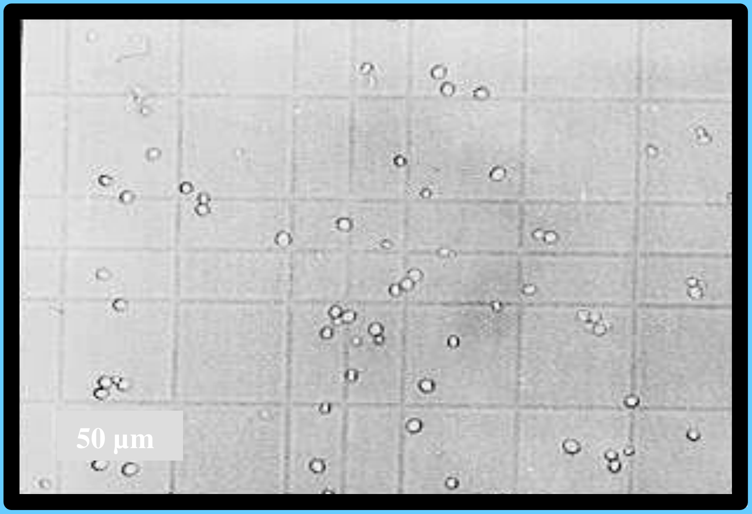
$$r_{cr} = \frac{a_\infty^2 \pi \gamma_{\min} \cos\theta_{\max}}{2D\eta c_{CMC}^2}$$

I. $r < r_{cr}$ **Surfactant concentration is zero on the moving meniscus at any SDS concentration: pure water on the meniscus!**

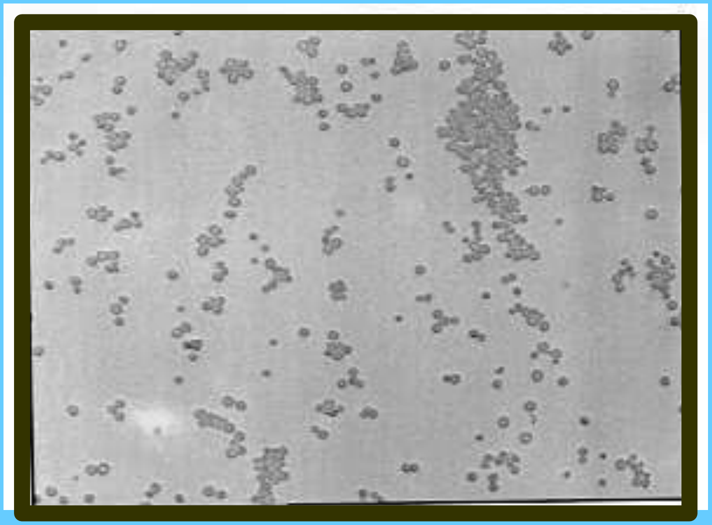
II. $r > r_{cr}$ **Surfactant concentration increases on the moving meniscus with SDS concentration, which results in faster imbibition.**

INFLUENCE OF CLUSTER FORMATION ON VISCOSITY OF CONCENTRATED SUSPENSIONS/EMULSIONS

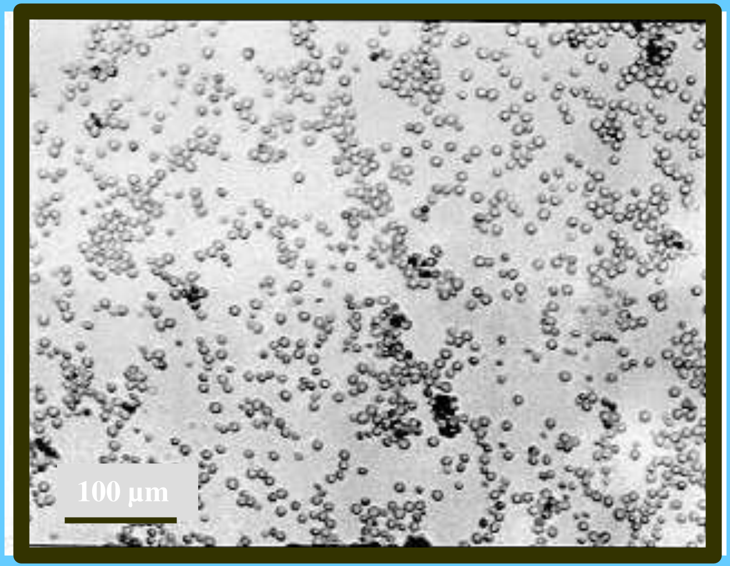
Cluster formation in yeast suspensions



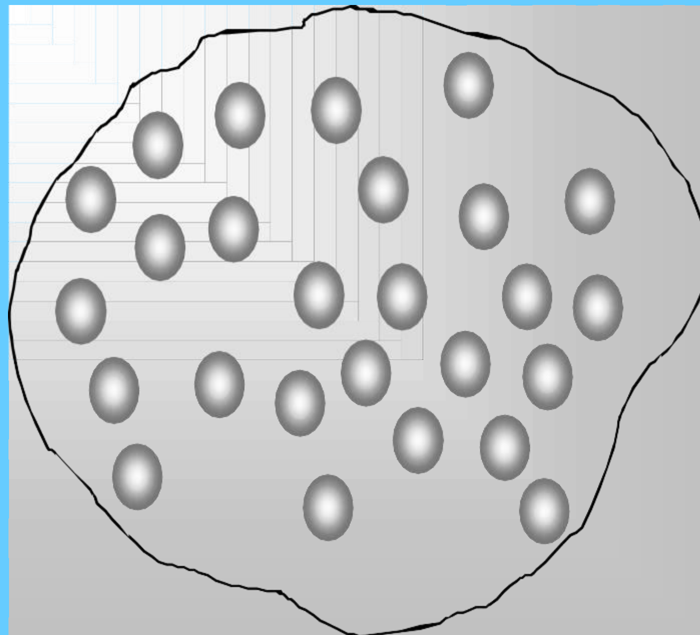
$\gamma = 0.002$

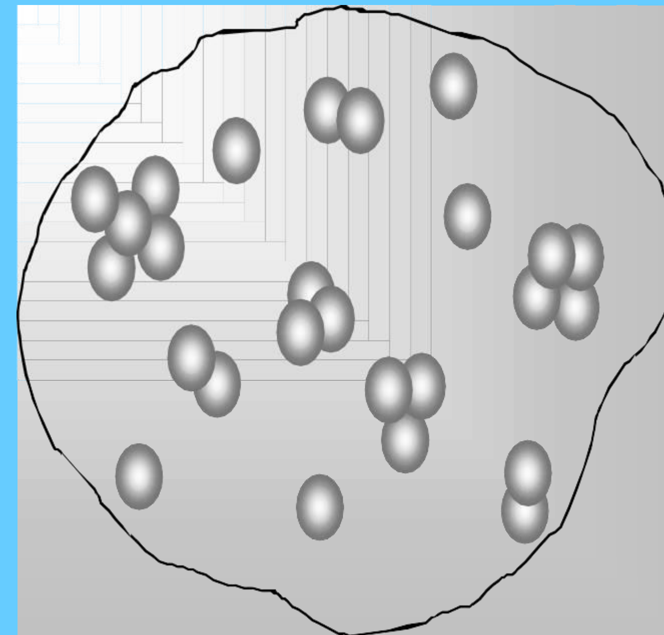


$\gamma = 0.02$



$\gamma = 0.04$



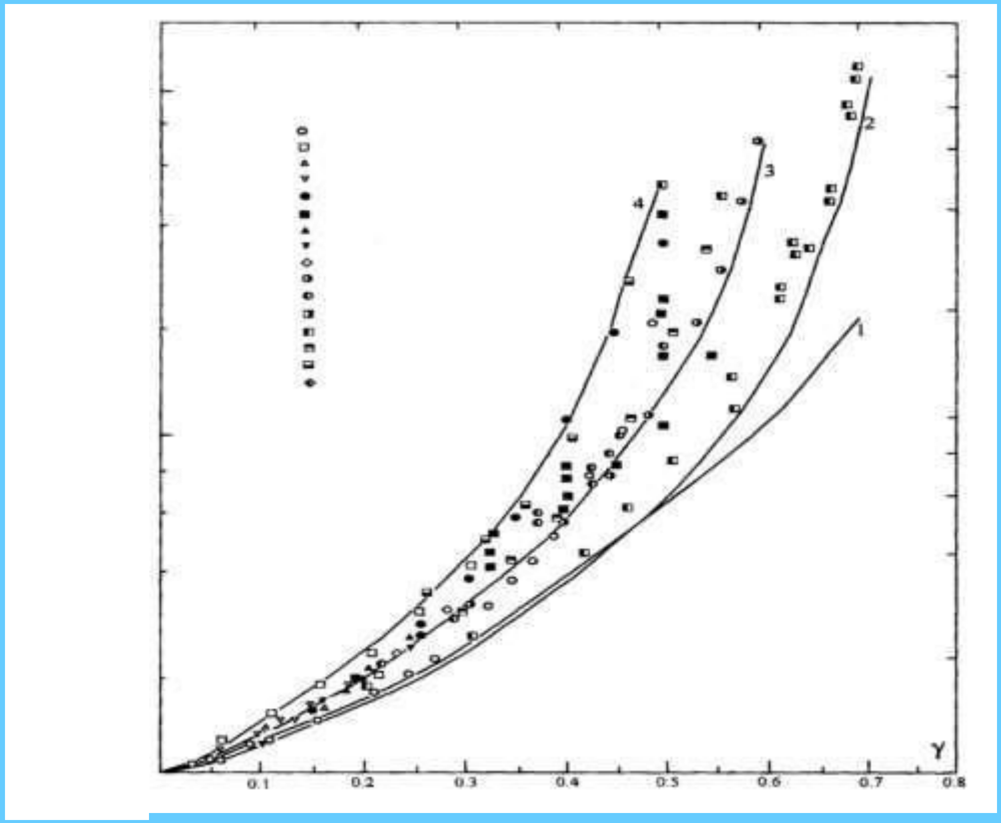


No clusters — Cluster formation

Viscosities are different though particle volume fractions are equal

Viscosity on volume fraction of dispersed particles.

η^{eff}/η^{m}



Experimental data from review (Thomas), solid lines according to our equation

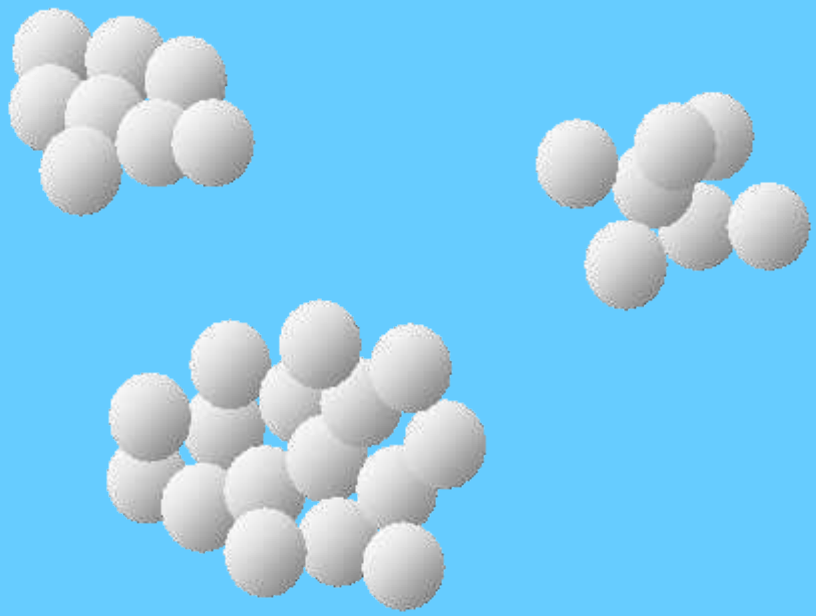
1. γ_m=1, A=1 (particles do not form clusters)

2. γ_m =0.73 (close to hexagonal packing of particles inside clusters), A=0.61

3. γ_m =0.65 (close to cubic centered packing of particles inside clusters), A=0.67

4. γ_m =0.56 (close to simple cubic packing of particles inside clusters), A=0.72

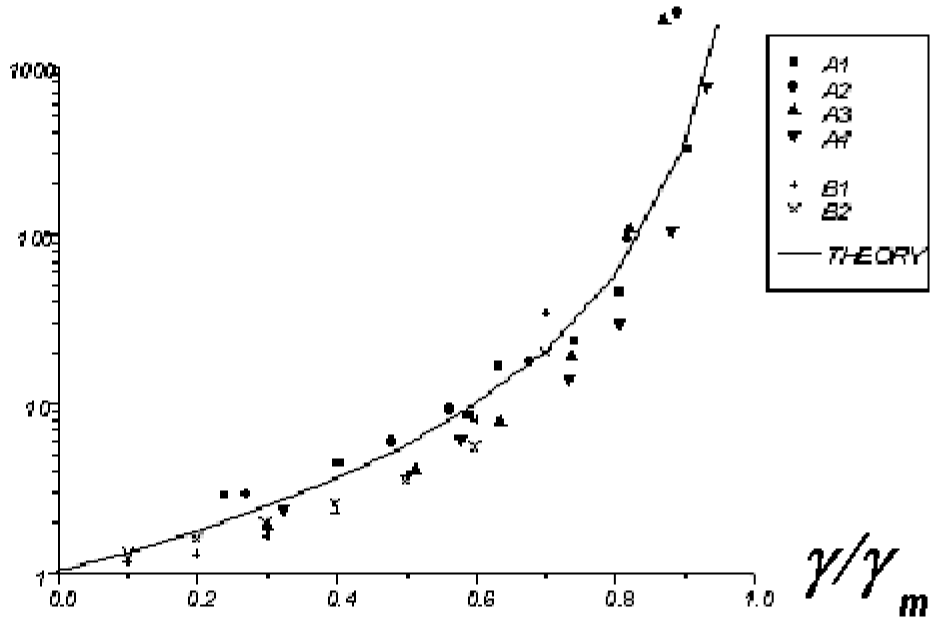
EMULSIONS



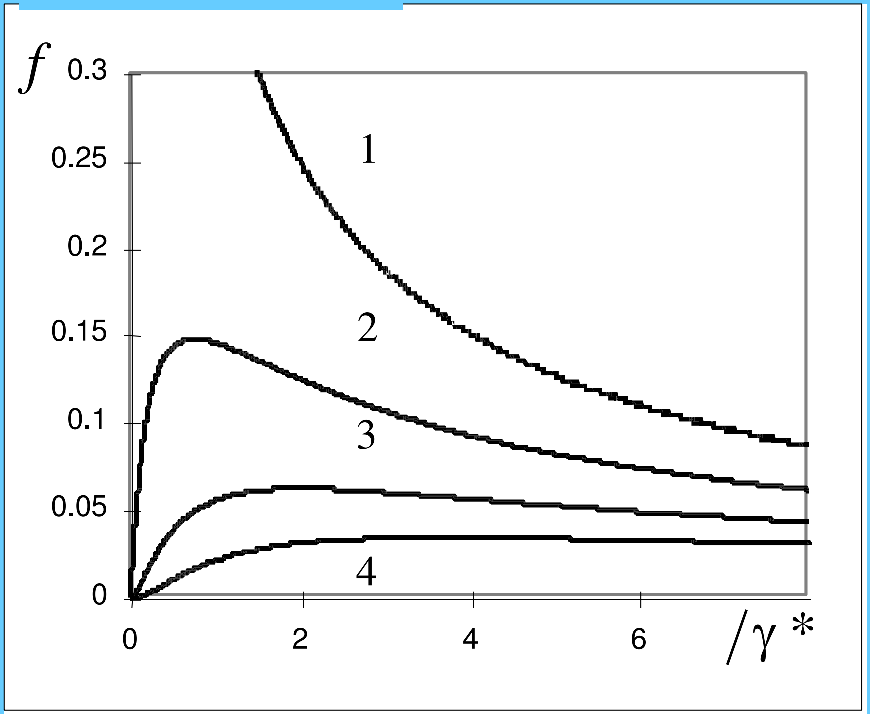
Developed flocculation

γ_m density of droplets inside flocs

$$\left(\frac{\eta}{\eta_0}\right)\left[\frac{2\eta+5\eta_C}{2\eta_0+5\eta_C}\right]^{3/2}$$

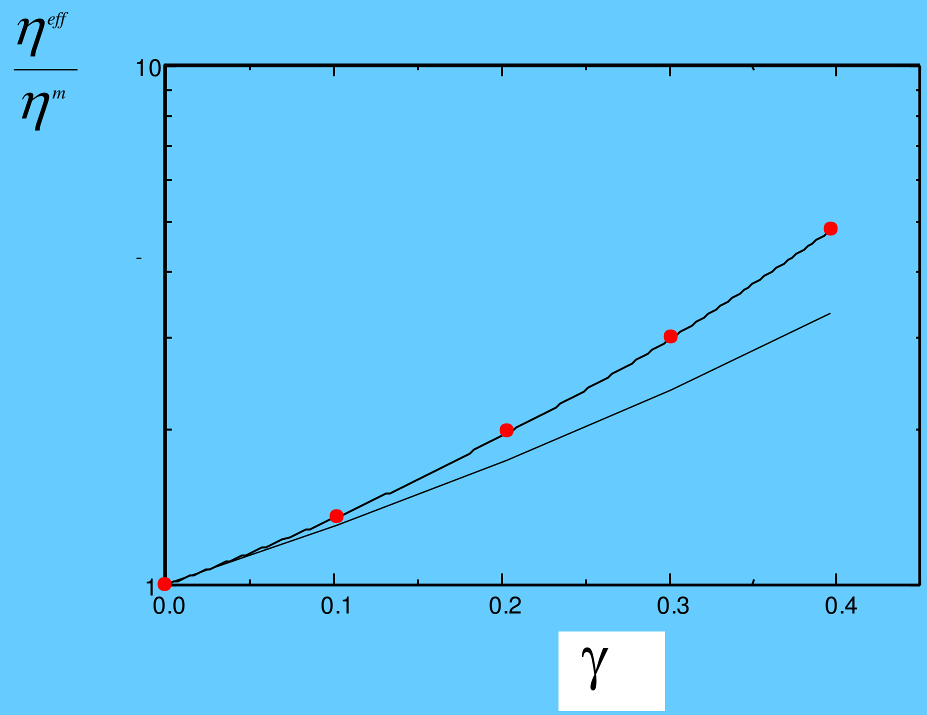


Theory of reversible coagulation



γ* volume fraction when clusters start to form

Low flocculated emulsion

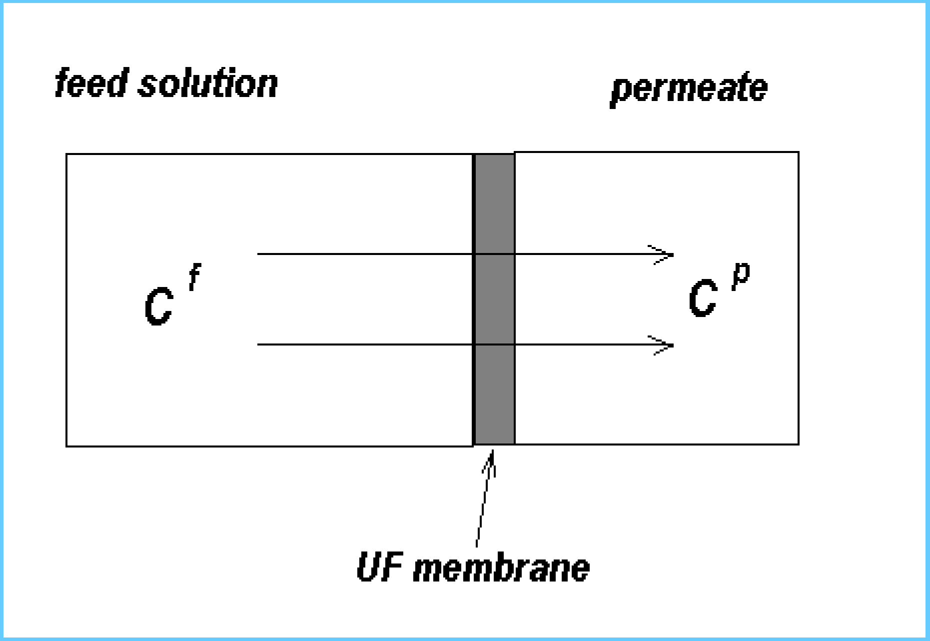


Milk at different volume fractions of fat (Leviton, A, and Leighton, A., 1936).

Curve 1 our theory (cluster formation)

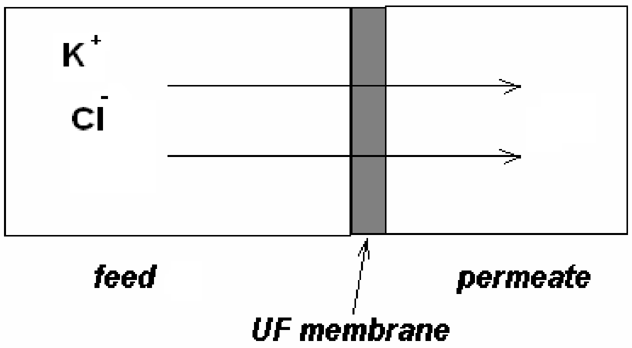
Curve 2 no cluster formation

DEADEND ULTRAFILTRATION



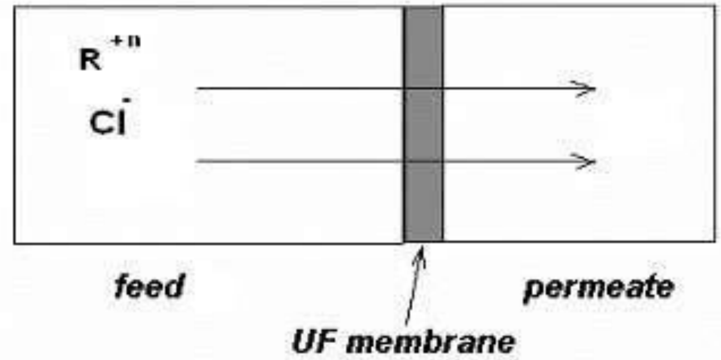
$$\lambda = \frac{C^p}{C^f}$$

Only KCl



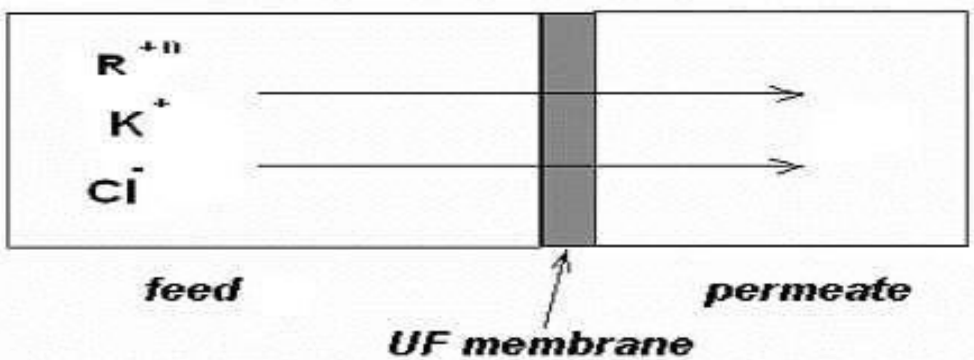
$C^f_{K^+} = C^p_{K^+}$ Rejection = 0

Only water soluble polymer



$C^p_R = 0$ Rejection = 1

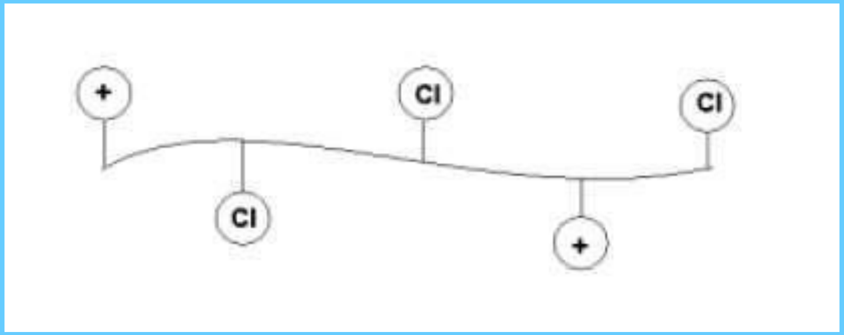
Mixture of water soluble polymer and KCl



Concentration of K is higher in the permeate than in the feed solution

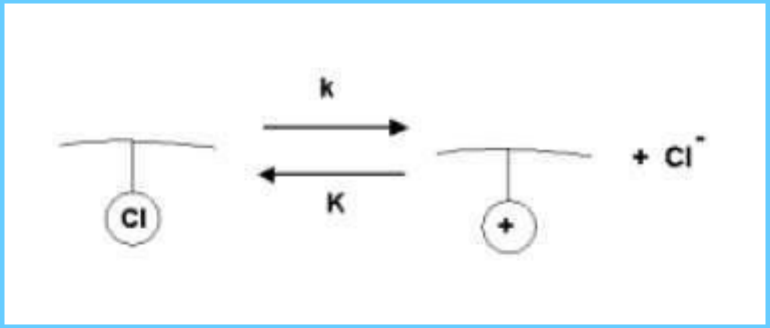
Water soluble polymer,

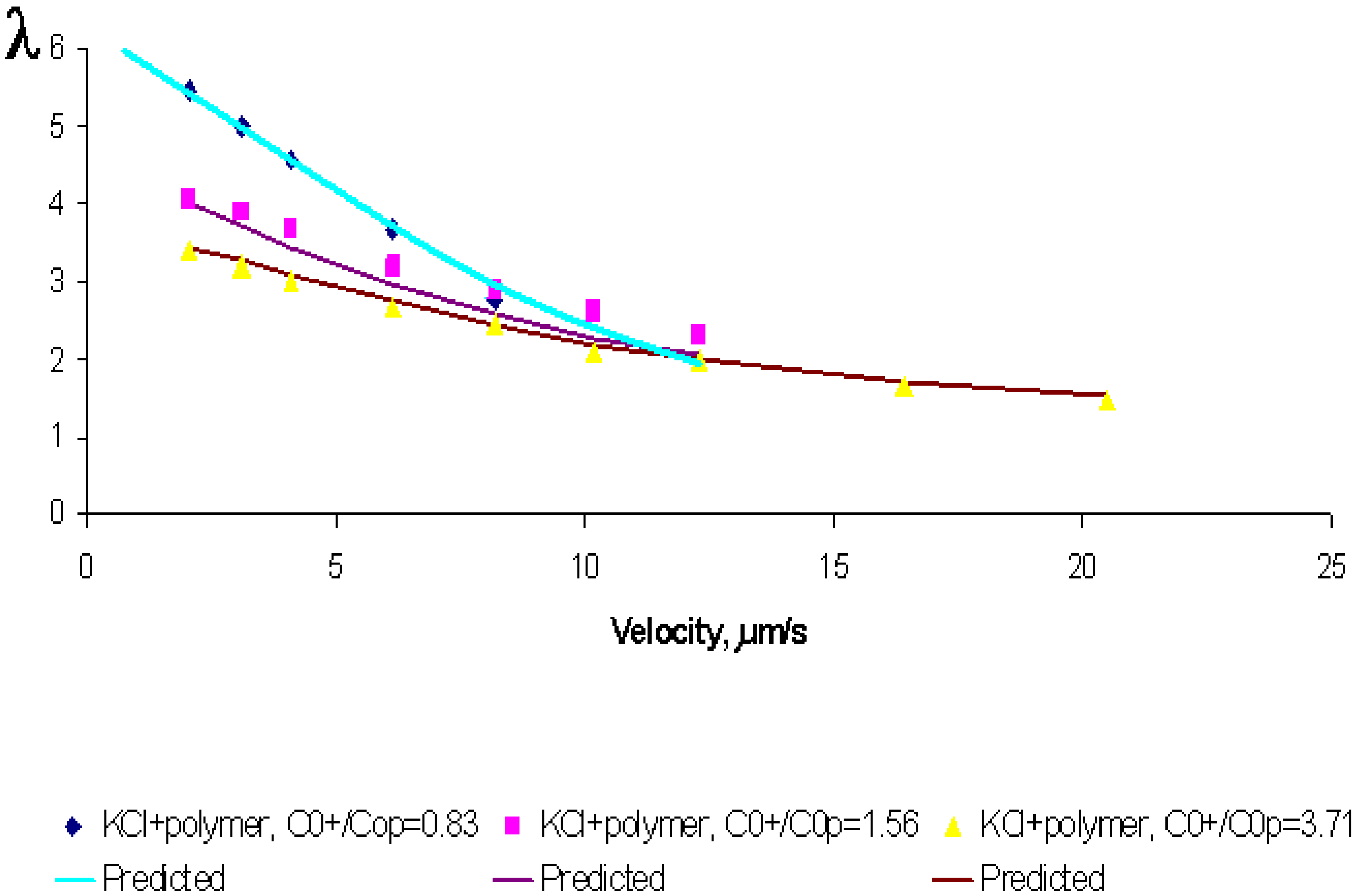
n-repeated units (n=5)



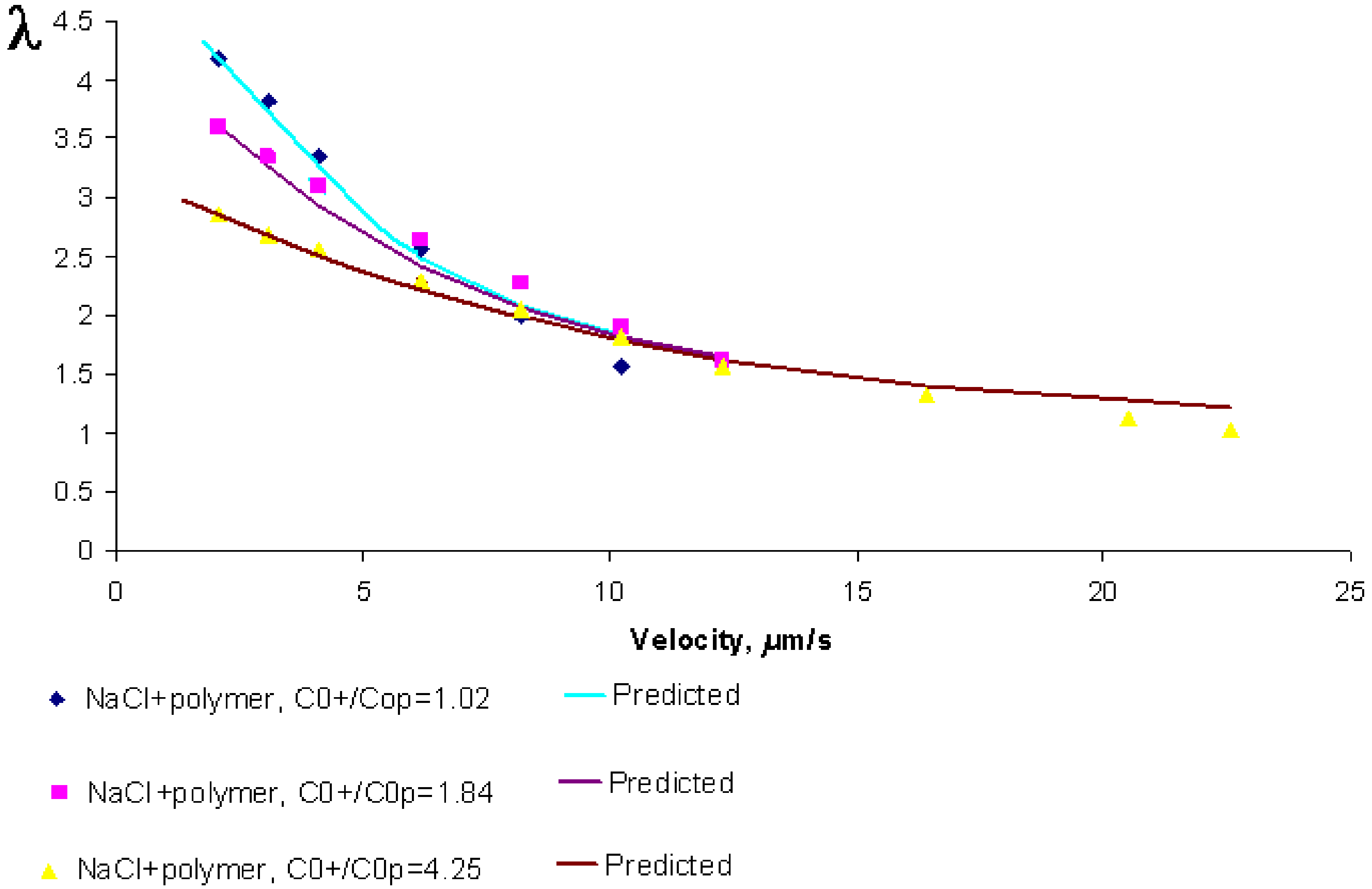
Dissociation/association

of each unit





$$\lambda = C^p/C^f > 1$$



$$\lambda = C^p/C^f > 1$$

Chemical Sciences Related Journals

- Journal of Thermodynamics & Catalysis
- Journal of Plant Biochemistry & Physiology
- Organic Chemistry: Current Research

Chemical Sciences
Related Conferences

- [Medicinal Chemistry & Computer Aided Drug Designing]
- [3rd International Conference on Medicinal Chemistry & Computer Aided Drug Designing]

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