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Study of Foam Film Drainage via micro-interferometric techniques

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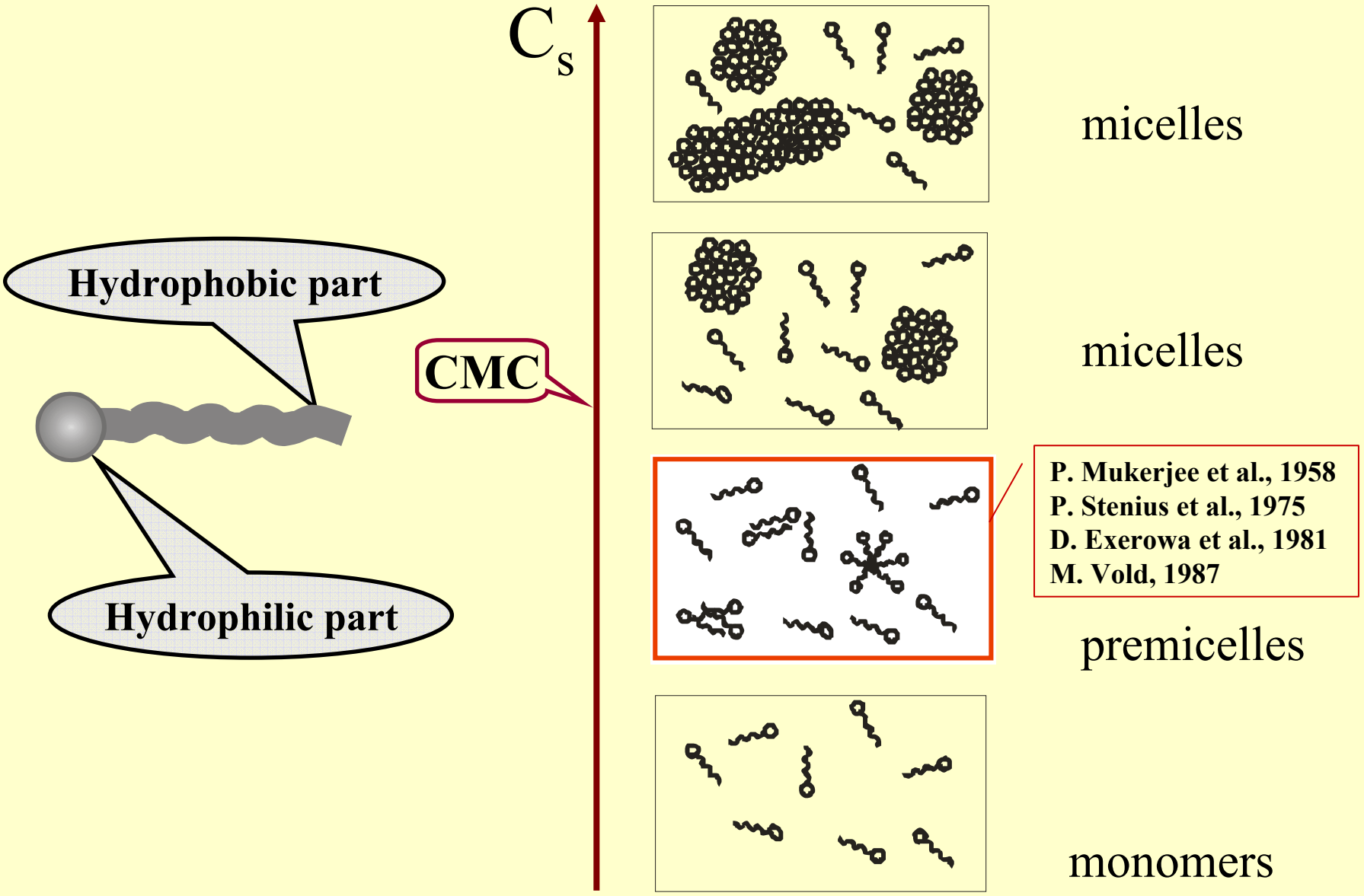
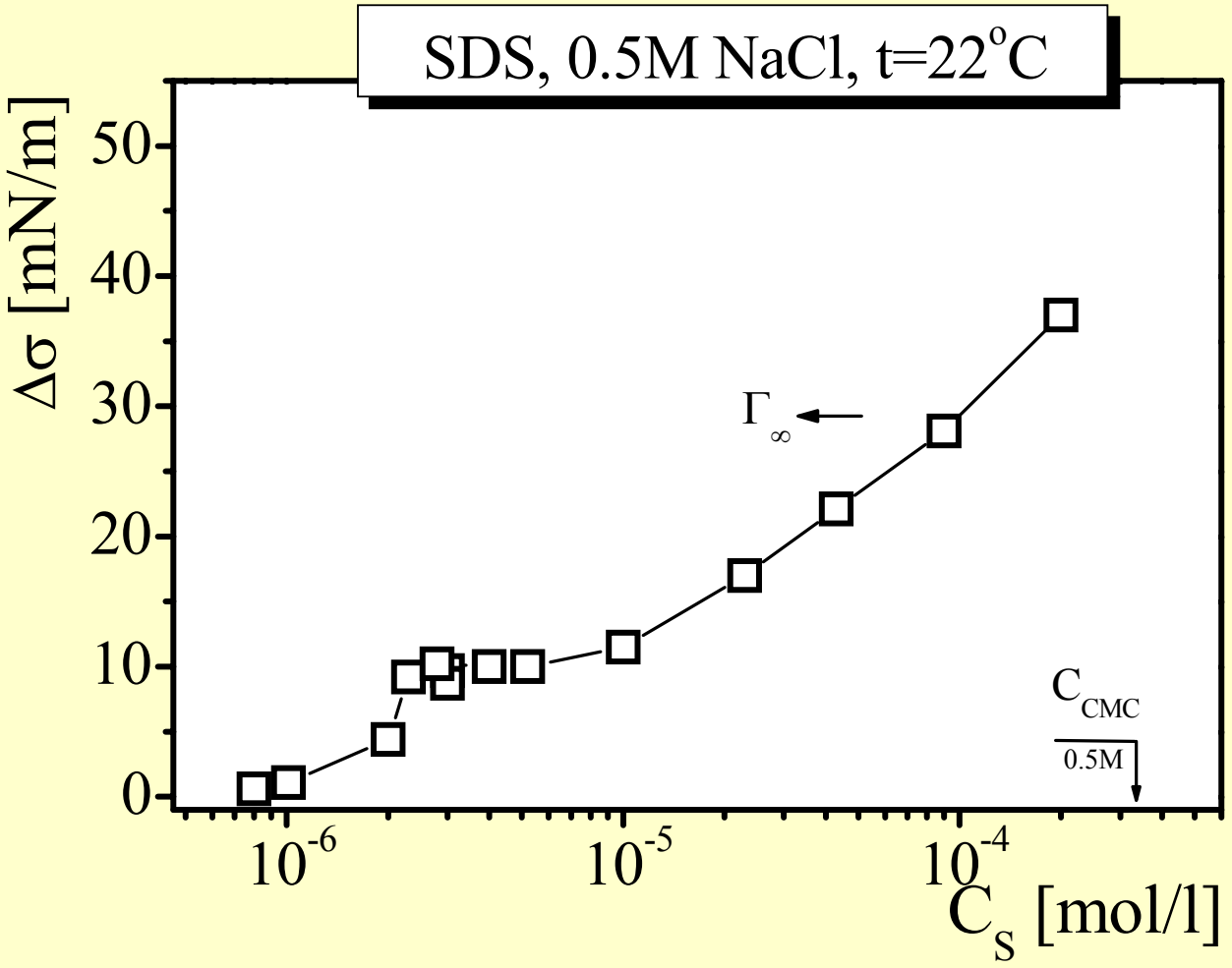
Aim

To outline the impact of amphiphlic self-assembled structures on the drainage of microscopic foam films from aqueous surfactant solutions

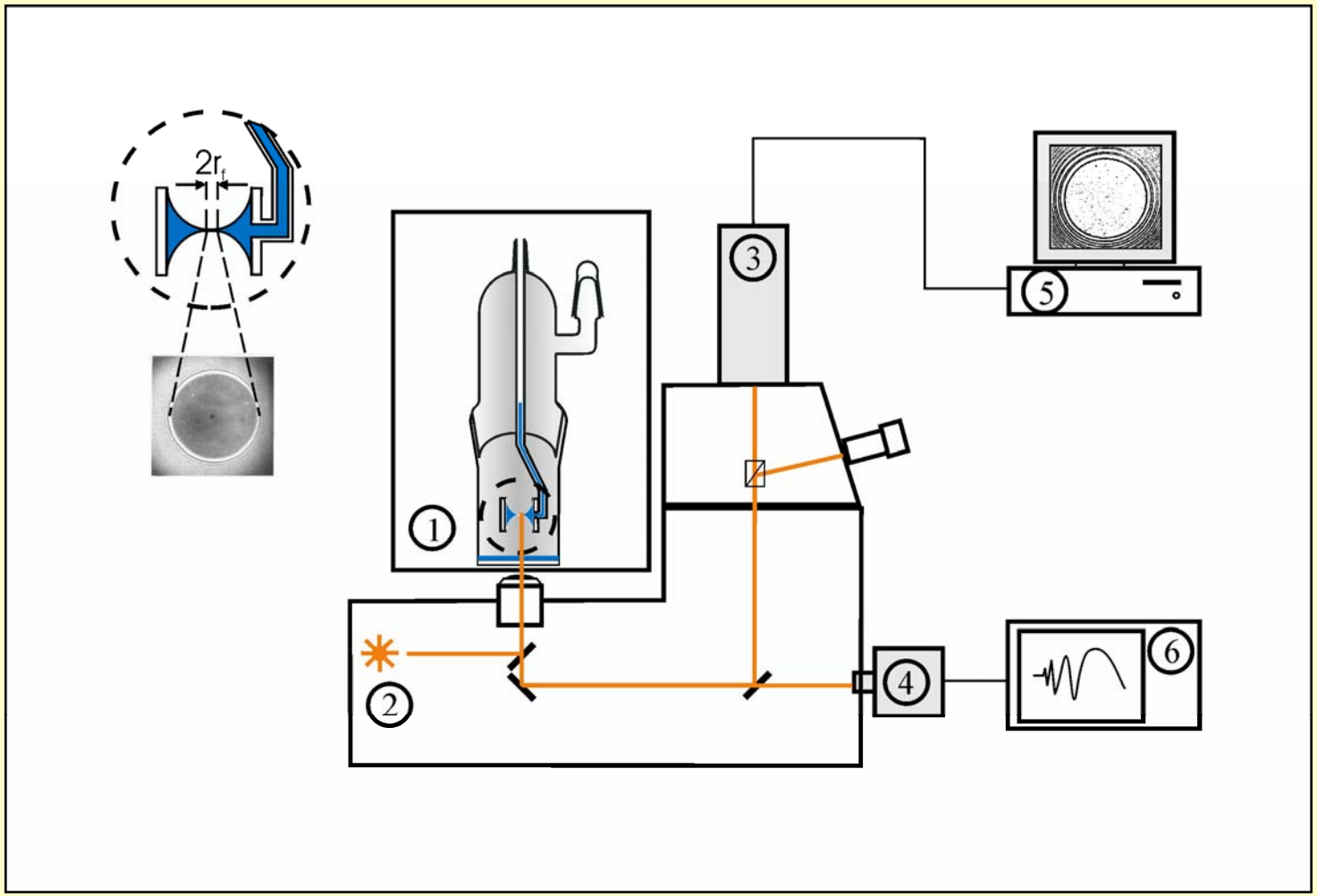

C_s
Hydrophobic part
Hydrophilic part
CMC
micelles
micelles
premicelles
monomers
P. Mukerjee et al., 1958
P. Stenius et al., 1975
D. Exerowa et al., 1981
M. Vold, 1987

Motivation



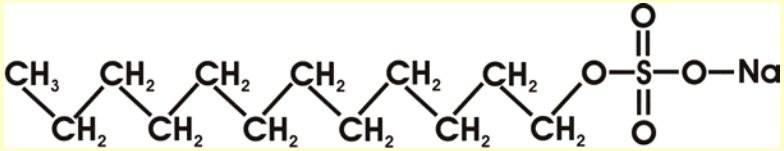
Exerowa et al., *J.Coll.Interf.Sci.,**1981**,81.*

Experimental setup

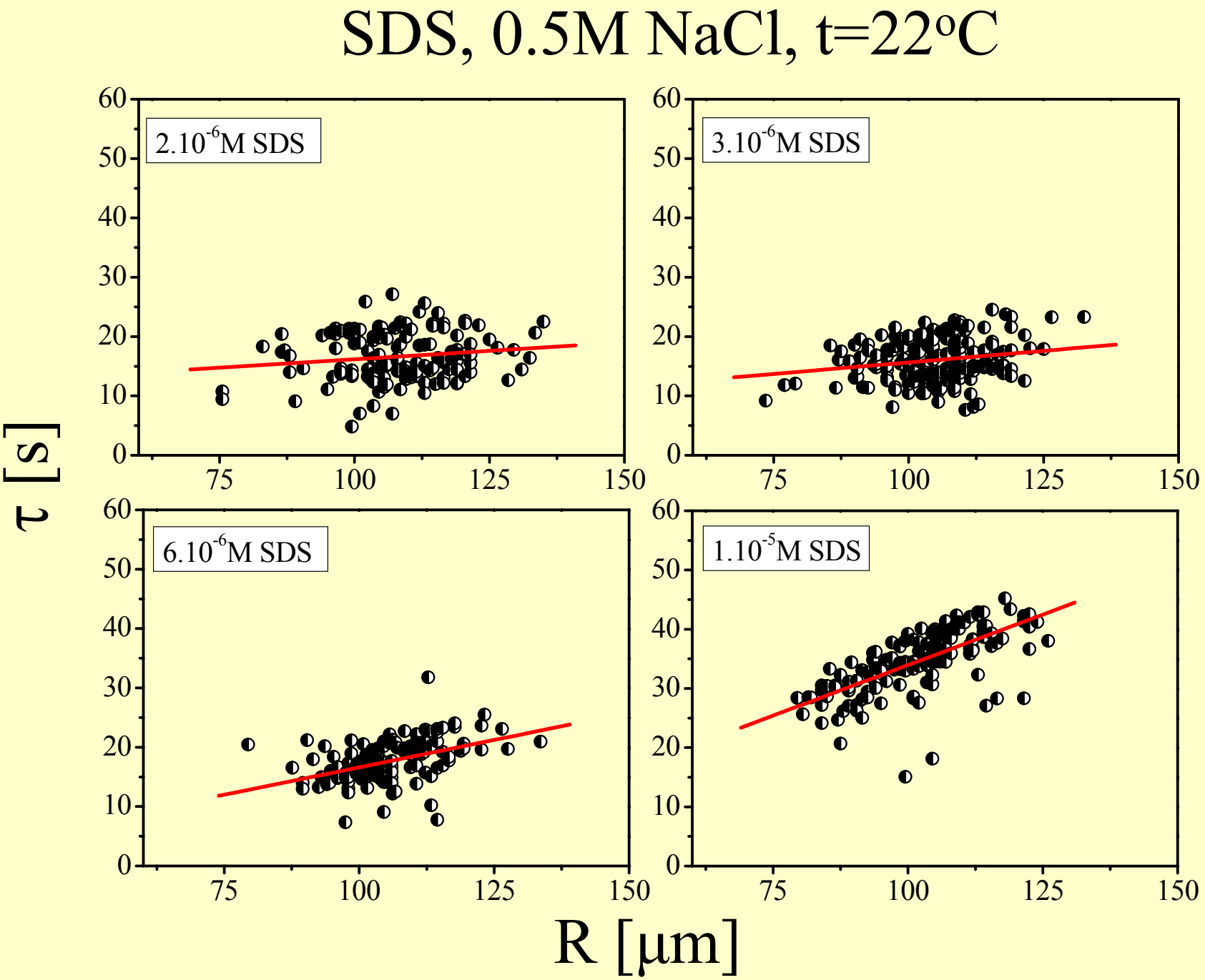


Experimental conditions

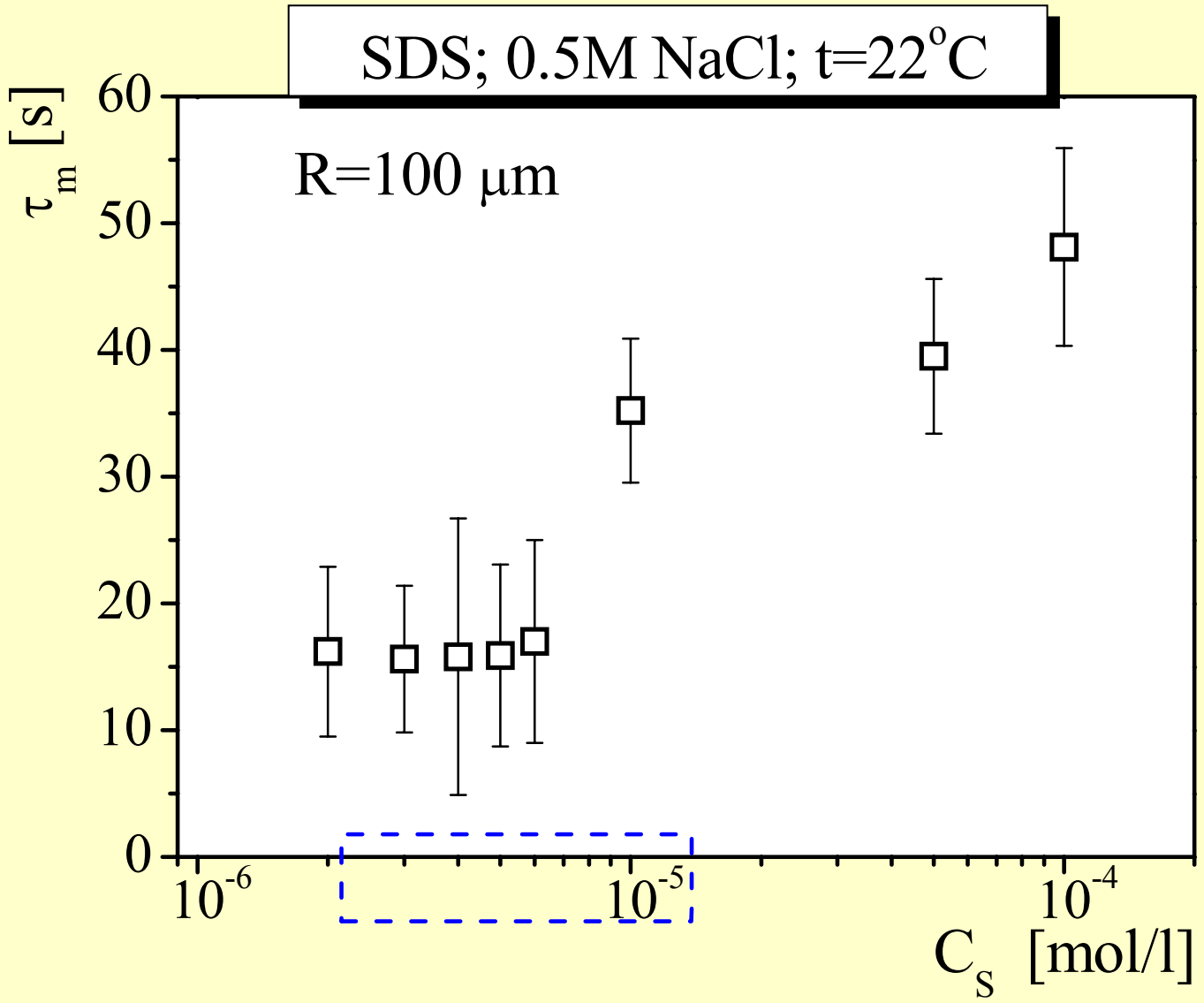
- Anionic surfactant SDS



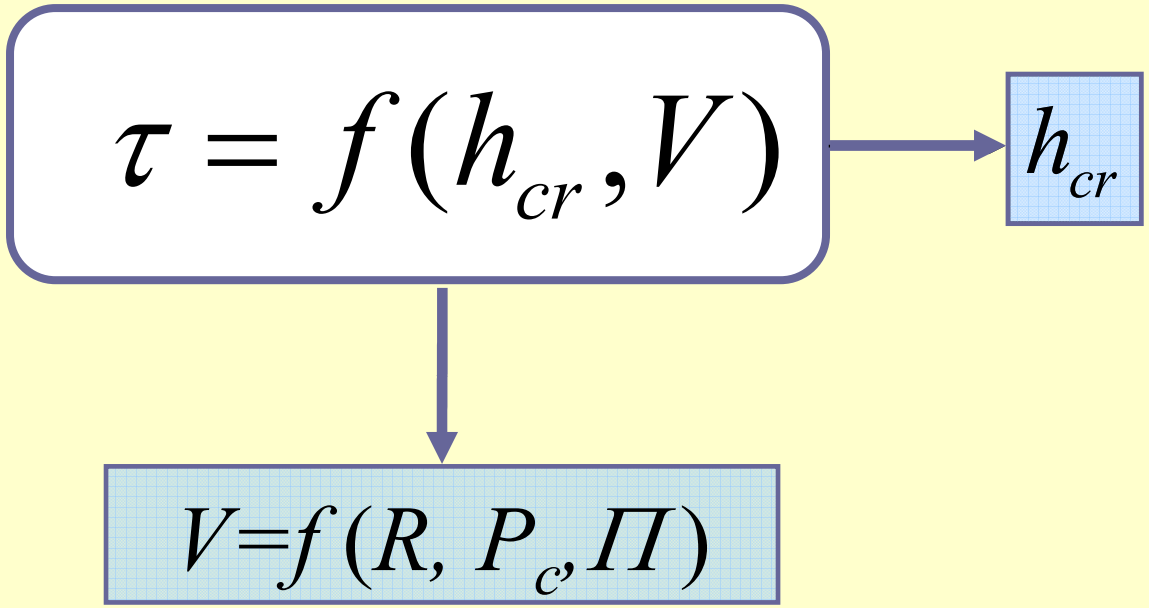
- Surfactant Concentration:
  - ✓ $2x10^{-6} \div 10^{-4}$ mol/l (0.5M NaCl)
- Electrolyte concentration :
  - ✓ 0.5M NaCl > $C_{el,cr}$


SDS, 0.5M NaCl, t=22°C
2.10-6M SDS
3.10-6M SDS
6.10-6M SDS
1.10-5M SDS
τ [s]
R [μm]
0
10
20
30
40
50
60
75
100
125
150

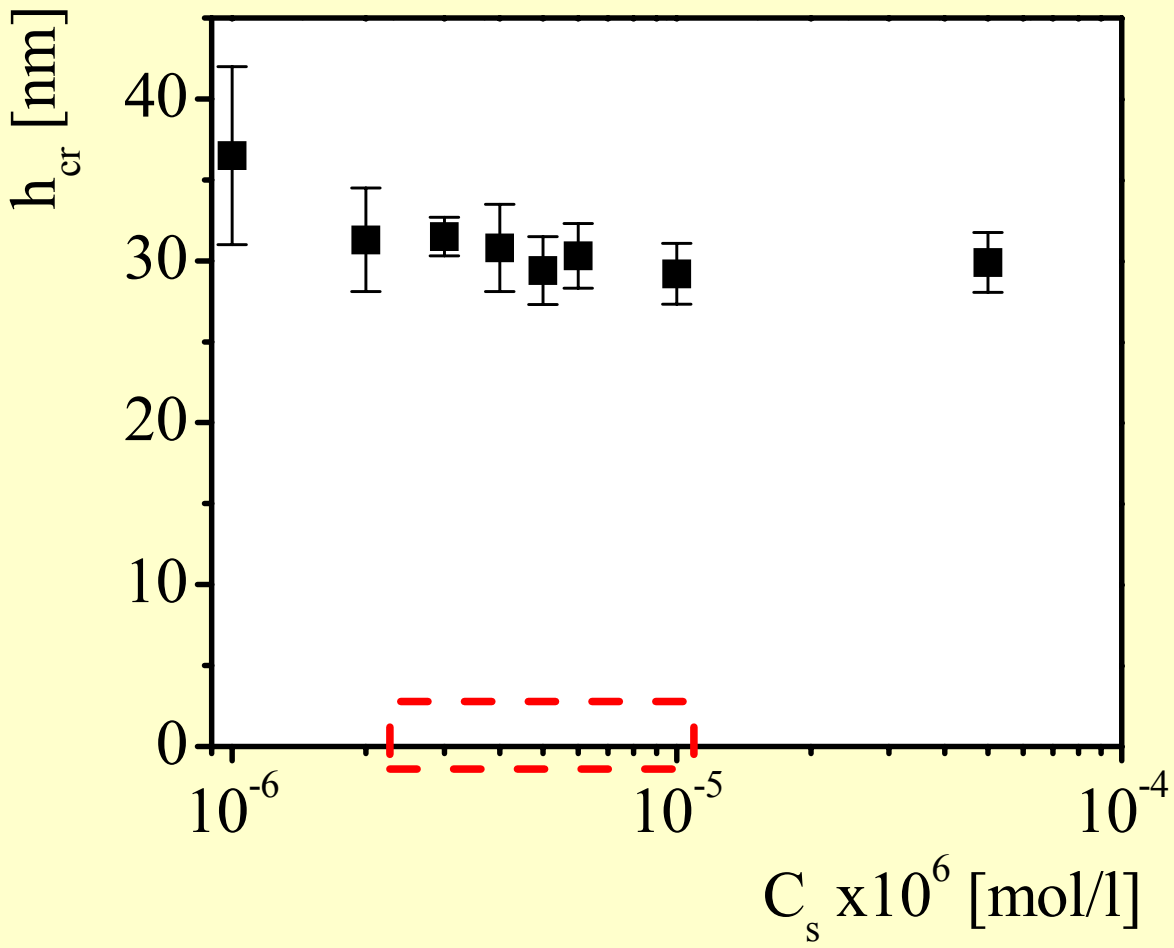
Foam film kinetics: drainage time



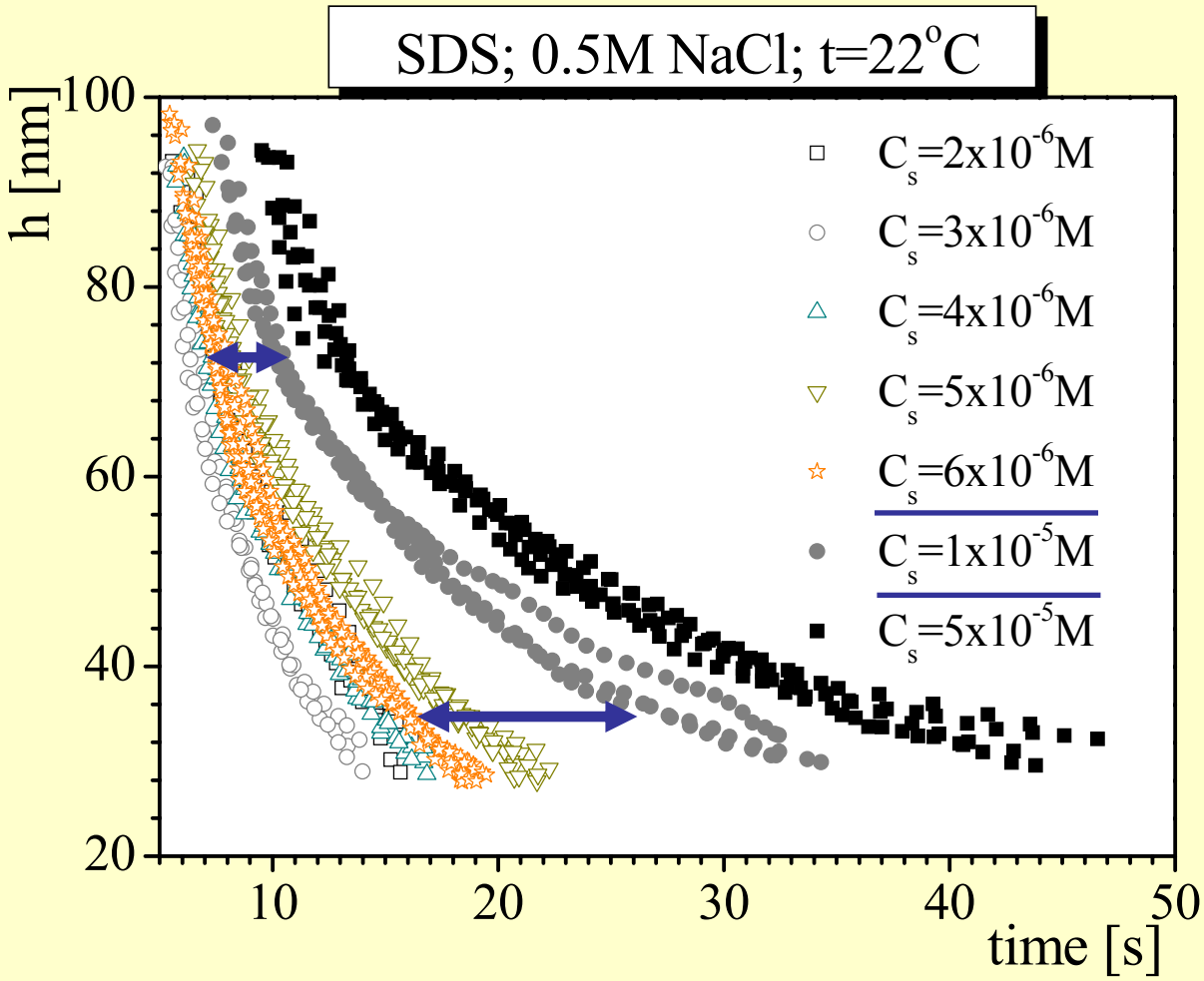
Time? What does it depend on?



What does time depend on? - critical film thickness



Foam film kinetics: h(t)



$$V_{\mathrm{Re}} = \frac{2h^3 \Delta P}{3\eta R^2}$$

Sheludko,
Adv.Coll.&Interface Sci., 1, 391,**1967**

$\Delta P = P_c - \Pi$ η=1.0x10^{-3} (Pa.s)

$$\tau = \int_{h_0}^{h_{cr}} \frac{\mathrm{d}h}{V}$$

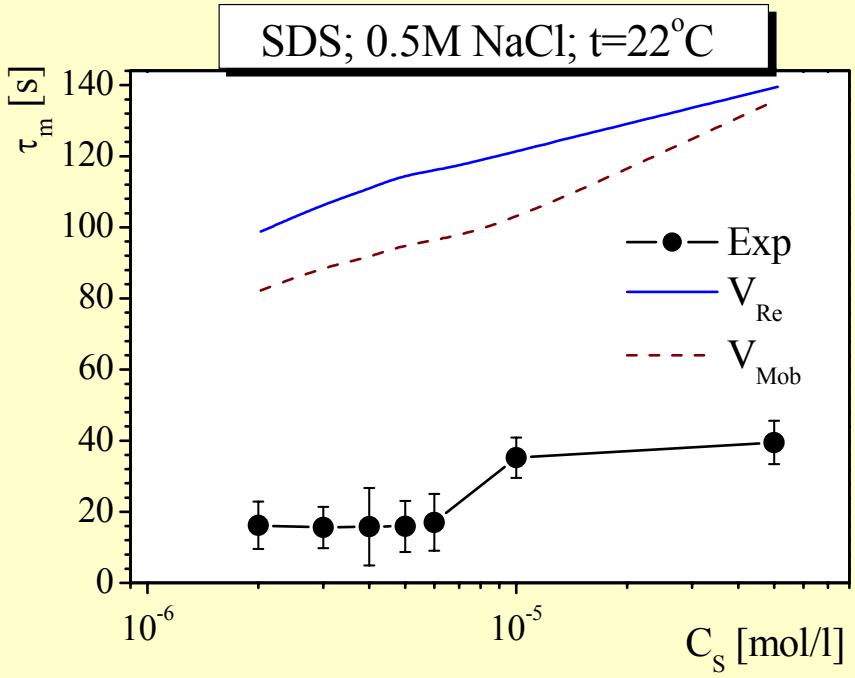
$$\frac{V_{Mob}}{V_{\mathrm{Re}}} = 1 + b + \frac{h_S}{h}$$

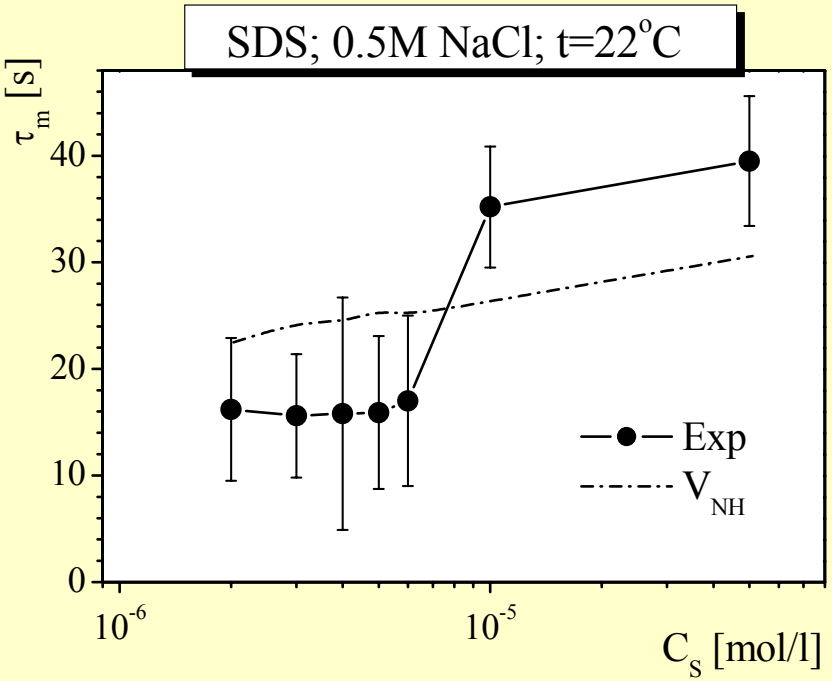
Radoev, Dimitrov, Ivanov,
Coll&polymer Sci., 252, 50, **1974**

$$b = -\frac{3\eta D}{\Gamma_0 \left(\frac{\partial \sigma_0}{\partial c_0} \right)} \qquad h_S = -\frac{6\eta D_S \left(\frac{\partial \Gamma_0}{\partial c_0} \right)}{\Gamma_0 \left(\frac{\partial \sigma_0}{\partial c_0} \right)}$$

$$V_{NH} = \frac{1}{6\eta} \sqrt[5]{\frac{h^{12} \Delta P^8}{4\sigma^3 R^4}}$$

Manev, Tsekov, Radoev,
J.Disp. Sci.&Technology, 18, 769, **1997**


SDS; 0.5M NaCl; t=22°C
τm [s]
140
120
100
80
60
40
20
0
10-6
10-5
CS [mol/l]
Exp
VRe
VMob


SDS; 0.5M NaCl; t=22°C
τm [s]
40
30
20
10
0
10-6
10-5
CS [mol/l]
Exp
VNH

Our interpretation

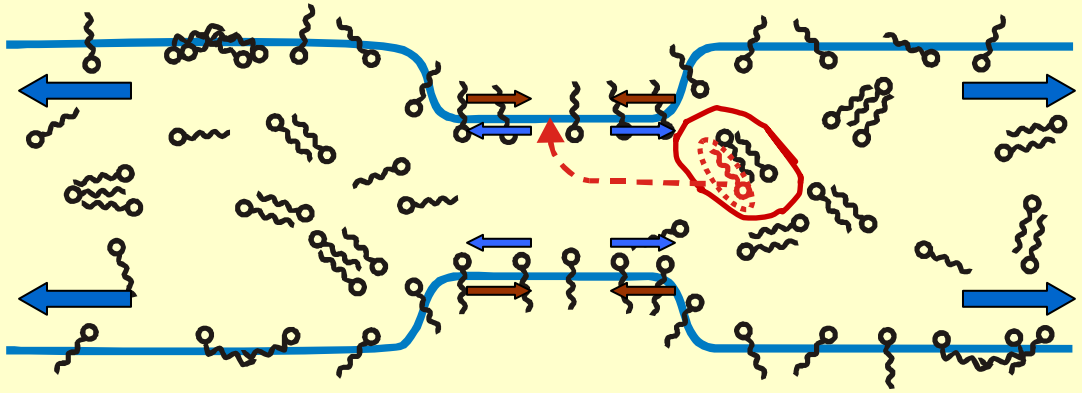
- Amphiphilic structures (premicelles) exist in initial surfactant solutions

- Under the action of negative (van der Waals) disjoining pressure, the surfactant aggregates disintegrate, and the size distribution curve is shifted to the monomers.
***Mileva E, Exerowa D**, Colloids Surf. A 149, 207, (1999)*

$$\Pi(h)=\Pi_{vw}(h) \quad \Rightarrow \quad X_n(h<h_o)<X_n(h_o)$$

- Films drain in a regime of high interfacial mobility and thickness inhomogeneities

Our interpretation



$$P_{n\tau} = \nabla_\tau \sigma \quad \Rightarrow \quad \mu^{\mathrm{f}} \frac{\Delta U}{H^f} \sim \left|\frac{\partial \sigma}{\partial c^f}\right| \frac{\Delta c_\tau^f}{R^f}$$

$$\nabla_\tau \left(\Gamma v_\tau^f\right) = j_n^f \quad \Rightarrow \quad j_n^f \sim \mathrm{D}^{\mathrm{f}} \frac{\Delta c_n^f}{H^f} \sim \varepsilon j_\tau^f$$

$$\Delta c_n^f = c^f - c_s^f, \qquad \Delta c_\tau^f = c^m - c_s^f$$

$$\mu \frac{\Delta \mathrm{U}}{\mathrm{H}} \sim \left|\frac{\partial \sigma}{\partial c}\right| \frac{\Delta c_\tau + c_{agg}}{R}$$

$$c_{new}^m = c^m + c_{agg}$$

Mileva, Radoev, (1993)

To summarize:

- ✓ Concentration coincidence of surface tension and the film drainage results is due to the presence of **amphiphilic structures** as coupled with the **local hydrodynamics** and **mass transfer of surfactant** molecules.