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FORCED COALESCENCE OF MICRONSIZE DROPS

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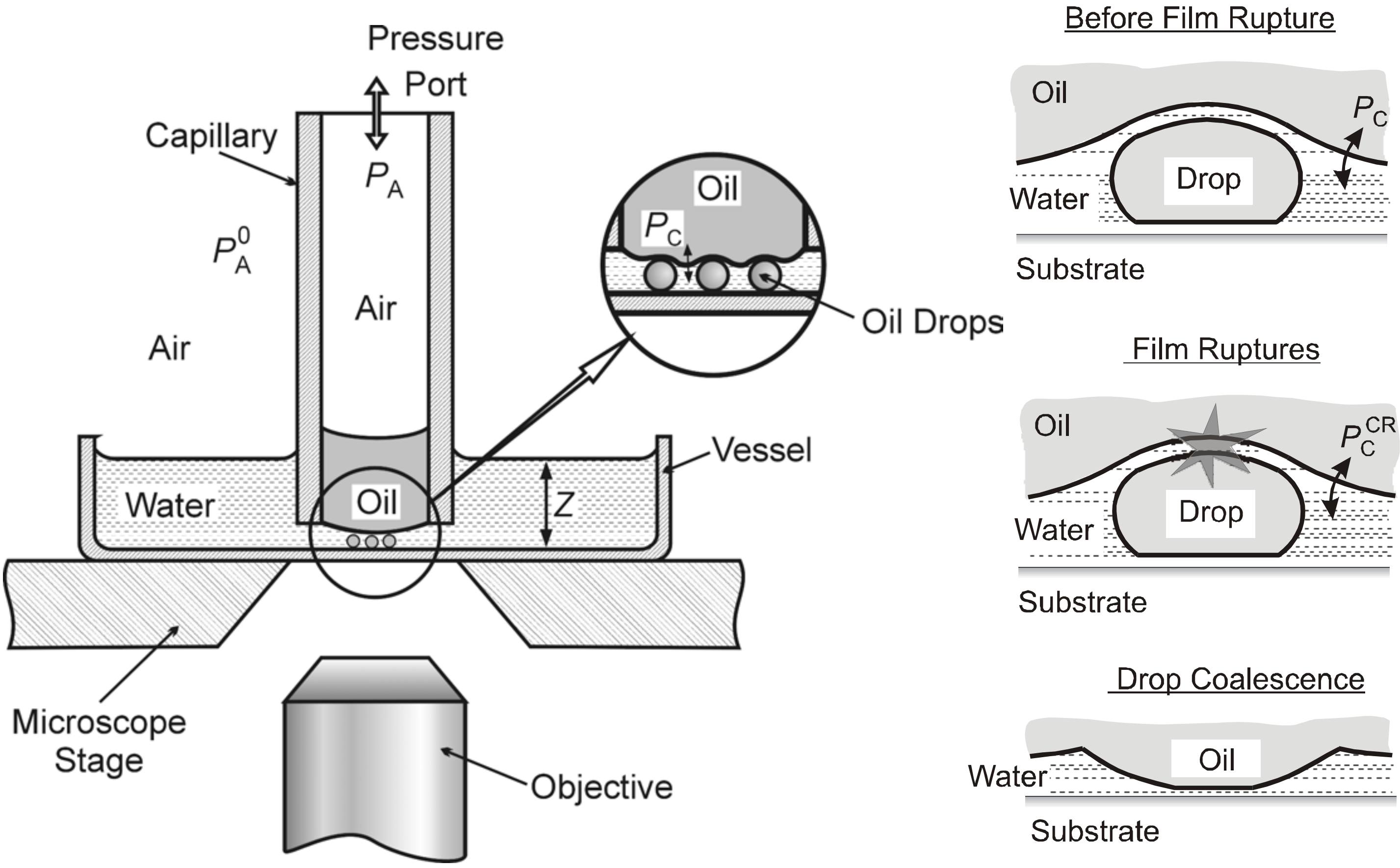
AIMS:

1. **Development of methods for evaluating the stability of micronsize emulsion and peudoemulsion films.**
2. **Studying the relation between stability of single films and the stability of batch emulsions and foams.**

Specific Applications:

1. Effects of protein adsorption and drop size on the stability of protein emulsions (two methods - FTT and centrifugation).
2. Determination of the entry barrier for globules of different oil-based antifoams - relation to mechanism of antifoaming.

Film Trapping Technique for Studying Emulsion Films



Capillary Pressure:

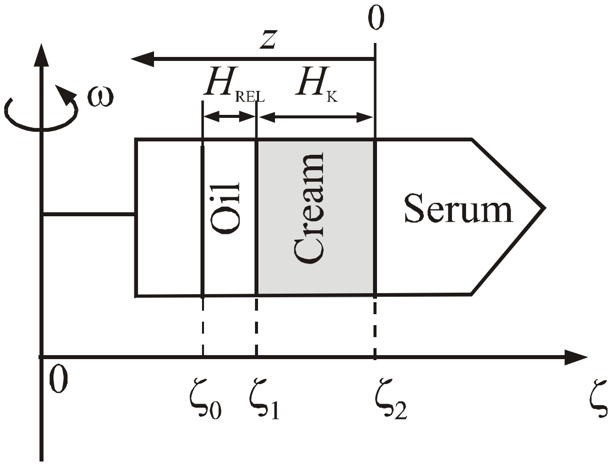
$$P_C = \Delta P_A - \Delta P_A^{INI} - \rho_W g Z$$

$\Delta P_A = P_A - P_A^0$ - pressure difference measured by a sensor

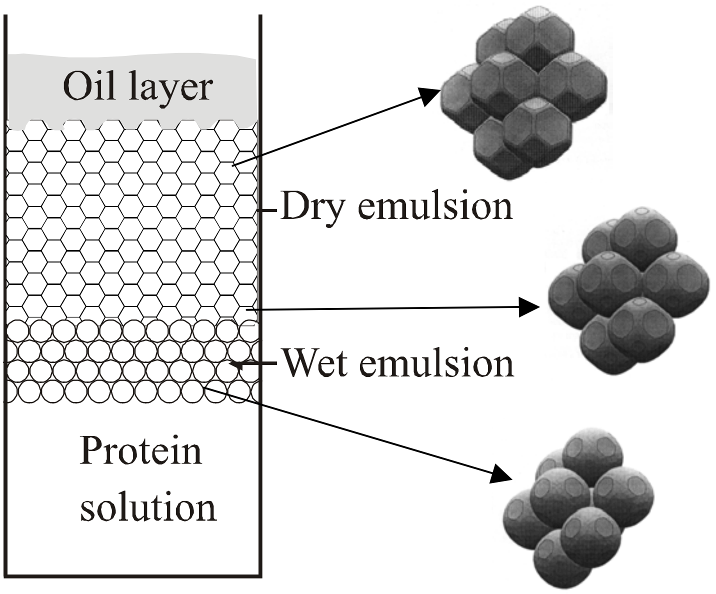
- **Quantitative characterization of the coalescence barrier, P_C^{CR} for single, micrometer-sized oil drops with large oil phase.**
- **The effect of drop size on film stability can be precisely evaluated.**

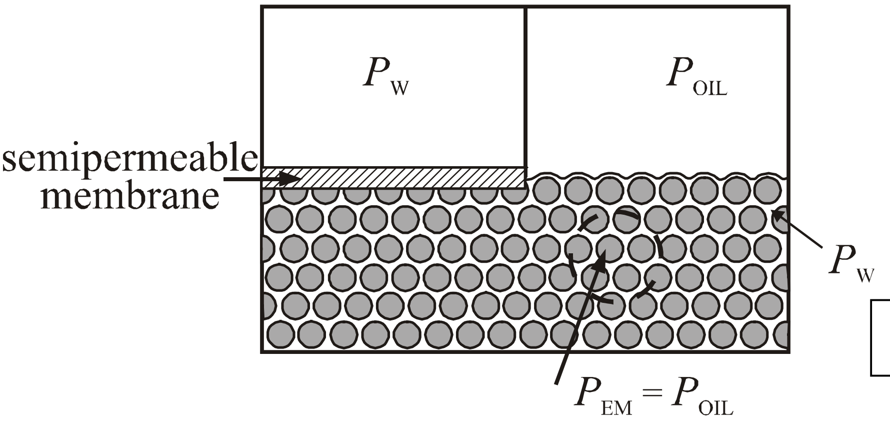
- ☐ **Limitation - only for relatively low protein concentrations.**

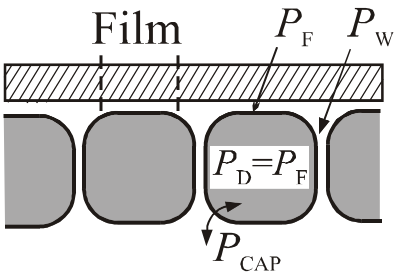
Centrifugation



$$g_K = k \times g$$







$$P_{OSM}(\Phi_{OIL}) = P_{CAP}(\Phi_{OIL})\theta_F(\Phi_{OIL})$$

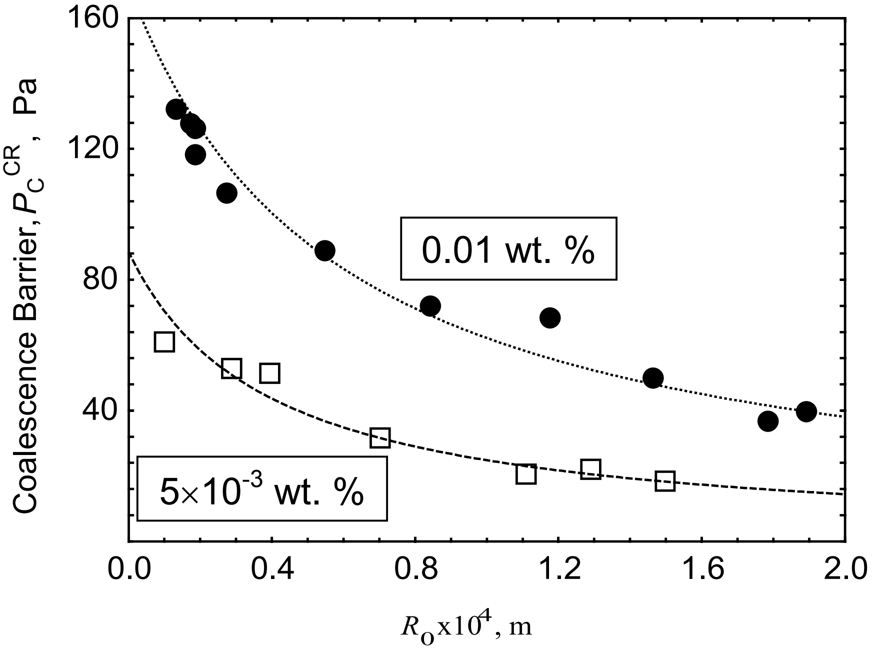
Critical Osmotic Pressure:

$$P_{OSM}^{CR} = \int_0^{H_k} \Delta\rho\, g_k\, \Phi_{OIL}(z)dz = \Delta\rho\, g_k\, (H_{OIL} - H_{REL}) = \Delta\rho\, g_k\, H_k \overline{\Phi}$$

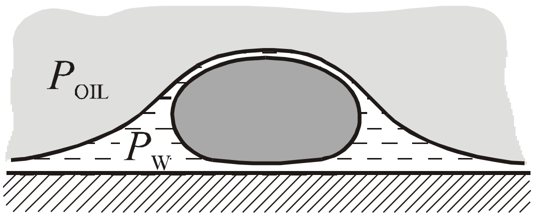
- **A quantitative method for characterization of emulsion stability.**
- **Can be applied at much higher protein concentrations.**
- **Rapid test for comparison of emulsion stability.**

Drop Size Effect on Emulsion Stability (FTT)

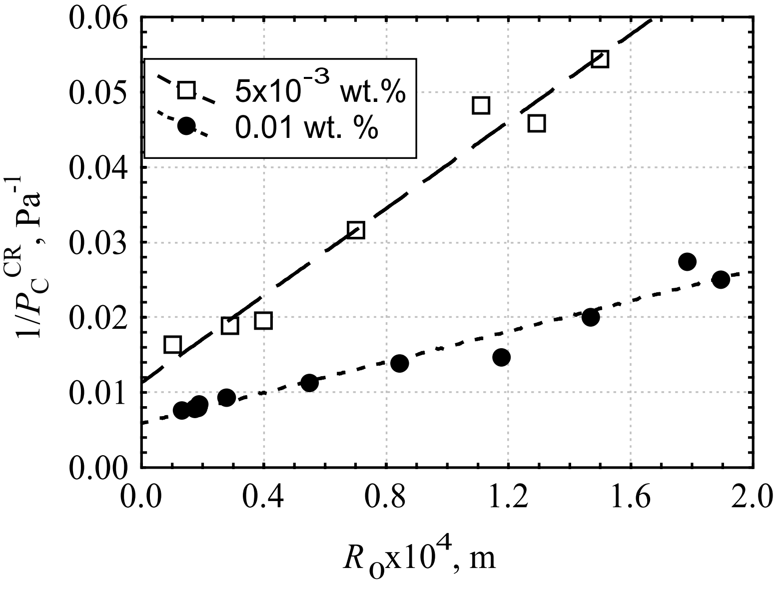
Oil drops stabilized by β-lactoglobulin (BLG)



FTT



$$P_C = P_{OIL} - P_W$$

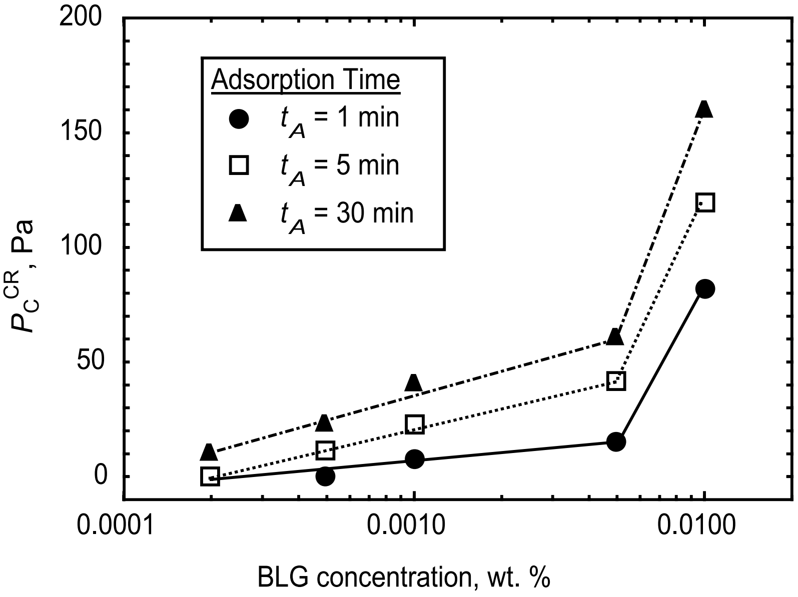


$$1/P_c^{CR} = A + B\,R_0$$

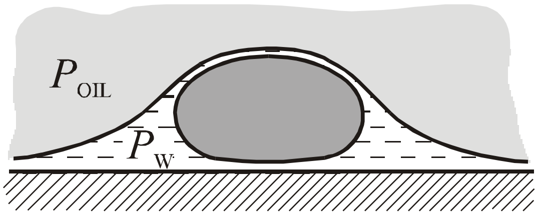
- **The inverse critical pressure is a linear function of the drop radius.**

Effect of Protein Adsorption on Emulsion Stability (FTT)

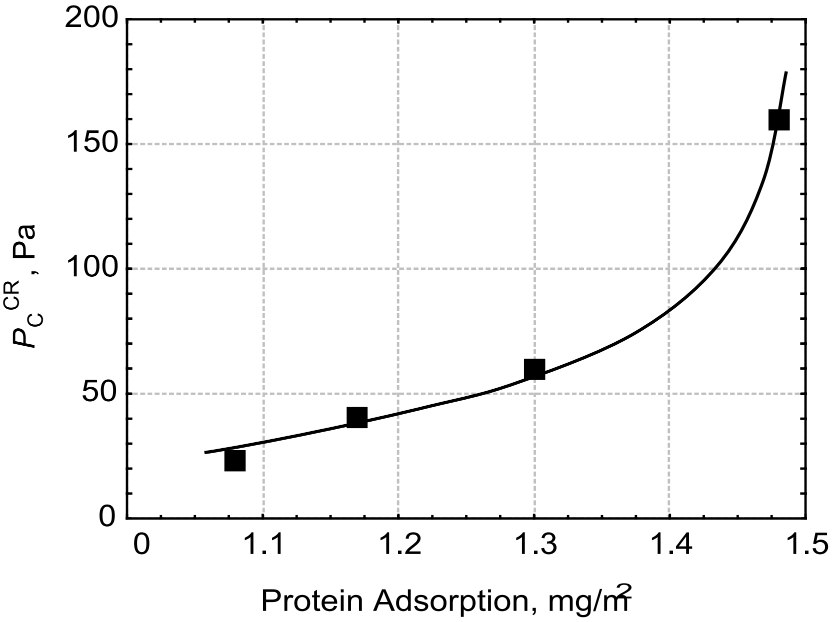
Stability of Emulsion Films



FTT



$$P_C = P_{OIL} - P_W$$



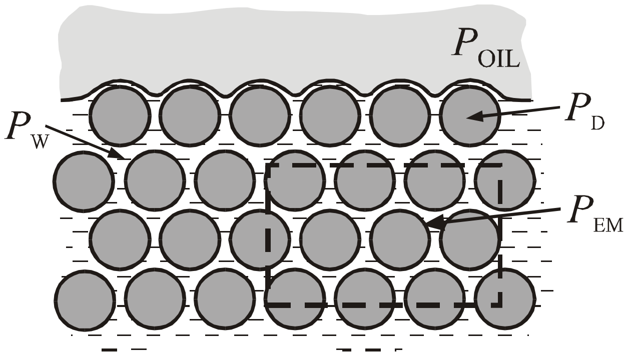
Protein adsorption from:

F. Gauthier, S. Bouhallab, A. Renault, *Colloids and Surf. B: Biointerfaces,* **21** (2001) 37.

- **The coalescence barrier increases linearly with lg(C_P) at low protein concentrations (at constant t_A)**
- **Steeper increase of coalescence barrier at $C_P \approx 0.01$ wt %.**
- **Linear increase of P_C^{CR} with the BLG adsorption at $\Gamma < 1.4$ mg/m^2, followed by a steep increase at $\Gamma \approx 1.5$ mg/m^2.**

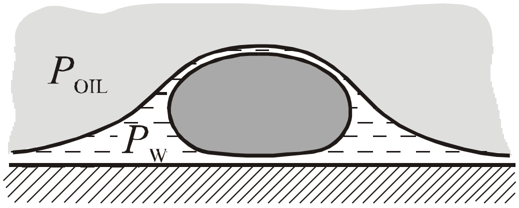
Relation between Centrifugation and FTT

Emulsion Column in a Centrifuge



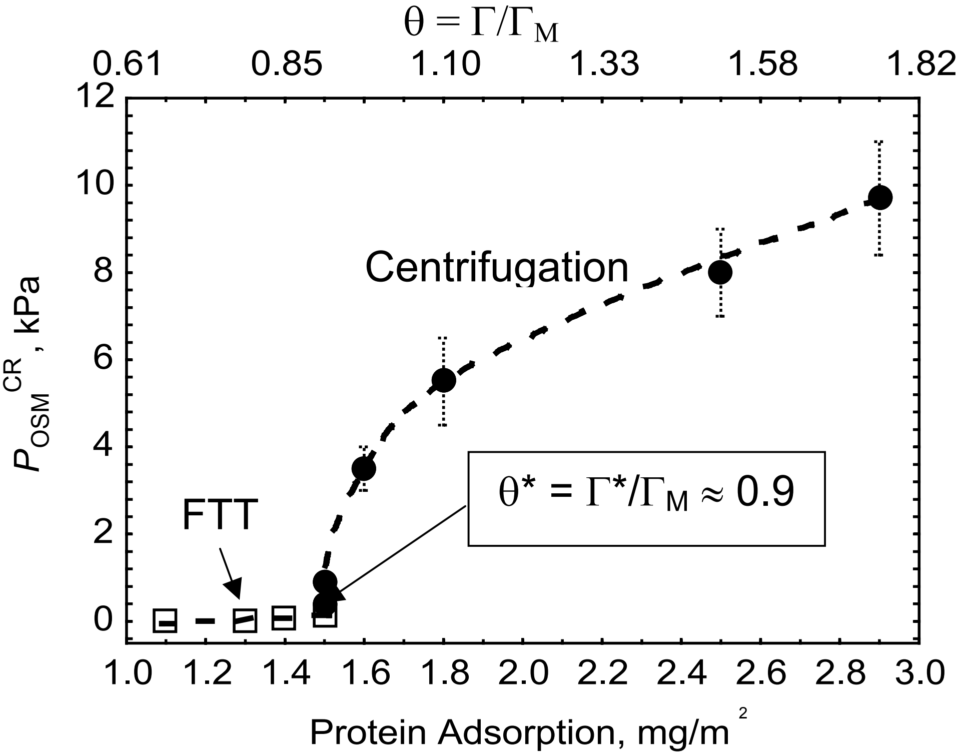
$$P_{OSM} = P_{OIL} - P_W$$

FTT



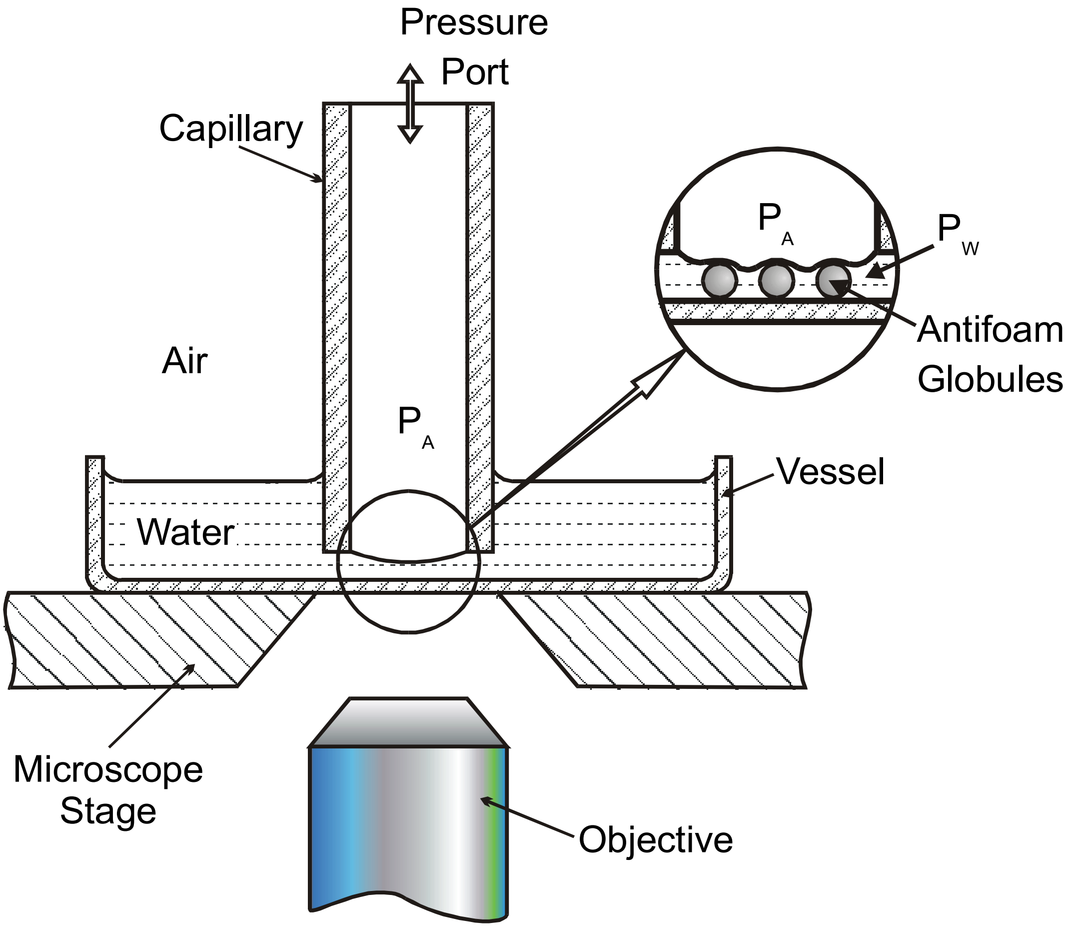
$$P_{CAP} = P_{OIL} - P_W$$

Emulsion Stability vs. Protein Adsorption

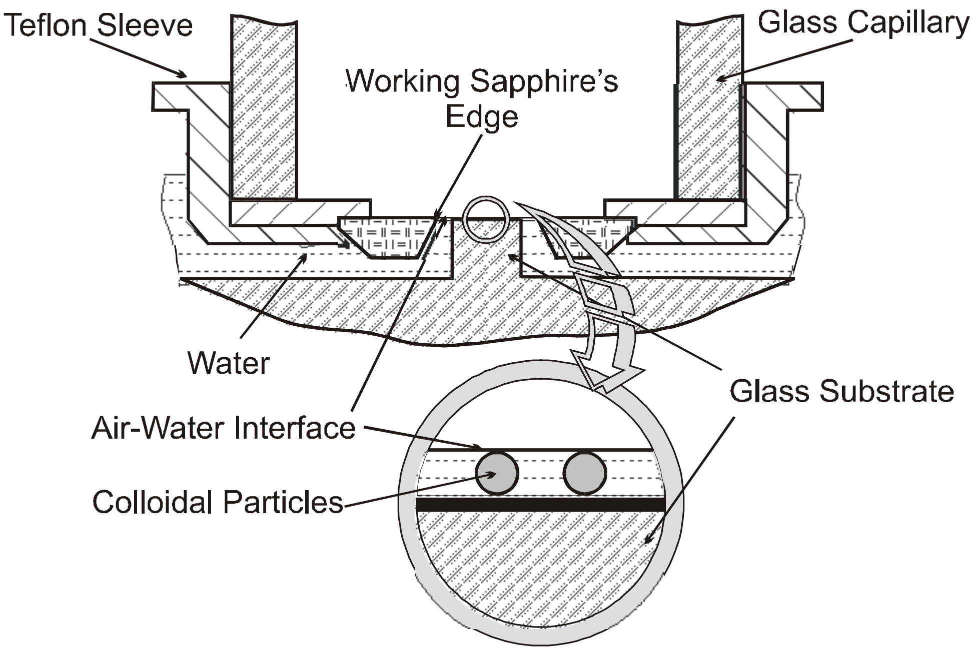


- **The coalescence barrier increases in a step-wise manner with protein adsorption (step at $\Gamma^* \approx 1.5$ mg/m^2).**

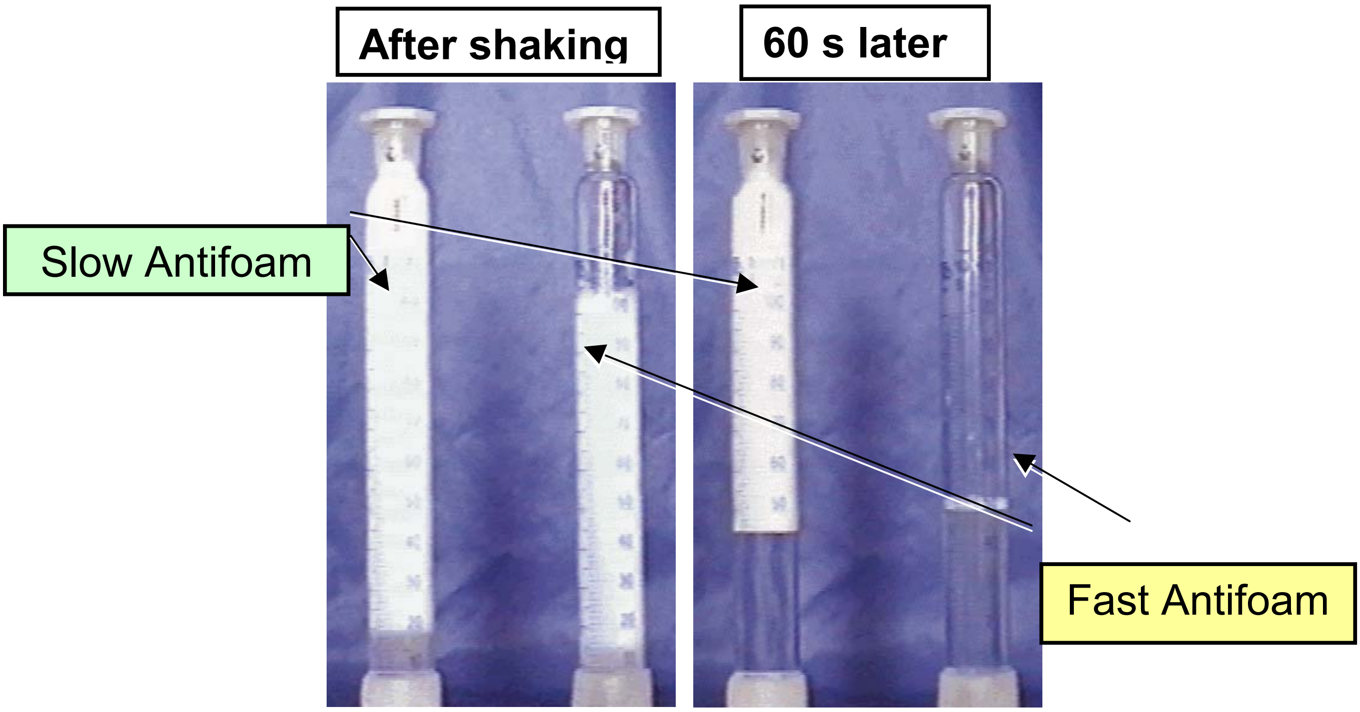
Film Trapping Technique for Antifoams



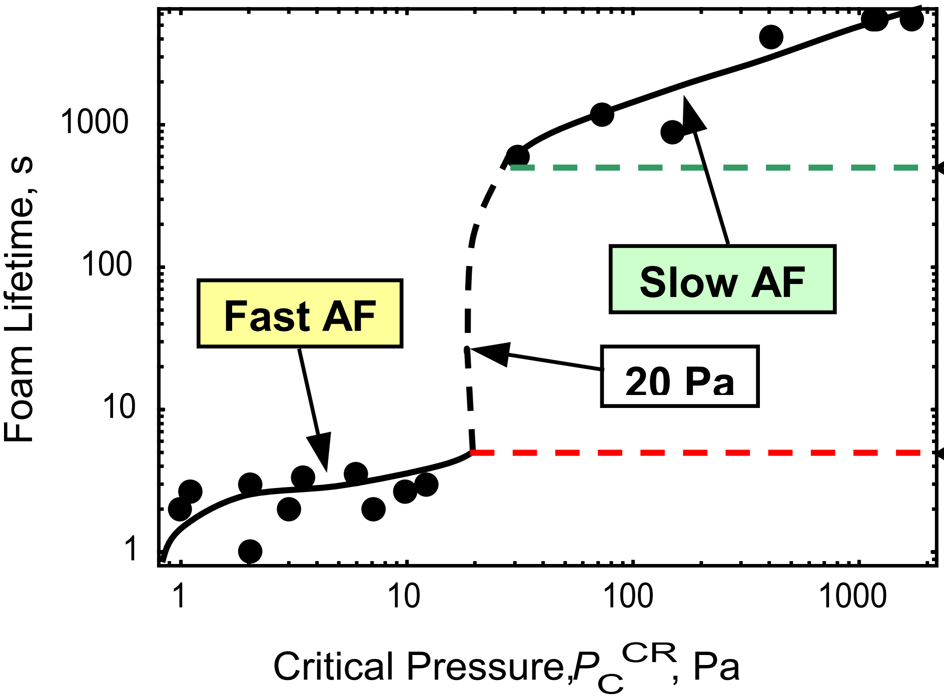
Attached Air-Water Meniscus for Low Capillary Pressures



Shake Test: Foam Stability



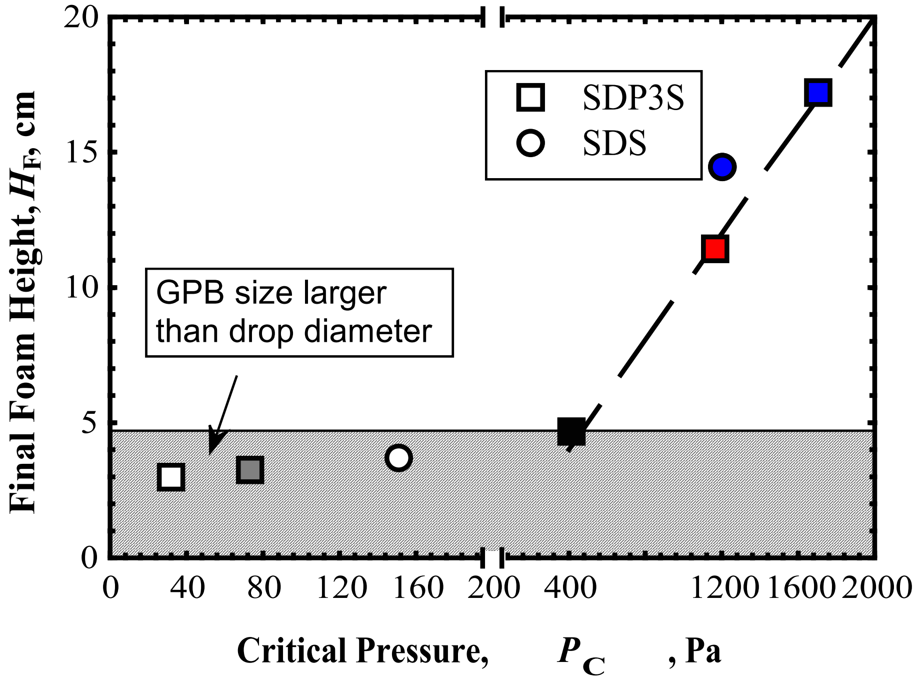
Boundary between Fast and Slow AF - FTT

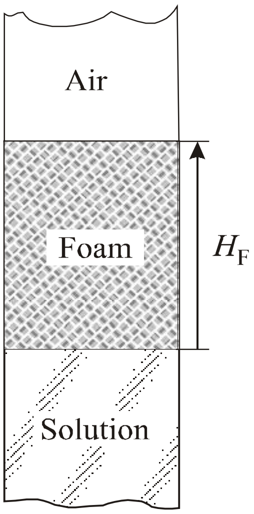


More than 8 min **until long living residual foam remains**

Less than 5 s (**no residual foam**)

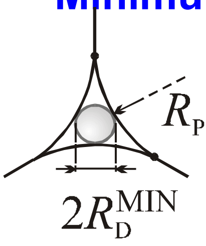
Correlation between P_C^{CR} and Foam Stability for Slow Antifoams (Oils)





Minimum Radius of the Trapped Sphere

$$P_C \approx \Delta\rho g H$$

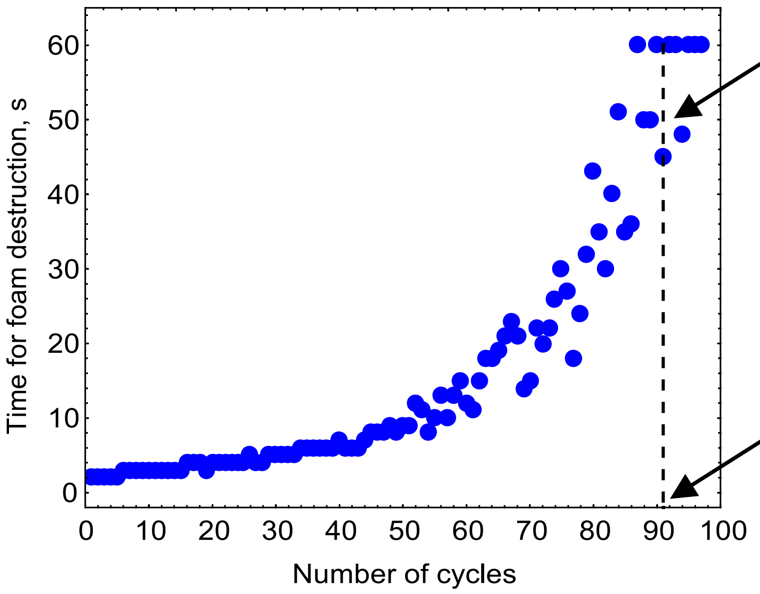


$$R_D^{MIN} \approx 0.15 \frac{\sigma_{AW}}{\Delta\rho g} \frac{1}{H_F} \approx \frac{45}{H_F} \ [\mu m]$$

- Above $P_C^{CR} = 400$ Pa, the upper layer of bubbles ruptures when $P_C^{CR} = \Delta\rho g H_F$. This determines the final foam height H_F.
- Below $P_C^{CR} = 400$ Pa, the decrease of P_C^{CR} does not affect the foam stability (drop size < Plateau channel cross-section)

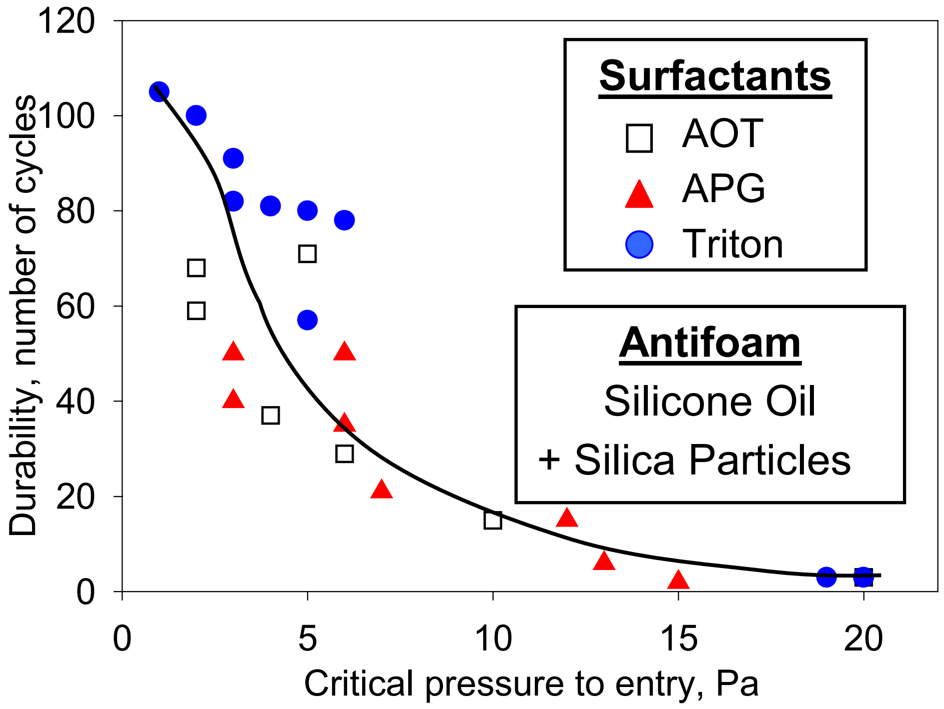
Typical drop radius R_D~10 μm ⇒ Minimum foam height $H_F \approx 5$ cm

Correlation between P_C^{CR} and Durability of Fast Antifoams



Antifoam Exhaustion

Antifoam Durability



The antifoam durability decreases when the height of the entry barrier increases

CONCLUSIONS

1. **A method allowing a direct measurement of the barrier to coalescence of oil drops with an oil/water or air/water interface was developed (FTT).**

2. **The inverse critical capillary pressure to coalescence is a linear function of the drop size for BLG stabilized emulsion films.**

3. **The coalescence barrier increases in a step-wise manner with protein adsorption for BLG stabilized emulsions.**

4. **The measured entry barriers, P_C^{CR}, reveal that P_C^{CR} determines the boundary between two types of antifoams - fast with $P_C^{CR} < 20$ Pa and slow with $P_C^{CR} > 20$ Pa.**

5. **A connection between P_C^{CR}, the final foam height, and the diameter of the antifoam globules is found and explained theoretically (for slow antifoams).**

6. **A correlation between P_C^{CR} and the durability of the fast antifoams is established experimentally.**