Natural Surfactants for Flotation Deinking in Paper Recycling

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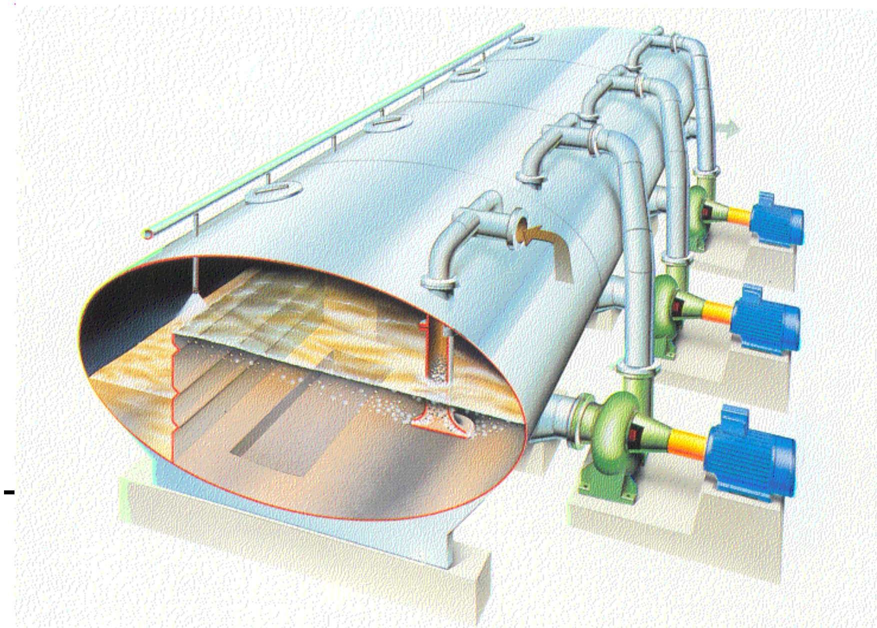
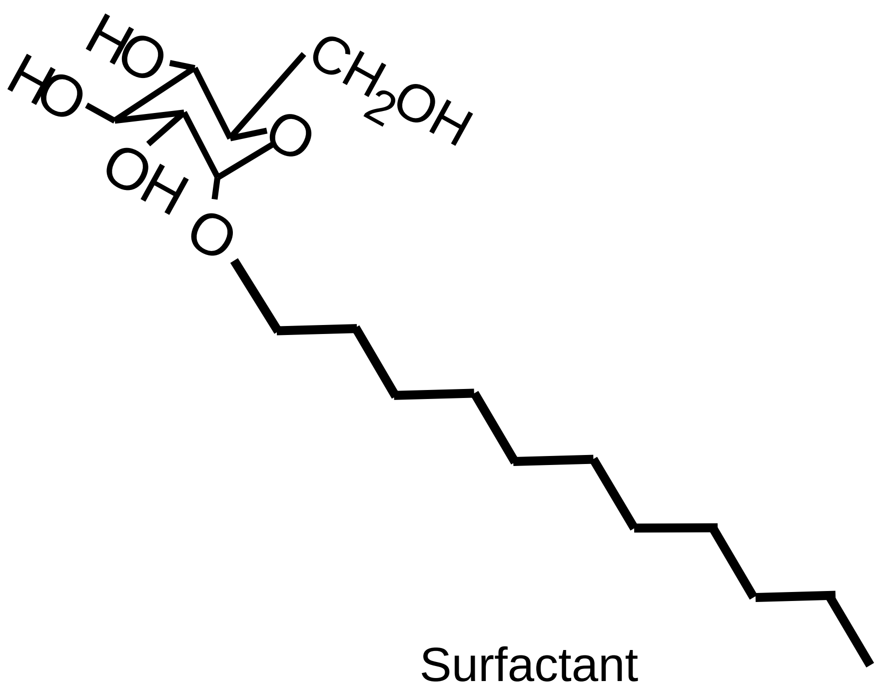
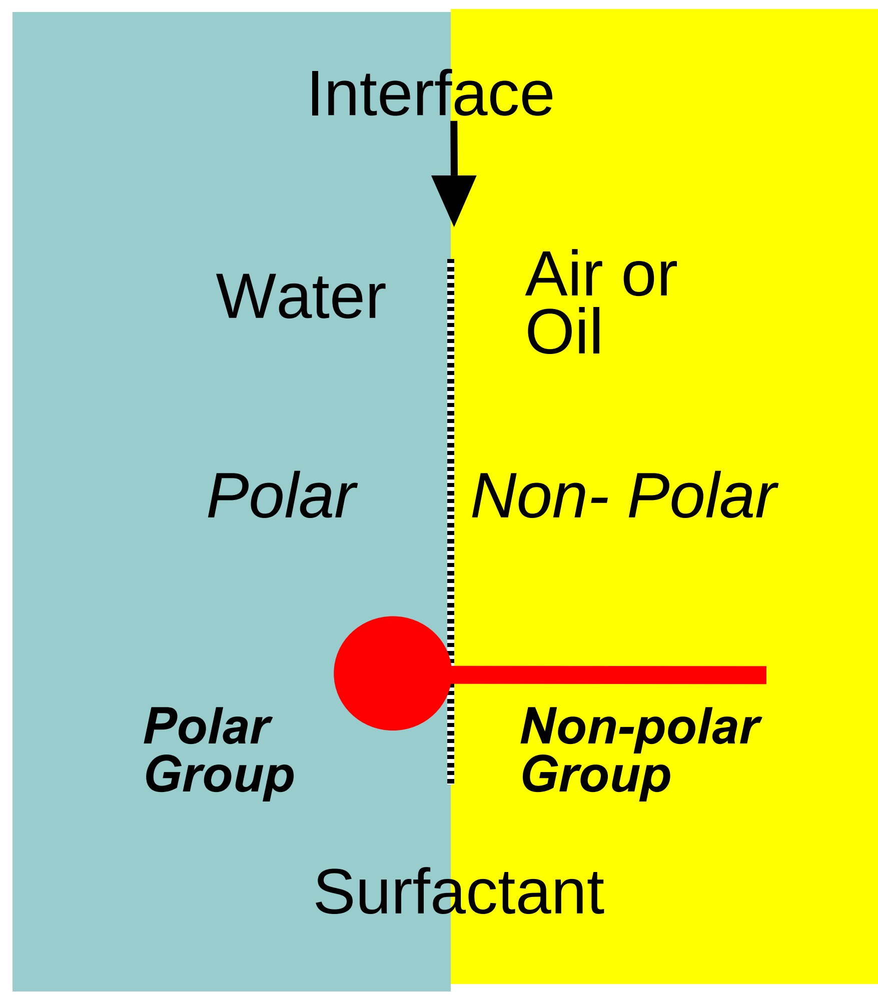
Introduction

- The flotation process necessitates stable foams to allow the separation of ink from fiber
- Foaming agents may be added to stock at 0.02 to 0.2 % of solids
- Currently, many of the foaming agents are petroleum-based and may not be environmentally friendly
- Are there more green alternatives that may lessen dependence on petroleum feedstocks?
- How to evaluate?

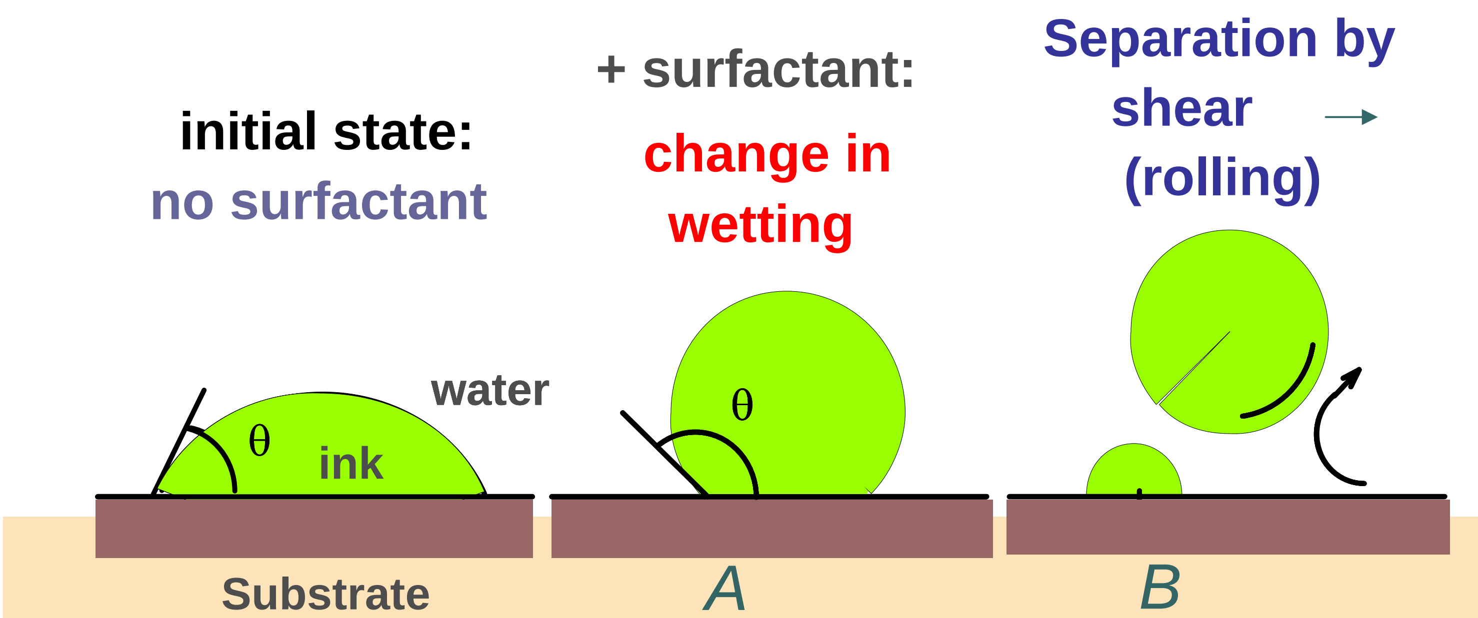


Surfactant at Interfaces: Modification of the surface energy



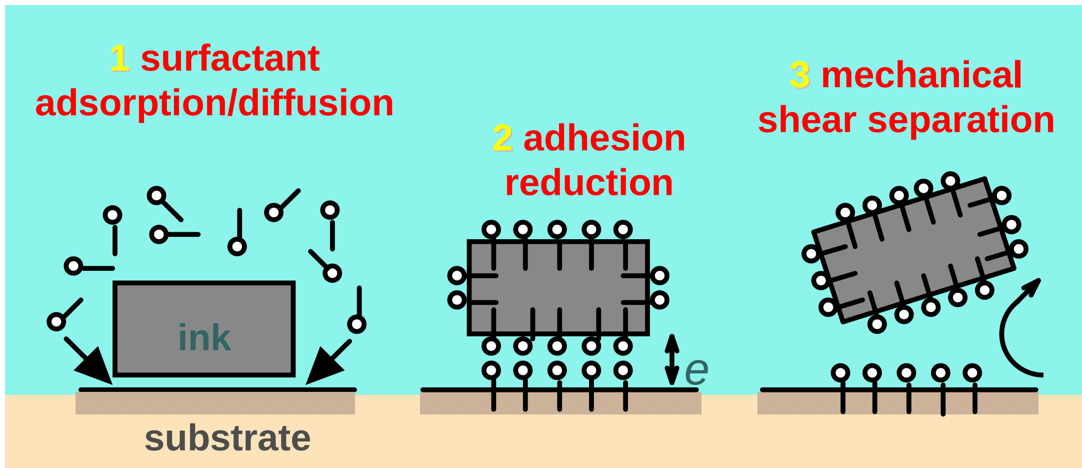


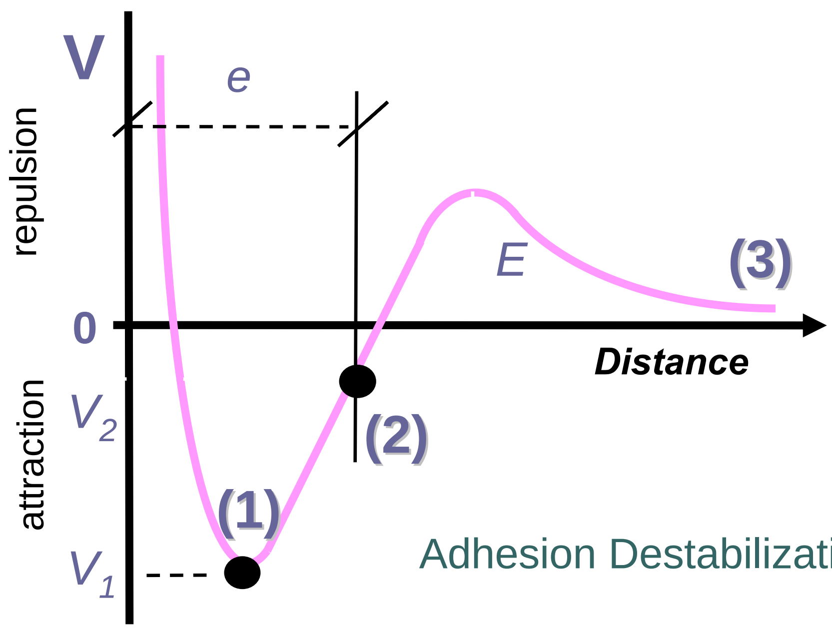
Detergency



initial state:
no surfactant
+ surfactant:
change in wetting
Separation by shear (rolling)
water
θ
ink
θ
Substrate
A
B

Detergency

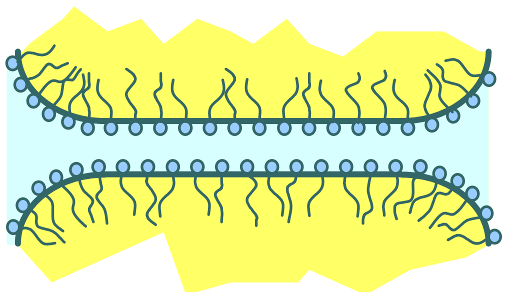


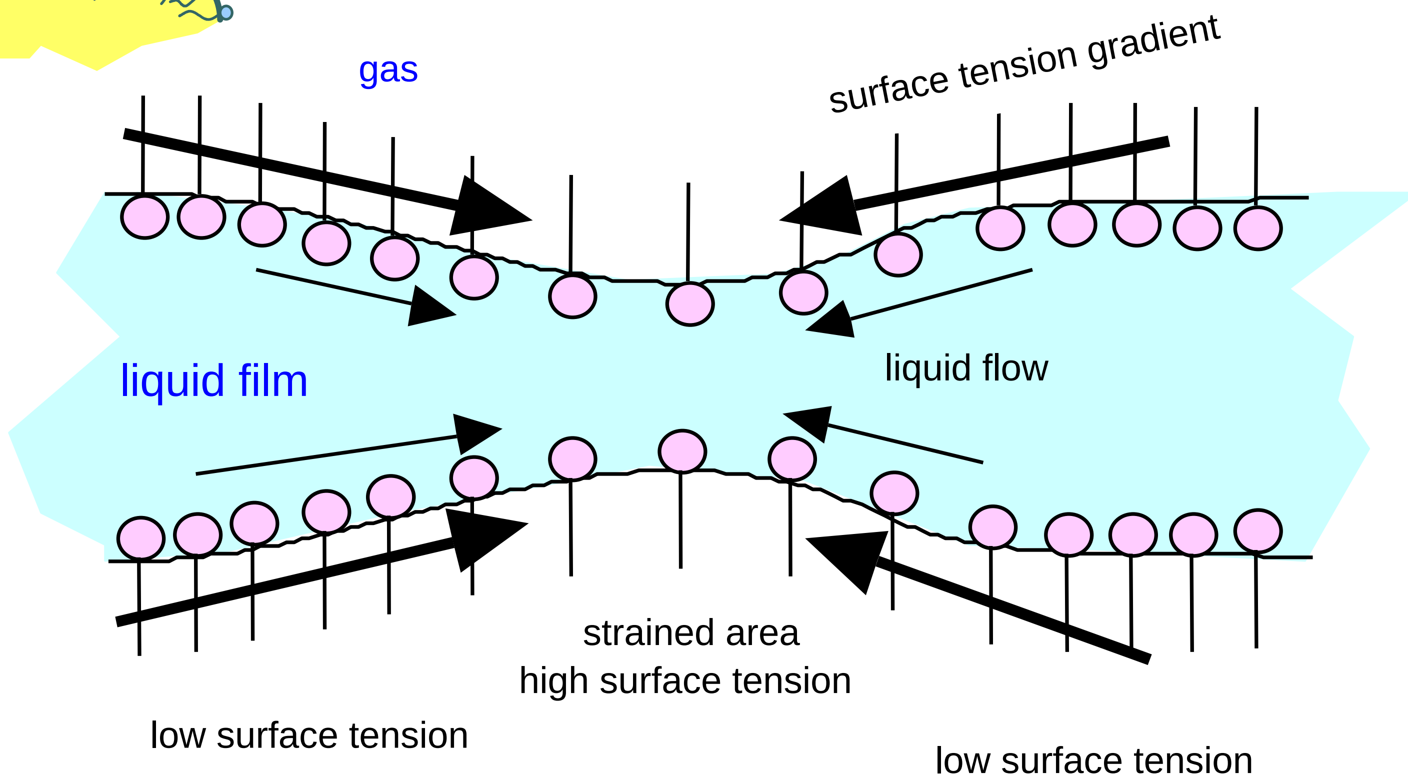


Adhesion Destabilization

(1) adhered particle
(2) particle separation
(3) particle removal

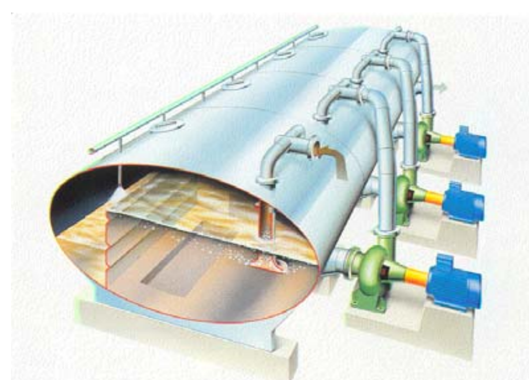
Surfactant at Air-Water Interface: Foam Stability





Introduction

- The flotation process is a complex process requiring multiple steps to occur:
  - Release of the ink from fiber
  - Attachment of ink to air bubble
  - Air bubble to be incorporated into stable foam
  - Foam to be separated from the liquid phase
- A surfactant can impact all of these steps……its effect on flotation can be difficult to interpret

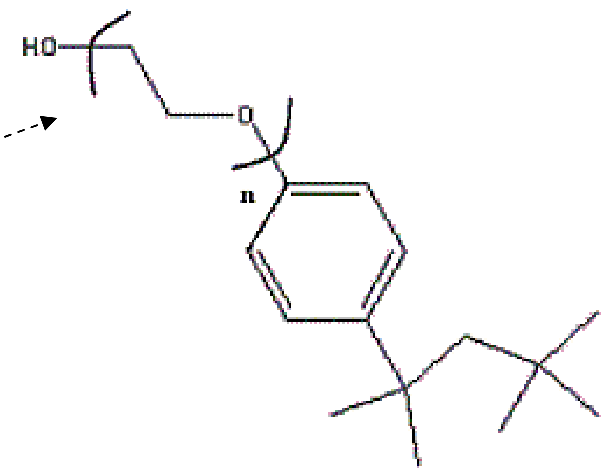


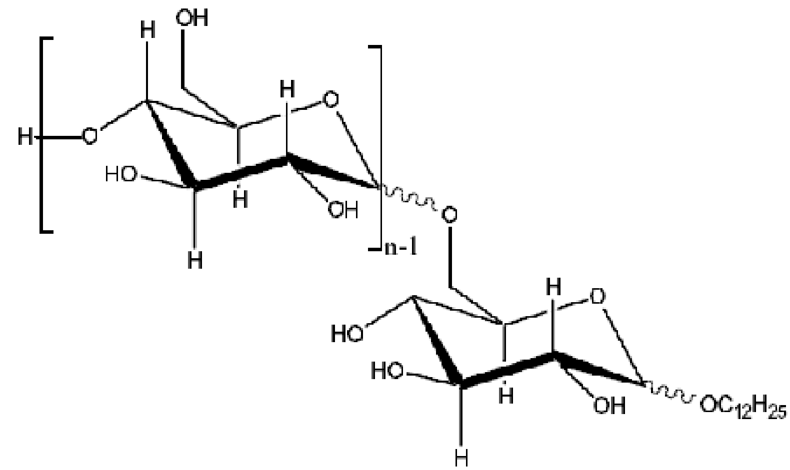
Outline

- Introduction
- Materials
- Results and Discussion
  - Detergency
  - Adsorption
  - Foamability
  - Flotation Deinking
- Conclusions
- Questions

Surfactants Studied

- Alkyl phenol ethoxylate (APE)
- Alkyl (C10-C16) mono and oligomeric D- glucopyranose
- Protein-based surfactant from soybean
- Commercially formulated surfactant blend



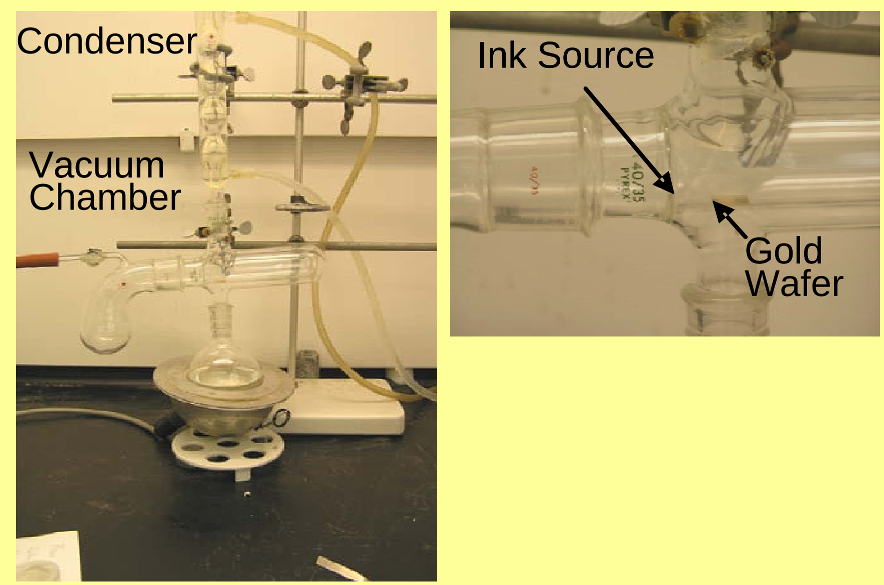


Recovered Paper Material

- Recycled Xeroxcopy Paper of 92 brightness and 30% recycled content
- Copied with text on both sides of the paper with a xerographic toner
- Pulped at 3% consistency in Tappi Disintegrator

Detergency Analysis

- Preparation of films via sublimation of tripalmitin, a fatty acid model of an ink
- Exposed ink surface to surfactant solution with shear in beaker
- Measured contact angle of water drop on surface of treated film



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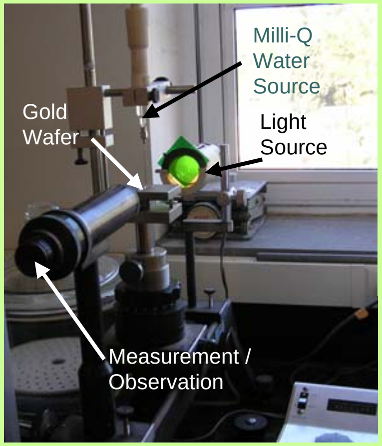
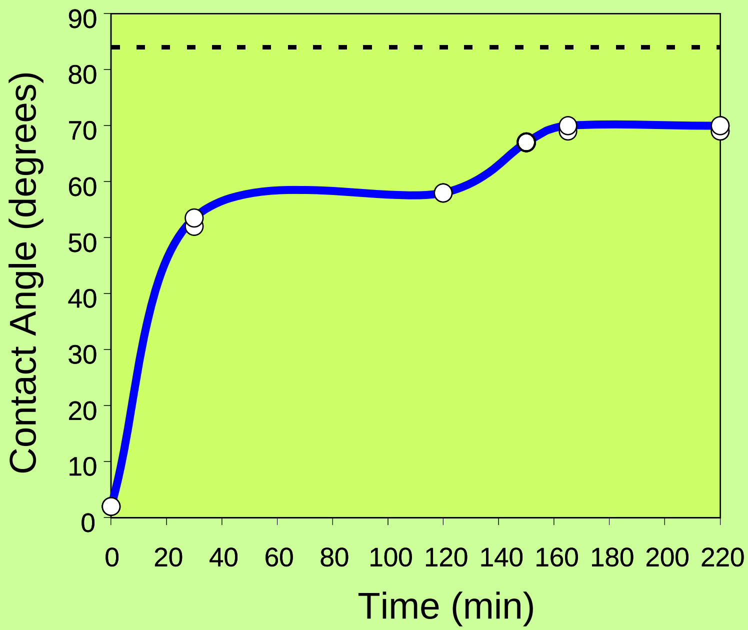
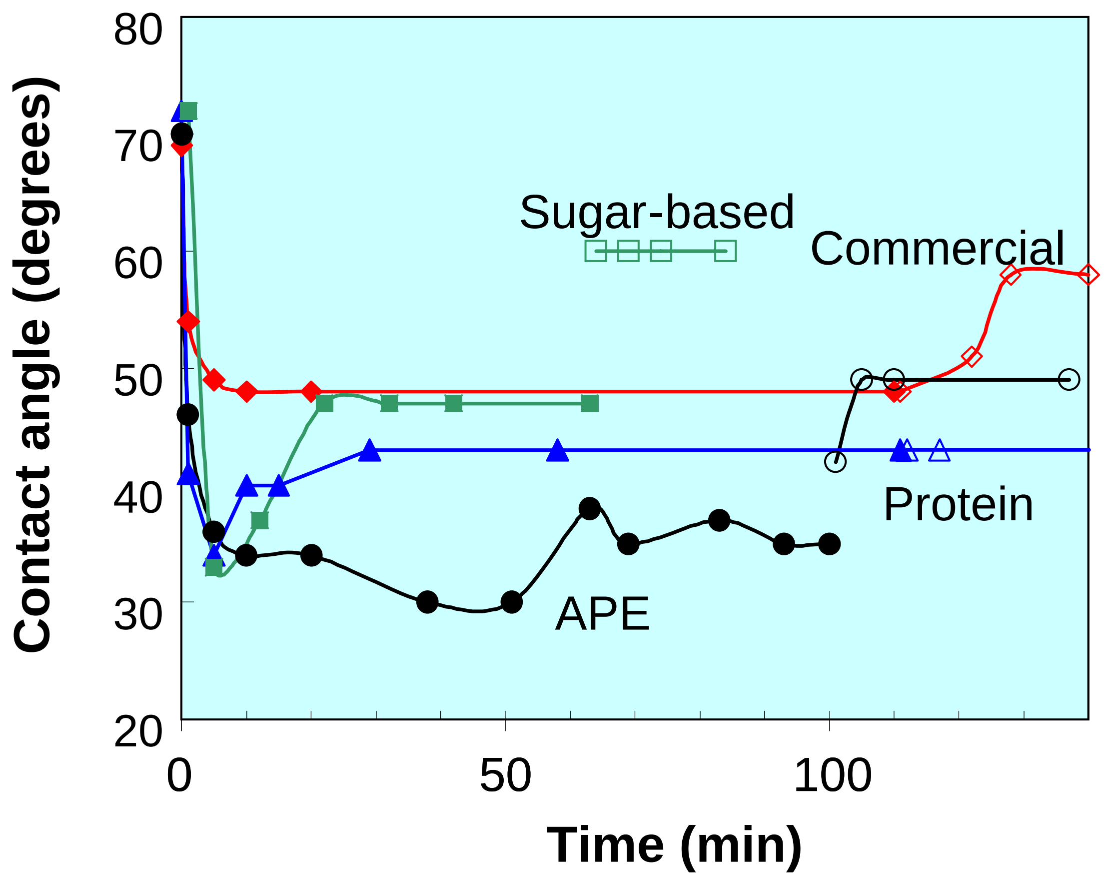




Detergency Analysis:

- Changes in contact angle after treatment of "printed" surfaces with surfactants, before (solid symbol) and after rinsing with water (washing, open symbols)
- Surfactants make inks more hydrophilic
- Different response to rinsing: different surface affinity



Detergency Analysis (Contact Angles):

- Changes in contact angle after treatment of "printed" surfaces with surfactants, before (solid symbol) and after rinsing with water (washing, open symbols)
- Surfactants make inks more hydrophilic
- Different response to rinsing: different surface affinity

Surfactant	% Change on Treatment	% Change on Rinsing
Commercial	30	15
APE	50	30
Protein-Based	40	42
Sugar Based	35	17

% Change Treat = 100%* [CA(no treat) – CA(treat)]/CA(no treat)

% Change Rinse = 100%* [CA(no treat) – CA(treat/rinse)]/CA(no treat)

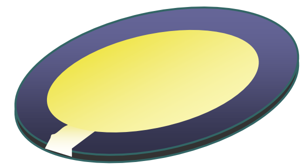
Quartz Crystal Microbalance

- Piezoelectric quartz crystal, sandwiched between a pair of electrodes
- Measures the resonance frequency and dissipation due to adsorption on surface
- .9 ng/cm2 sensitivity in water

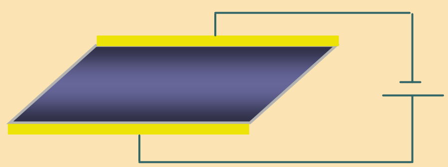
Q-Sense E4 unit

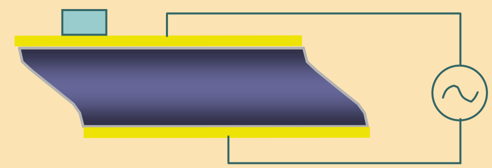
$$\Delta m = \frac{-\rho_q t_q \Delta f}{f_0 n} = \frac{-\rho_q v_q \Delta f}{2 f_0^2 n} = -\frac{C \Delta f}{n}$$

QCM-D ping principle



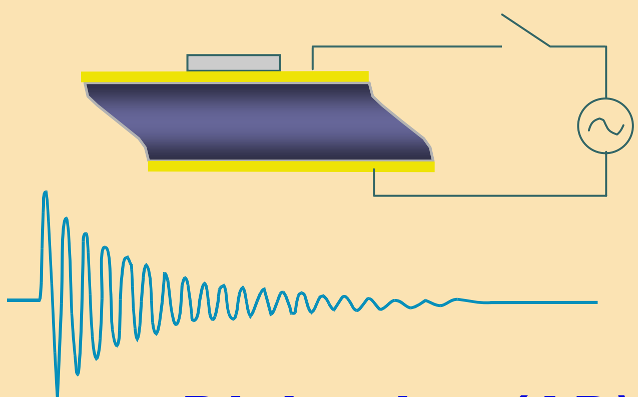
Qcmddemo.exe



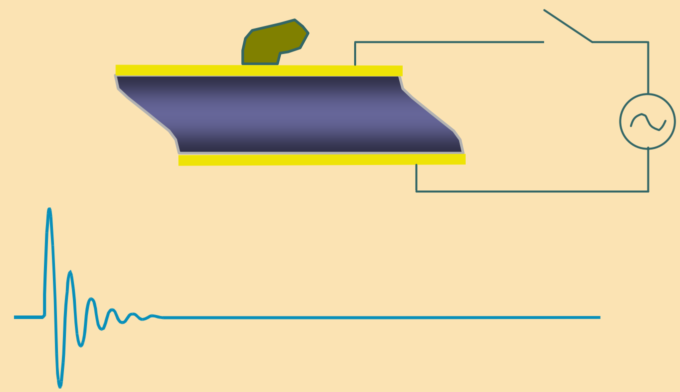


***Frequency change (Δf)*: related to the mass of the attached film**

“rigid” film

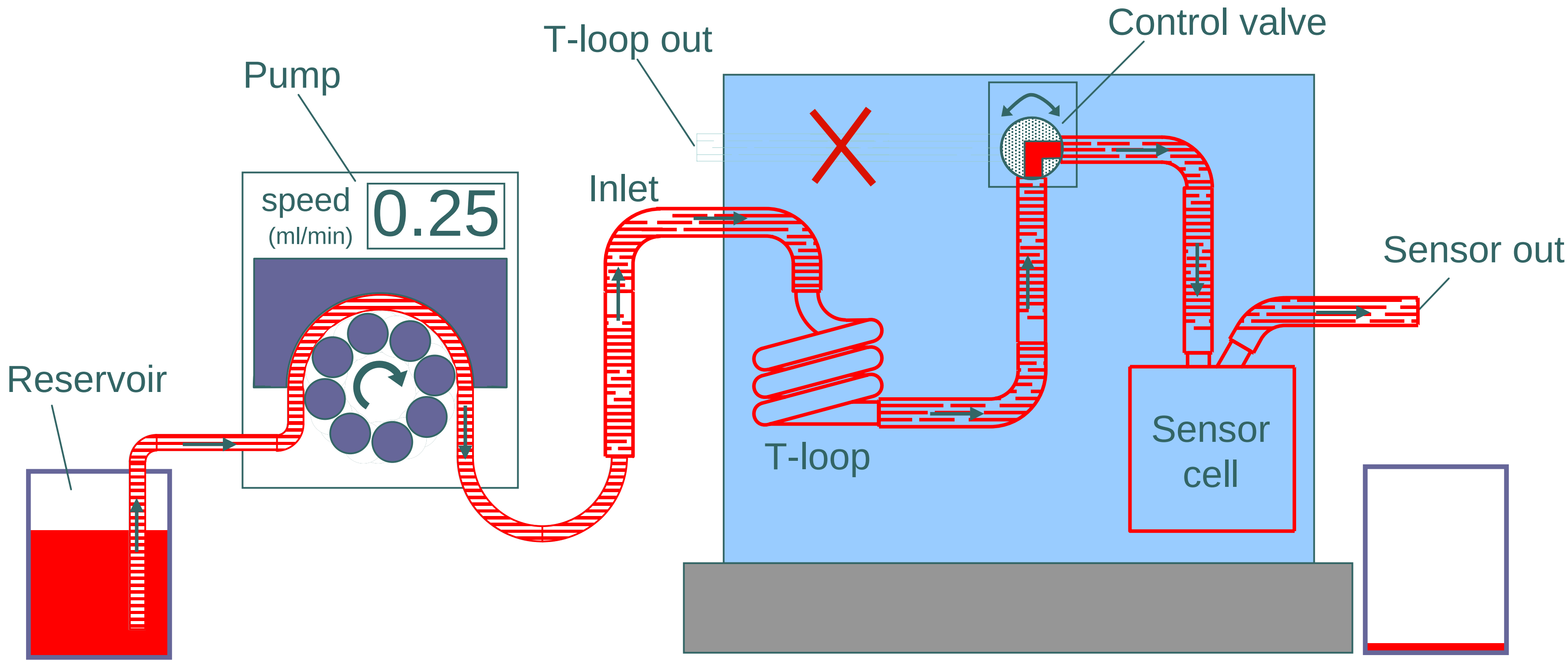


“soft” film

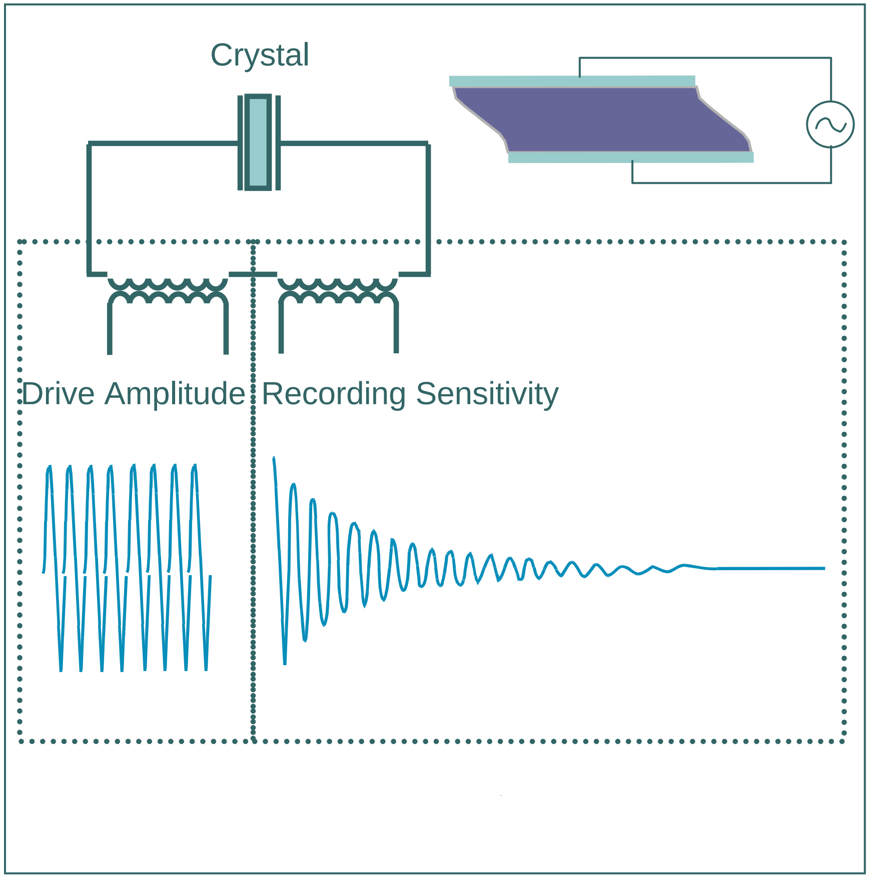


***Disipation (ΔD)*: related to the viscoelasticity**

Flow with T-loop – Liquid Transport



QCM: Measurement principle



Mathematical representation of the decay curve

$$A(t)=A_0 \cdot \exp(-t/\tau) \cdot \sin(2\pi f t+\phi)$$

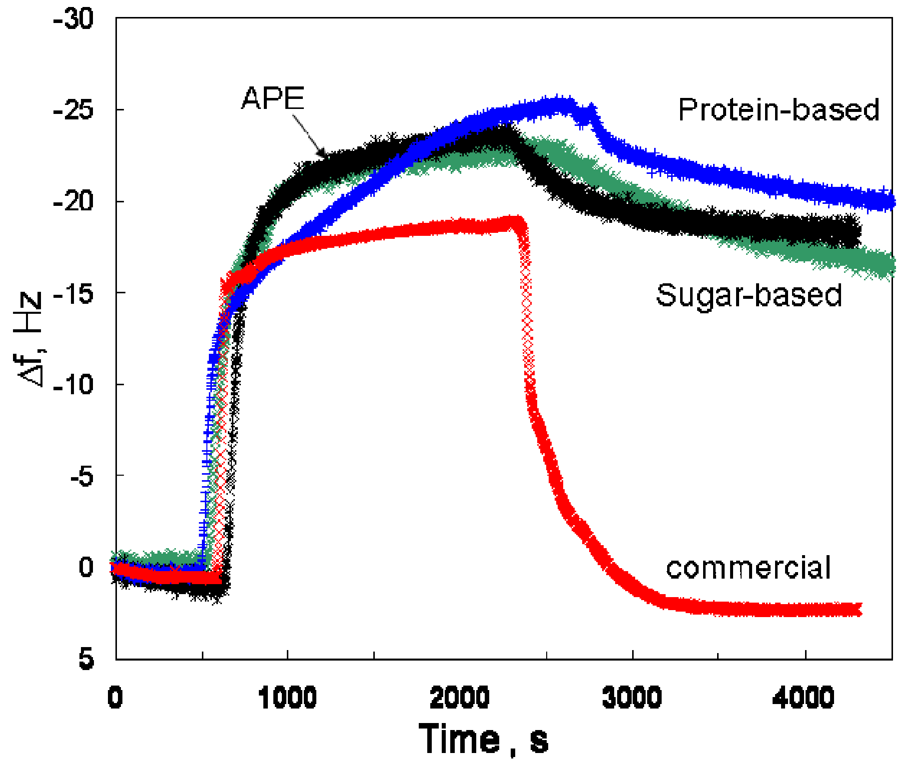
$$D=1/\ \pi f \tau$$

Fitting routine; Levenberg-Marquandt's (Numerical Recipies)

•Decay recording – electronics unit
•Decay fitting - PC

QCM Results

- Surfactant solution injected around 500 s
- Rinsing with water at about 2500 s
- Commercial surfactant had lowest affinity to model ink film
- Protein had highest affinity
- Kinetics revealed

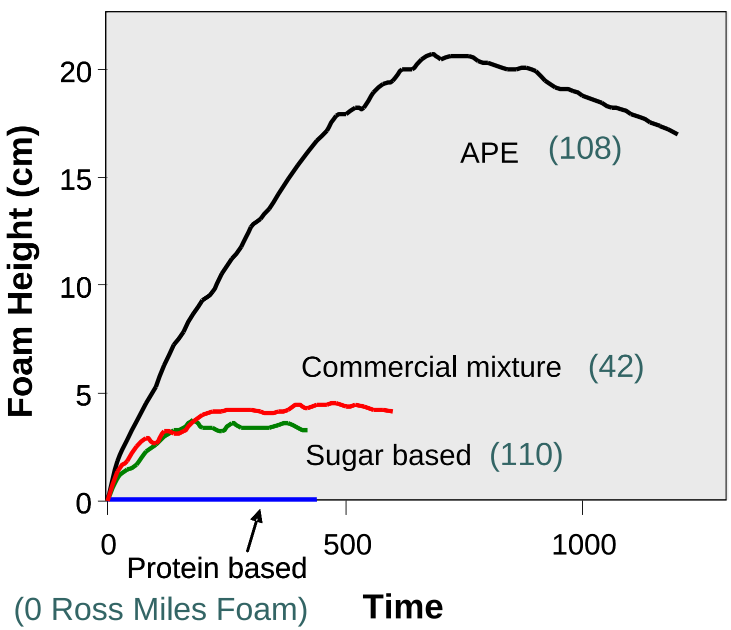


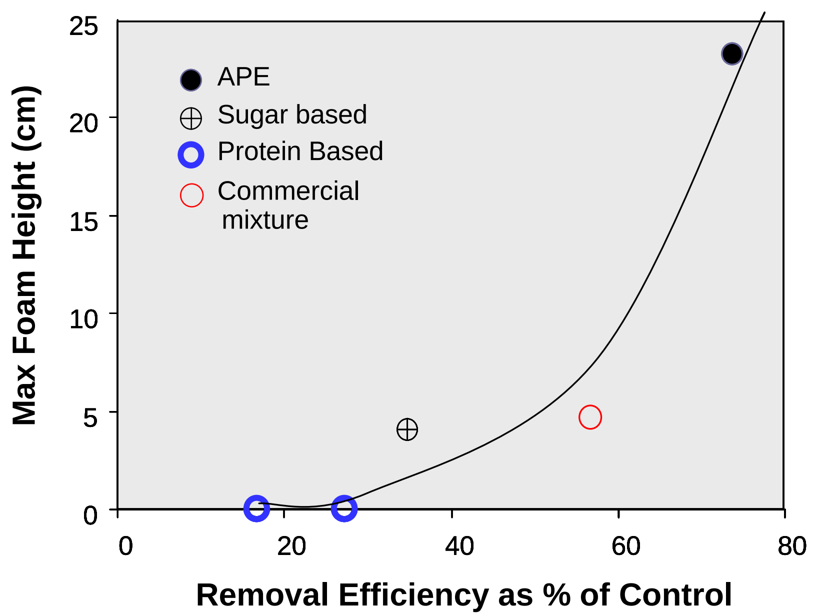
Type	Amount adsorbed (ng)	Surfactant released (ng)
Commercial	10.1	11.3
Synthetic	12.8	3.0
Protein-based	13.6	3.1
Sugar-based	12.4	3.7

Dynamic Foamability

- 400 ml of 0.025 g/L surfactant solution
- Air flow of 185 ml/min through air dispersing stone
- Foam height recorded vs time

Dynamic Foamability

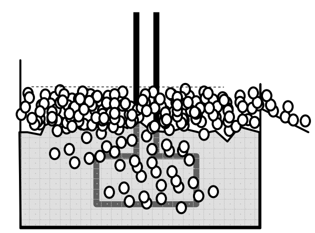




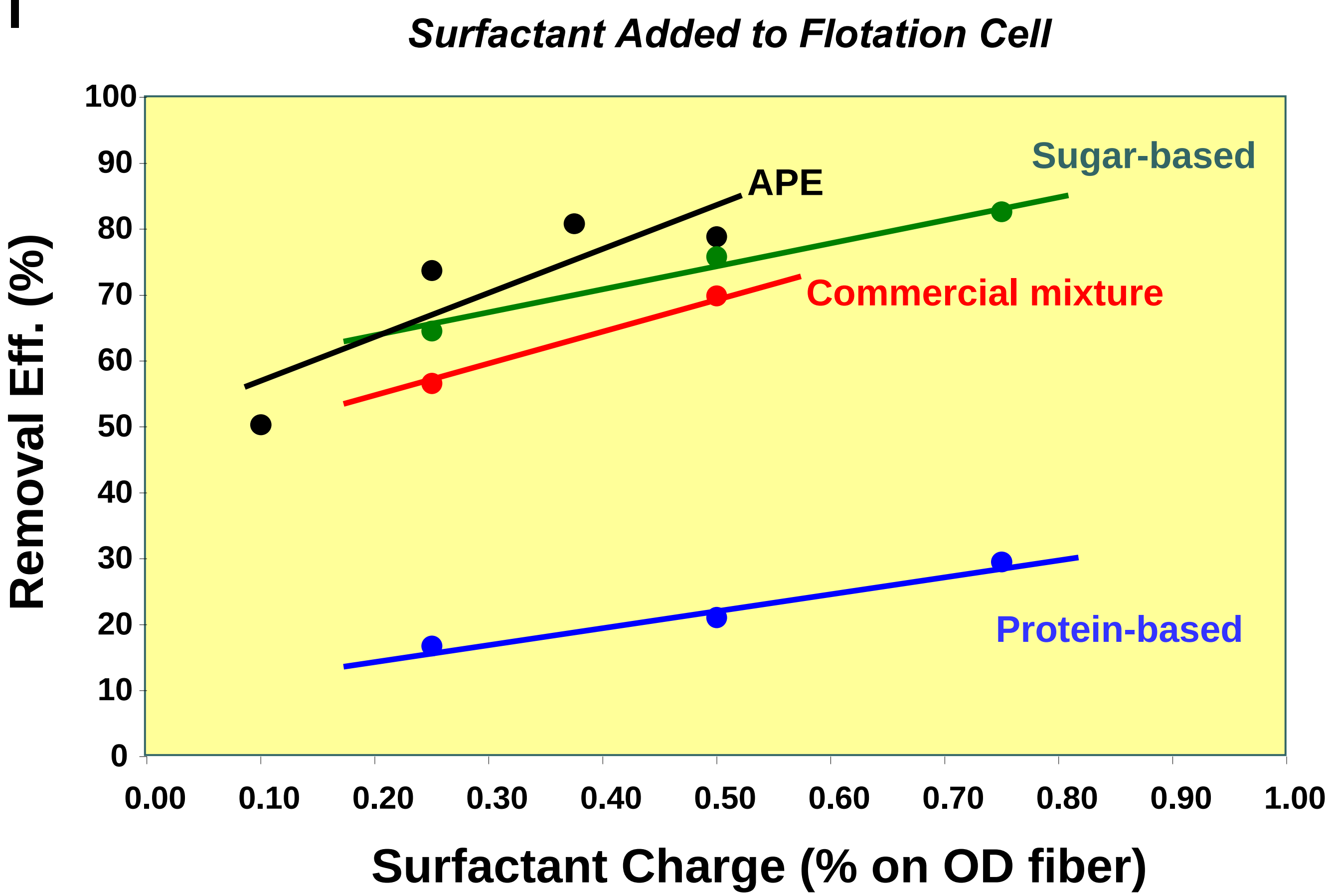
Flotation Deinking Experiments

- Pulping 3% K, 10 min, 50 C, Tappi Disintegrator
- Flotation Wemco Lab Cell, 1% K, RT, stopped when foam production ceased, ranged from 60-210 s
- Image Analysis, Scanner system, 0.007 mm^2 smallest particle size considered

$$RE\% = \frac{(PPM_{Control} - PPM_{Sample})}{PPM_{Control}} * 100$$

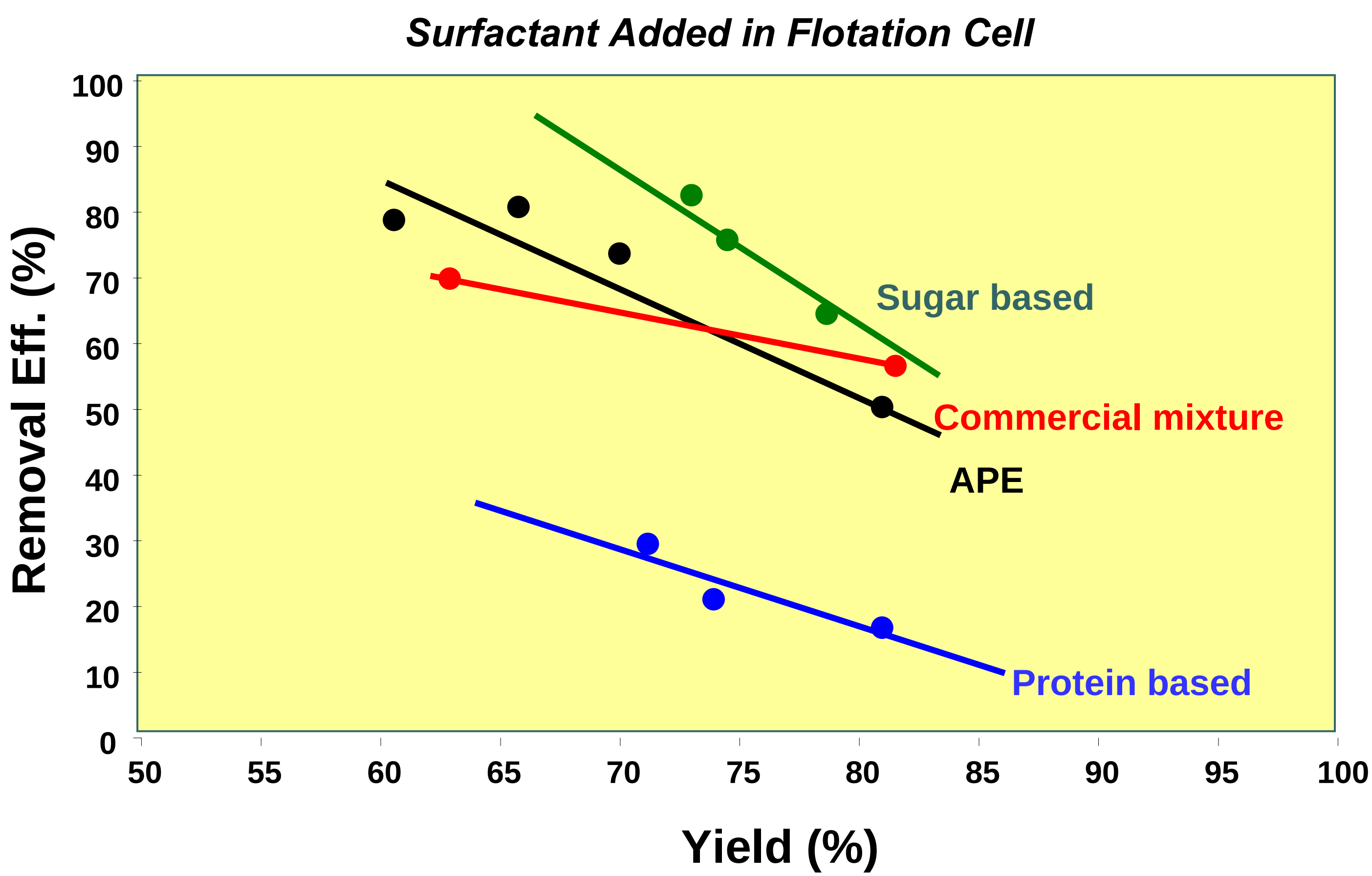


Flotation Results: Efficiency vs surfactant charge



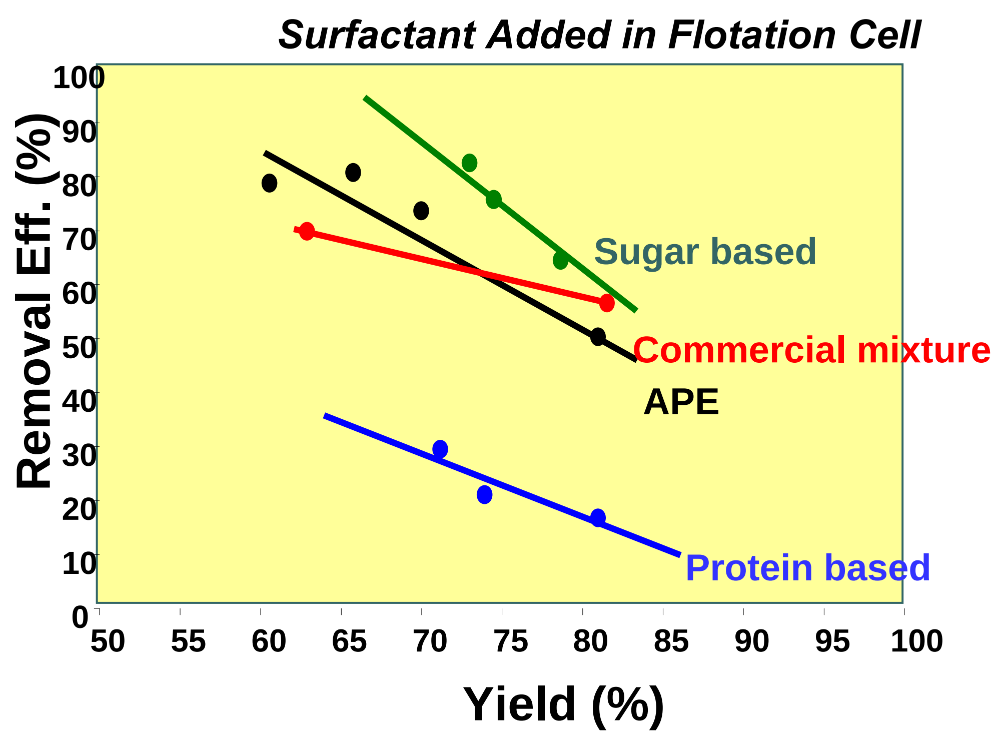
- At a given surfactant charge, the removal efficiency correlates with the foamability ➔ does not reflect selectivity of separation

Flotation Results: Selectivity



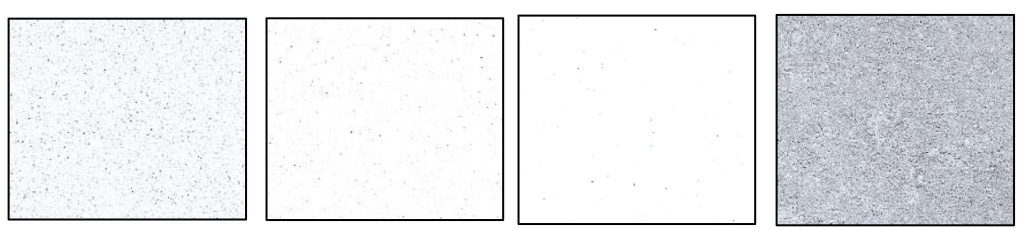
Flotation Results: Selectivity

- Protein-based surfactant has significantly lower selectivity:
  - highest adsorption onto model ink (QCM)
  - largest decrease in contact angle on model ink
  - Higher MW, charged material
- Indication that the protein-based surfactant sterically stabilizes toner in water
  - Cationic starch interference of toner agglomeration *(Berg and coworkers, 1994; Venditti and coworkers 1999)*
  - Acrylate adhesive anti-deposition on polyester by cationic starch *(Venditti and coworkers, 1999)*



Conclusions

- Methods to distinguish differences in adsorption, desorption and detergency between different surfactants have been demonstrated
- Foamability has a strong correlation with removal efficiency, independent of yield considerations
- Selectivity is related to adsorption, surface modification of toner (contact angle) and steric stabilization of ink particles
- The surfactant with the sugar moieties had similar flotation removal efficiencies than did synthetic (APE) surfactants



Acknowledgements

- NCSU Undergraduate Research Program and
- EPA People Prosperity and the Planet (P3).
- Support by University of Guadalajara for visiting research experience of Luis Castillo at NCSU is gratefully acknowledged.

- We would also like to acknowledge the assistance of Dr. Xavier Turon with the QCM experiments.