Foaming Emulsions

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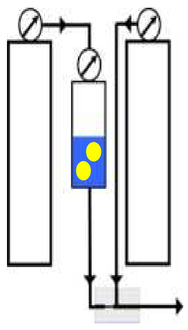
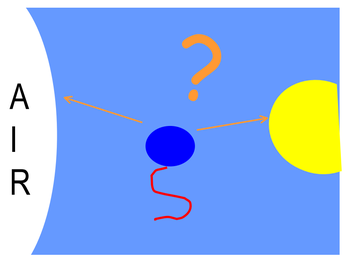
Introduction

Mixtures of foams and emulsions are found in many industrial products, where either they are purposefully created for reasons of function and texture or they are an unwanted side product due to the foaming of an emulsion during preparation or use. Interestingly, depending on the volume fractions of air, water, surfactant and oil, emulsions can strongly increase the stability of foams or act as antifoams [1-2]. We have studied the foamability and stability of model foam-emulsion systems with varying oil/air/water/surfactant concentrations [3].

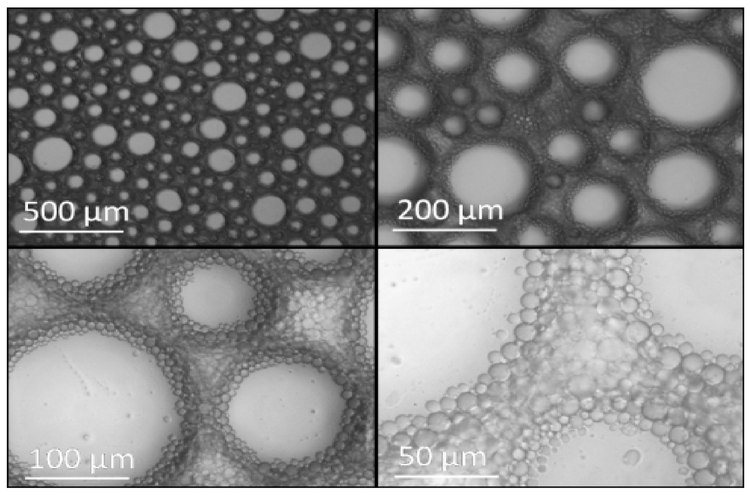
System Details

1. Emulsion prepared using an ultraturrax ($R_{emulsion} \approx$ 7 µm).
2. The emulsion is foamed using a high pressure turbulent mixing apparatus with a T-junction ($R_{bubble} \approx$ 100 µm).

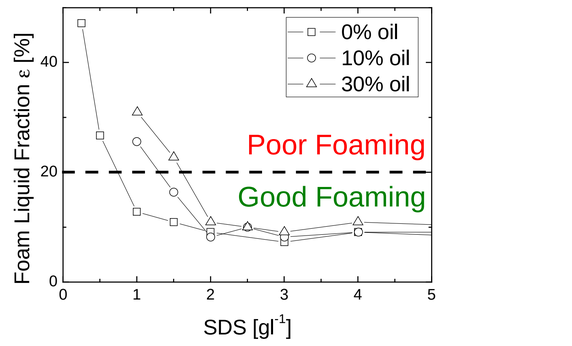




A single surfactant, sodium dodecyl sulphate (SDS) is used for stabilisation of all the interfaces. The oils used for the emulsions are *n*-dodecane or rapeseed oil.

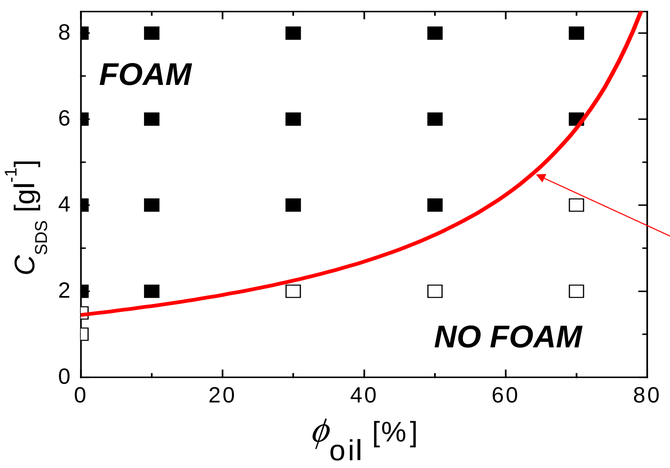


Bubbles and emulsion droplets under a microscope



The ***foamability*** of the sample is a *relative measure* and depends on the preparation method. Above the definition of good foaming for the *n*-dodecane system.

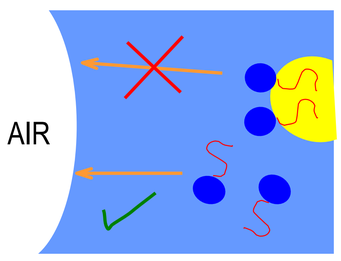
rapeseed oil



Foamability

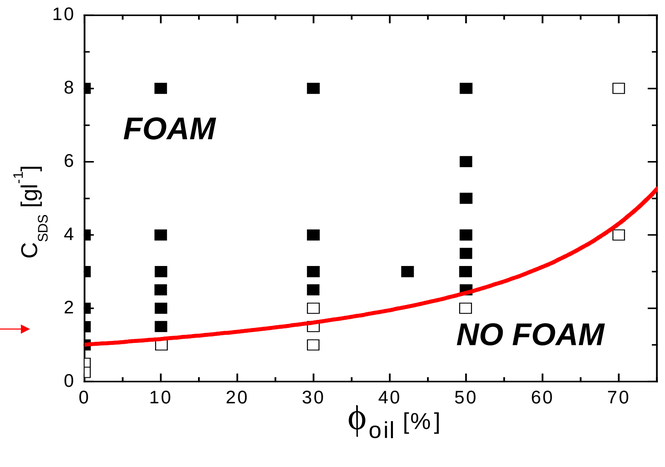
Limit of Foamability. Assuming that the SDS used for the stabilisation of the emulsion is not available for foaming, we can calculate the amount of interface the SDS can cover to predict the foamability. The surface covered by one SDS molecule, Γ, as 50 Å^2.

$$C_{SDS} = \left[c^*_{free} + \frac{M_W}{N_A \Gamma} \frac{3R}{\phi_{oil}} \right] \frac{1}{1-\phi_{oil}}$$



Works very well, for both oils ! The surfactant cannot leave the emulsion interfaces for foaming, and there is a unique c^*_{free} for a given preparation method and surfactant.

n-dodecane



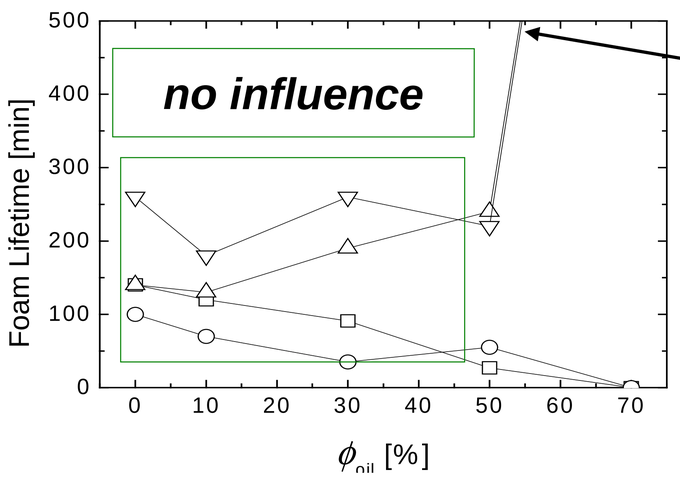
Foam Lifetime

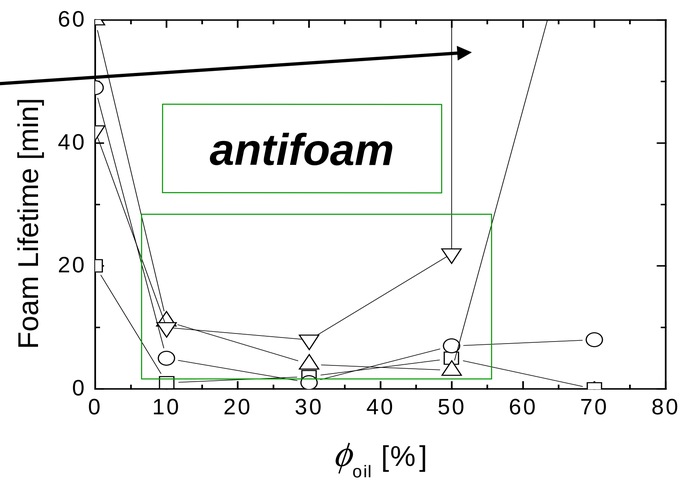
Foams with long life-times for both oil types.

The foam lifetime, depends strongly on the oil used. For rapeseed oil, the emulsion has very little effect on foam stability, whilst for n-dodecane the emulsion acts as an antifoam. However, for both systems at high C_{SDS} and ϕ_{oil} very stable foams can be created and the differences between the oils are again rather small.

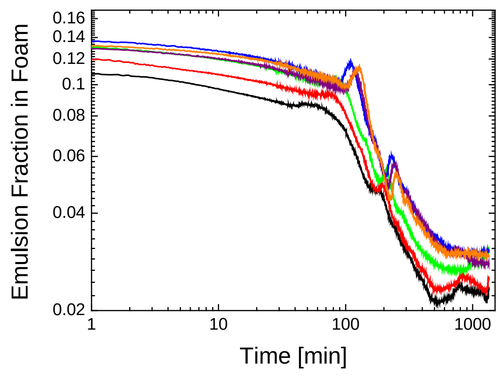
○ *2 g/L SDS* △ *8 g/L SDS*

□ *4 g/L SDS* ▽ *16 g/L SDS*

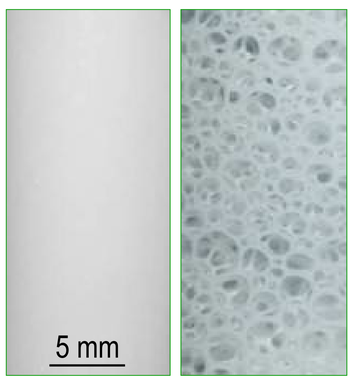




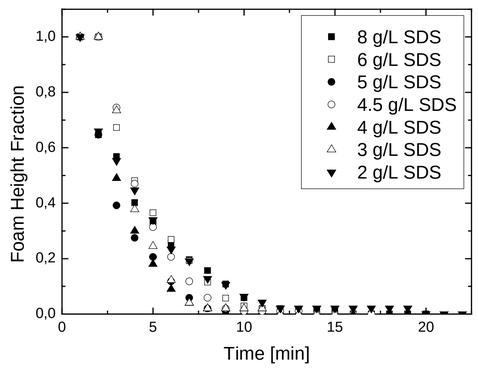
Foam Aging



Drainage of an Emulsion Foam



Emulsion foams: On the left a rapeseed foam ϕ_{oil} = 70% immediately after preparation and two hours later, as the bubble size has increased siginificantly. On the right a n-dodecane foam with ϕ_{oil} = 30% immediately after preparation and a few minutes later, as it starts to collapse.



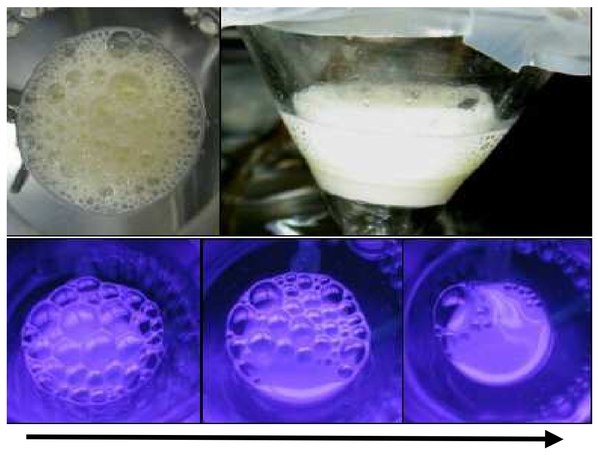
Collapse of an Emulsion Foam

Solid Foams from Stable Emulsion Foams

After the preparation of stable foamed emulsions, the emulsion phase can be polymerised to create solid foams. A styrene emulsion is foamed and then polymerised. Collaboration with **Fabian Schüler** and **Cosima Stubenrauch**, Dublin, Ireland and Stuttgart, Germany.

Applications

Active Control of Foamability Using an Emulsion [4]. The use of a light sensitive polymer in the emulsion formulation allows for the active control of foaming.using UV-light or temperature. The emulsion foams under blue light, but stops foaming after a few minutes under UV-light. Collaboration with **Patrick Perrin**, ESPCI, France.



Conclusions

The emulsified foam systems are very versatile. The ***foamability*** of the system is controlled by the surfactant and surprisingly the SDS already at the emulsion interfaces cannot be used for foaming. The ***foam stability,*** however, depends strongly on the oil type, although with lots of SDS and high ϕ_{oil} very stable foams can be created with both systems. The very stable emulsion foams have particularly interesting ***aging*** properties (coarsening, rheology and drainage) and still hold secrets to be uncovered.

References

1] Koczo, K., Lobo, L. A., Wasan, D. T., *J. Coll. Int. Sci.,* 1992, **150**, 492-506. [2] Denkov, N.D., *Langmuir,* 2004, ***20,*** 9463-9505.

[3] Salonen, A., Rio. E., Drenckhan, W., Saint-Jalmes, A., Langevin, D. *European Roads Review*, CME 2010. [4] Salonen, A., Langevin, D., Perrin, P., *Soft Matter*, 2010,