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POROUS CERAMICS FROM SURFACTANT-PARTICLE MIXTURES

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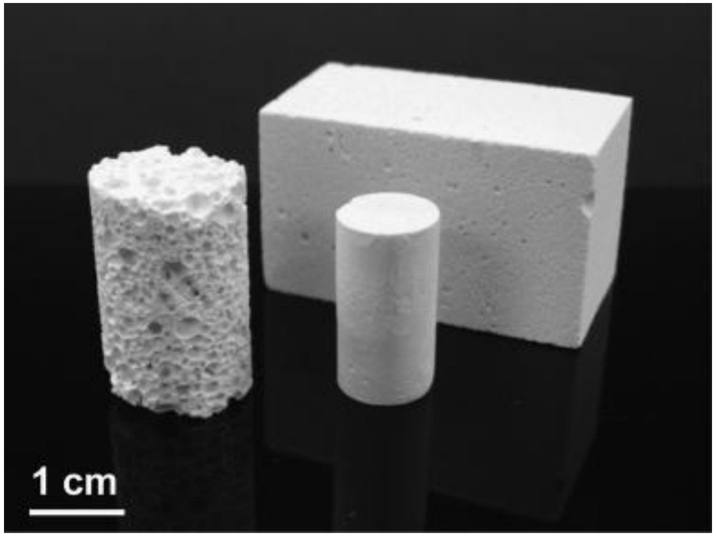
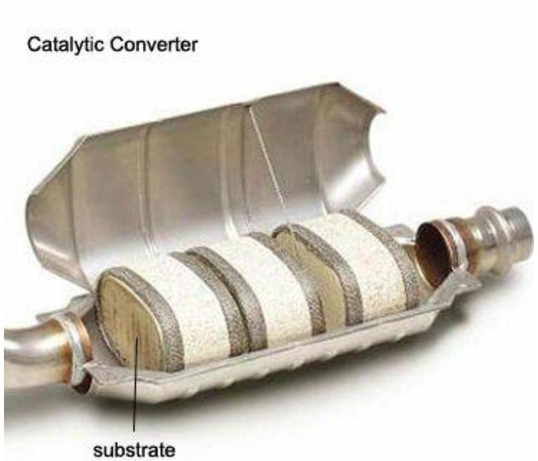
Motivation of the study

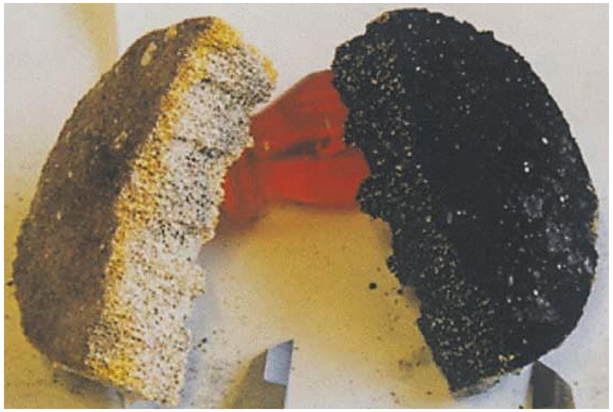


F.K. Juillerat et al.
J. Am. Ceram. Soc. (2011)

Potential applications:

- ✓ **Catalyst support**
- ✓ **Filters**
- ✓ **Thermal and noise insulations**
- ✓ **Tissue scaffolds**

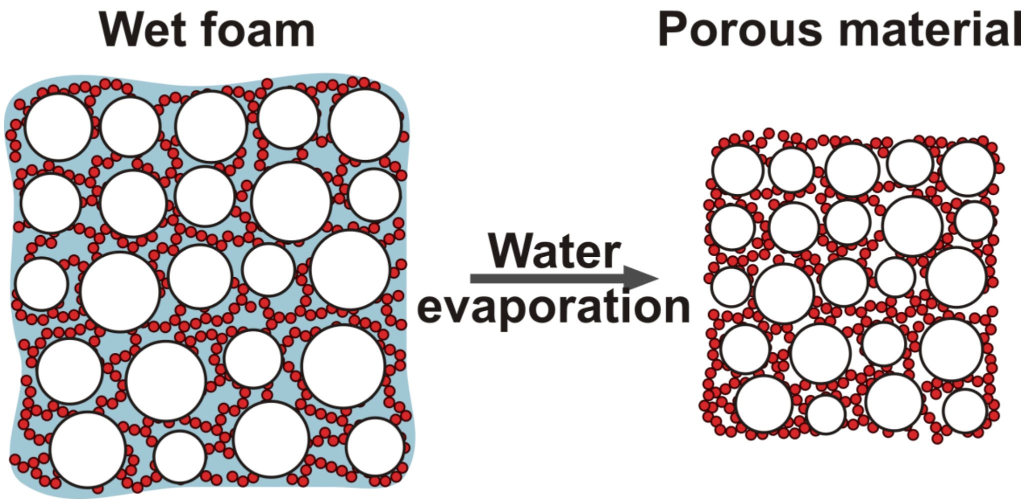




Dekoninck et al., WIPO Patent "High-performance Thermal Insulation Materials". WO 2013/007958 A1.

Basic steps


KENWOOD
CHEF premier


Wet foam
Porous material
Water
evaporation

Main problems (summary)

- Difficult foaming of suspensions
- Water drainage from wet foam
- Bubble Ostwald ripening
- Bubble coalescence
- Foam cracking upon drying

Overview of surfactant-particle foams (for negatively charged particles)

Surfactant type	Foaming of the formulation	Stability to drainage
Anionic	Excellent	Very low
Nonionic	Possible	Low
Cationic	Possible	Strongly depends on conditions
Zwitterionic (we were first)	Good	Strongly depends on conditions

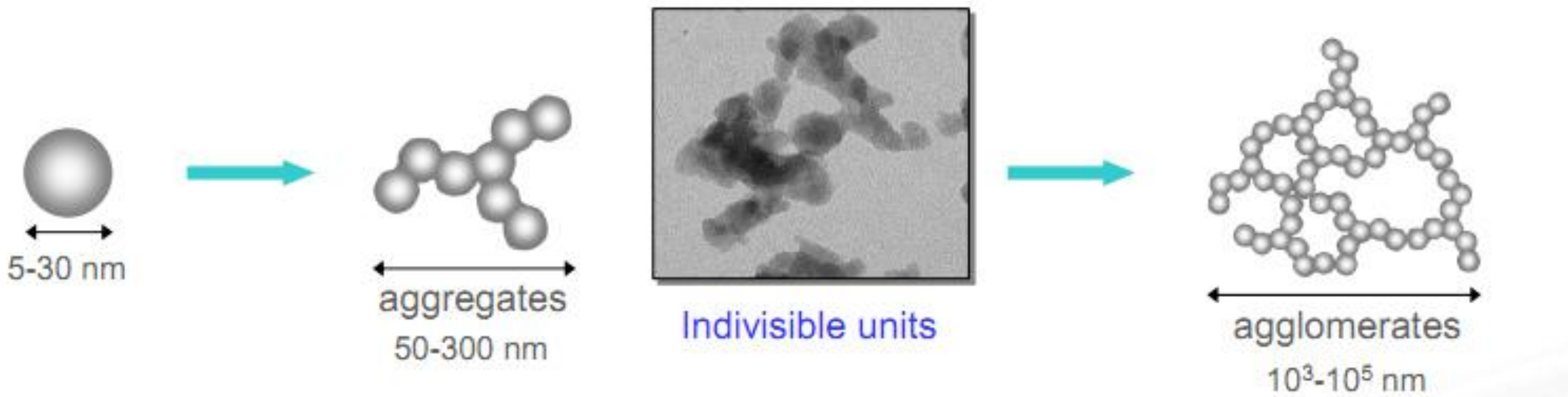
Aims of our study

- Which factors govern foam formation and stabilization?
- How could we control these processes for various systems?

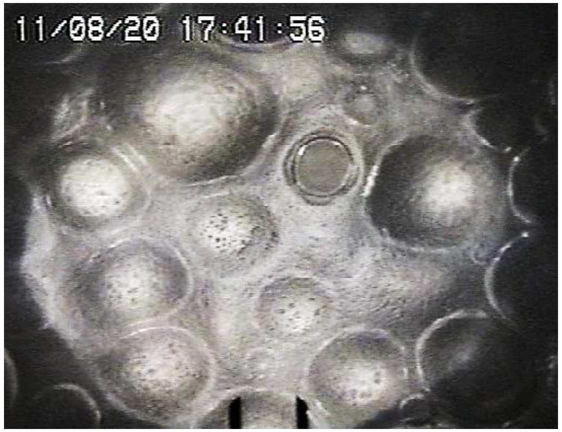
Materials

Precipitated silica particles

(hydrophilic, negatively charged surface)

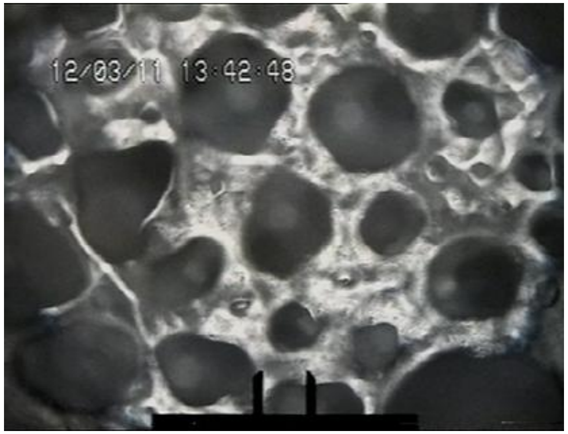


Tested surfactants



← **Cationic**

Zwitterionic →



Methods

1. Surfactant Solution

Stirring, 1000-1200 rpm

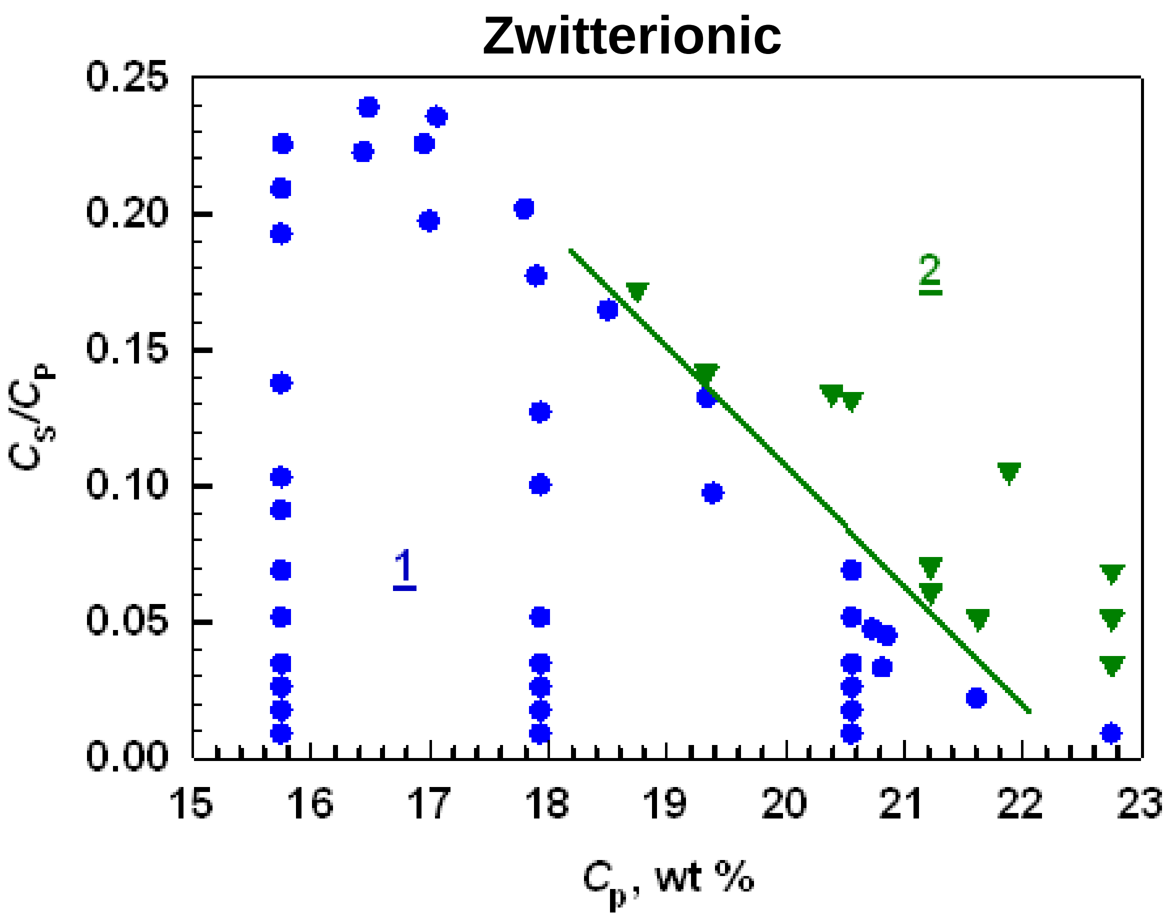
2. Add Particles

Ultrasonic homogenization
(low viscosity)

3. Repeat step 2 until (low) yield stress is present

4. Generate foam

Foam formation diagram



Region 1:

0.35 < Φ <0.96

Region 2:

Φ < 0.35

Air volume fraction

$$\Phi = \frac{V_{air}}{V_{foam}}$$

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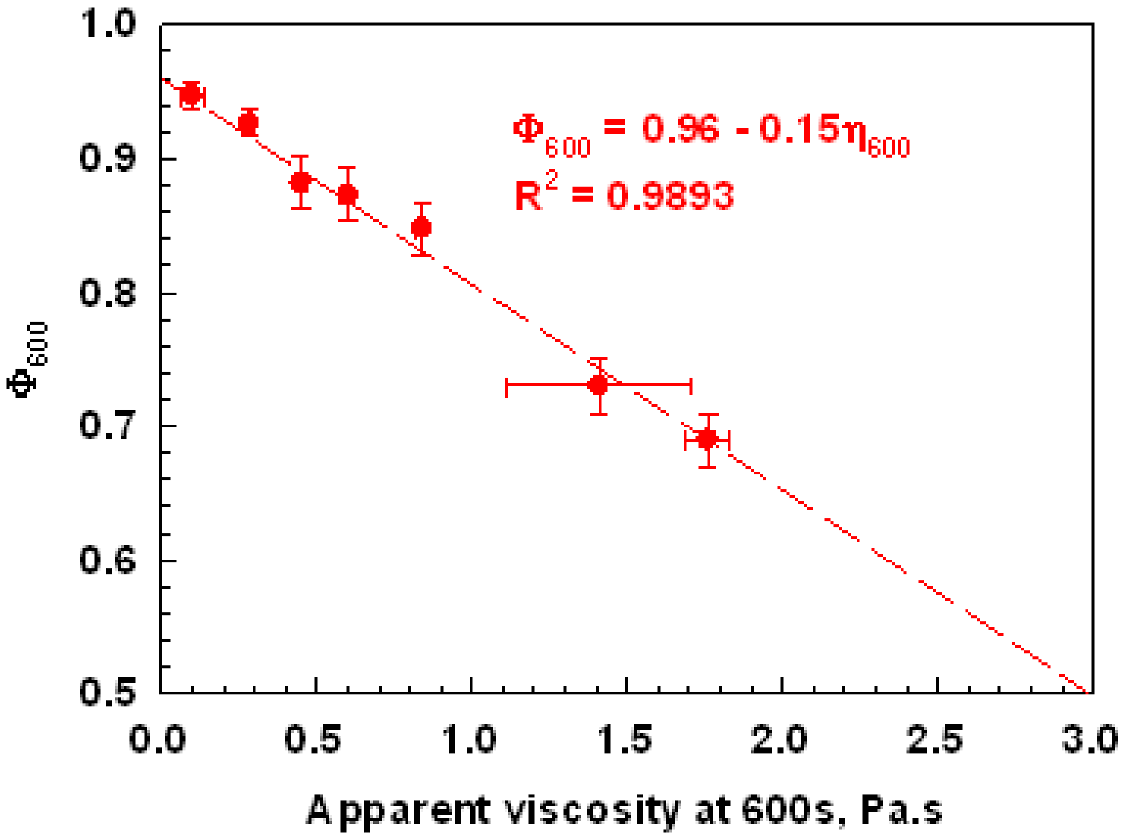
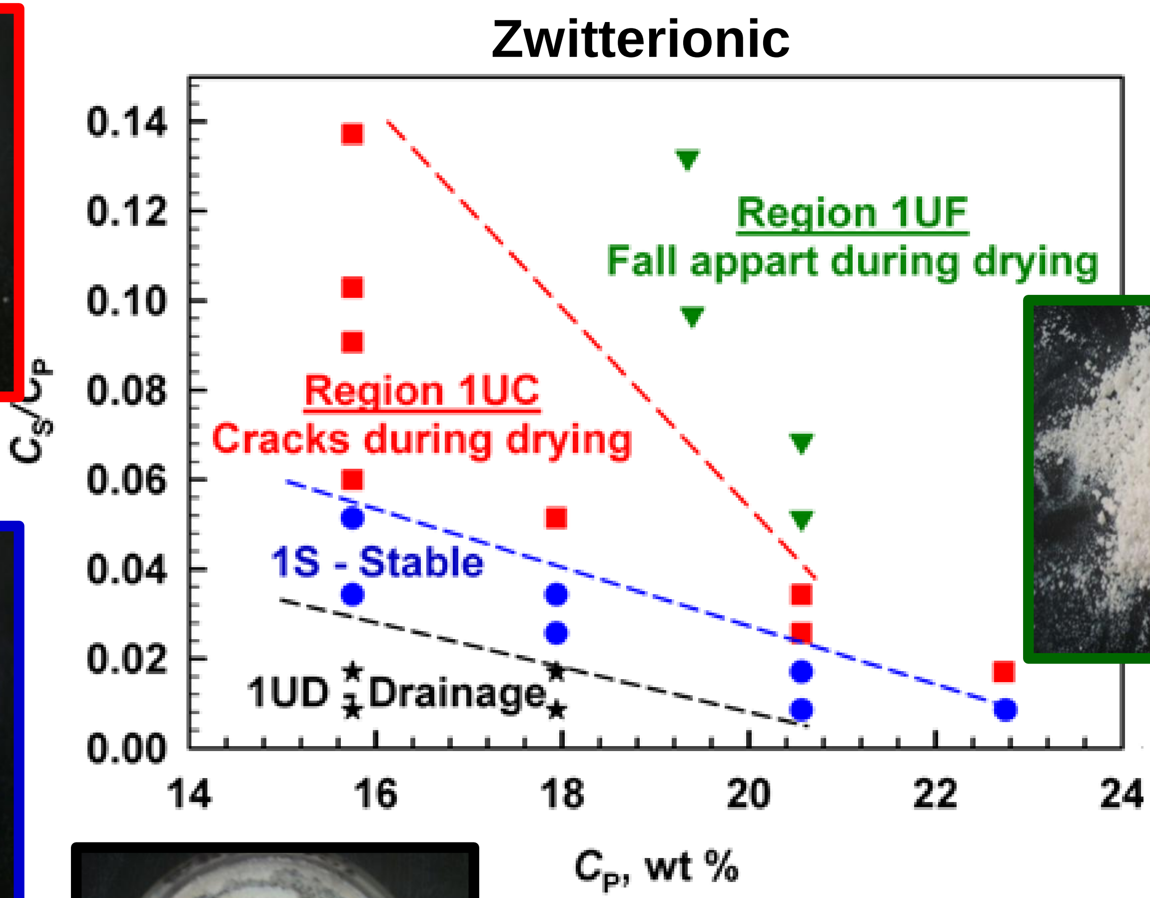
Foaming – effect of suspension viscosity

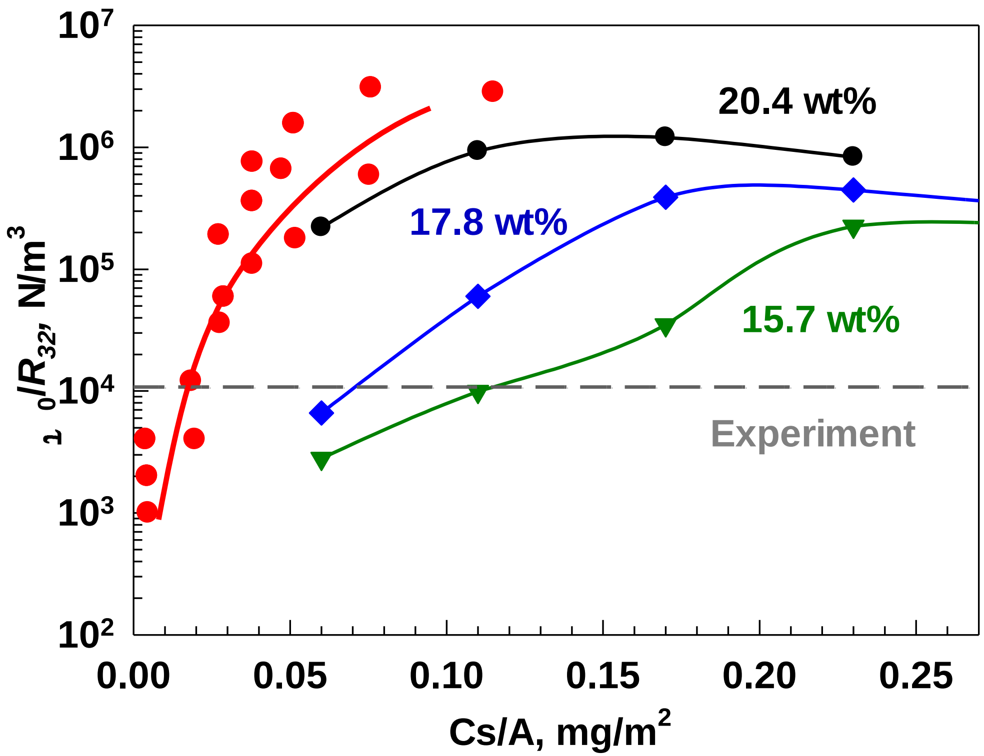


Foaming depends strongly on the viscosity of the suspensions

Foam stability



Stability against drainage



- ❑ **3 concentrations of particles**
- ❑ **Cationic and zwitterionic (C_S от 0.01 до 4 wt %)**

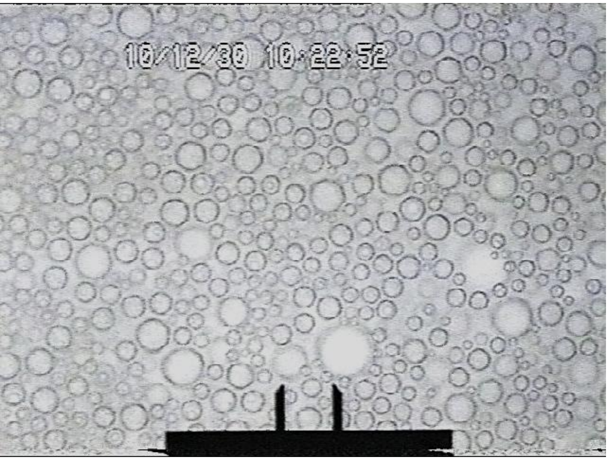
Chaplain & Mills, 1992

$$\frac{\tau_0}{R_B} = \Delta\rho g \approx 10.8 kN / m^3$$

Balance between bubbles size and yield stress guarantees stability

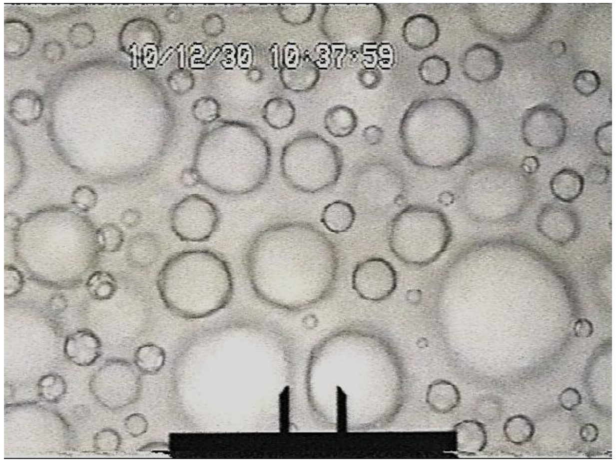
Ostwald ripening – effect of surfactant type

Zwitterionic, t = 0

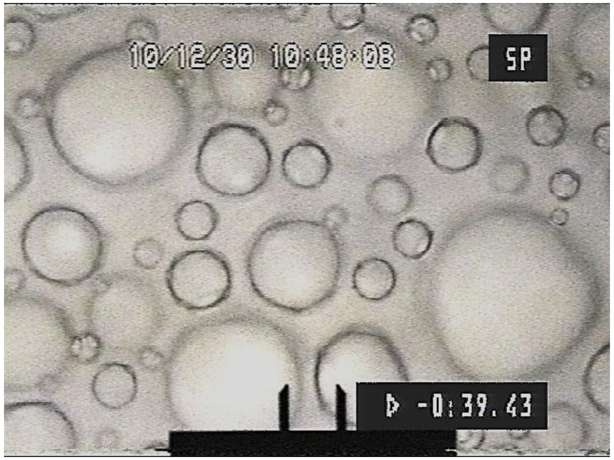


100 µm

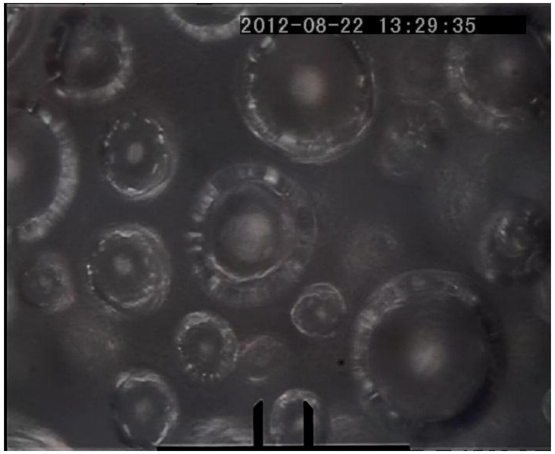
t = 15 min



t = 25 min

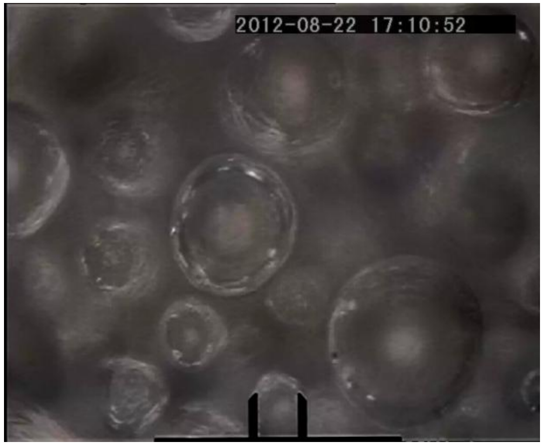


Cationic, t = 0

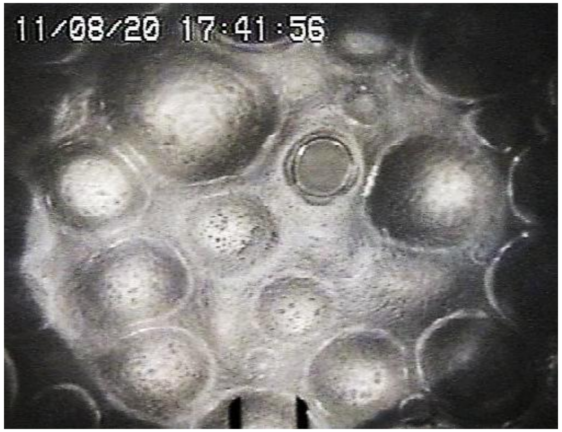


50 µm

t = 230 min



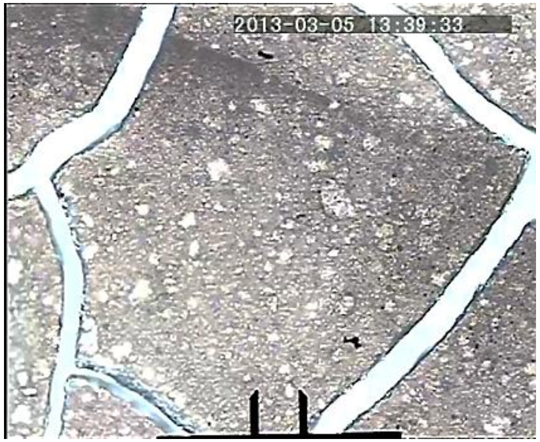
Particle-stabilized bubbles



Stability against drying

Dried wetting films

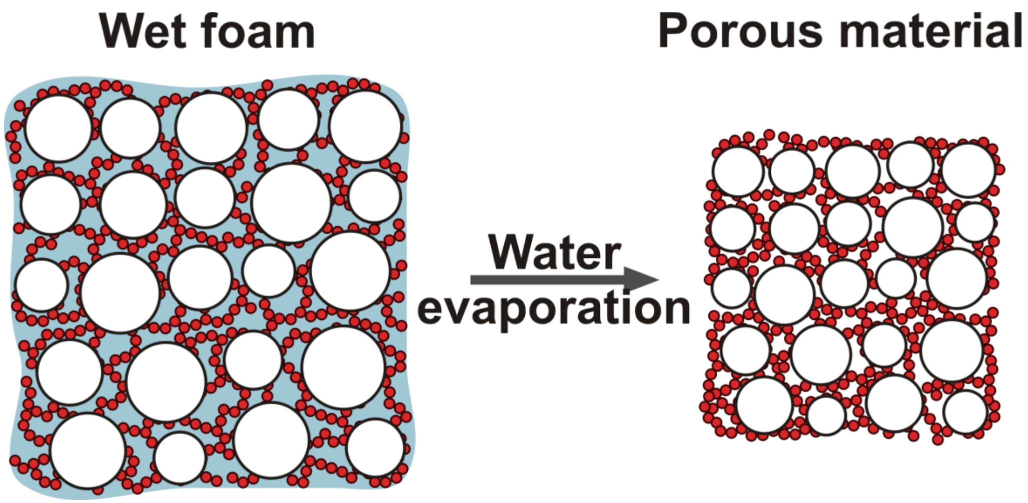
50 µm

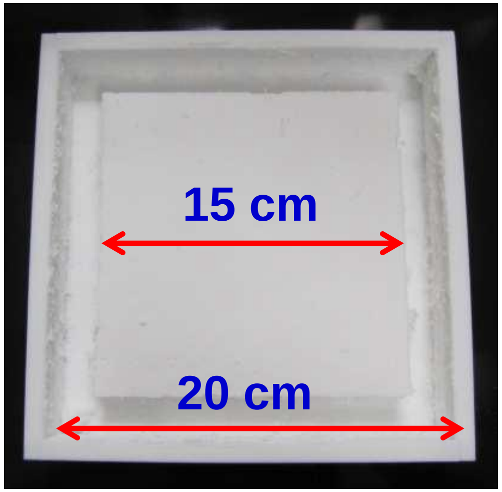


Resulting bulk material

Aggregation of particles = inhomogeneous distribution of capillary forces

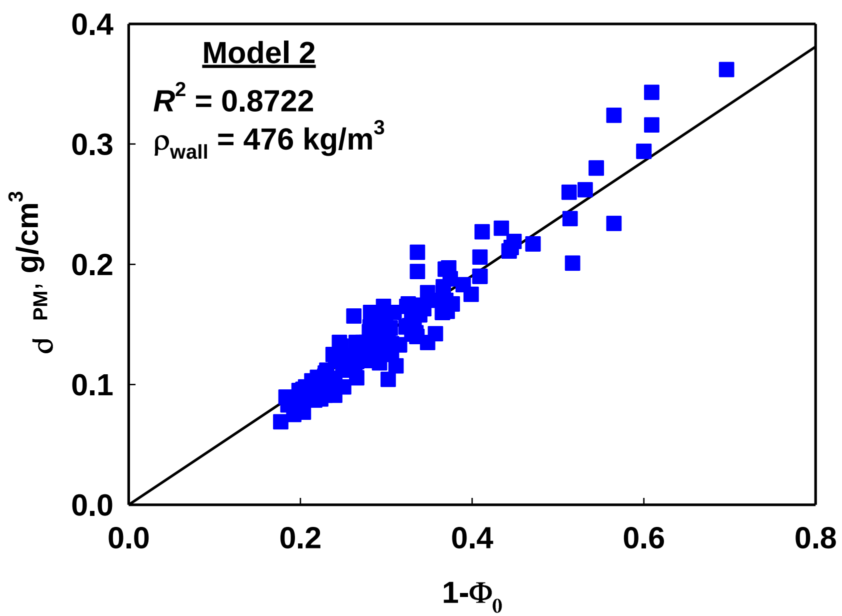
Isotropic shrinkage during drying





Mass balance:

$$\rho_{PM} = \rho_{wall} \;\; 1 - \Phi_0$$



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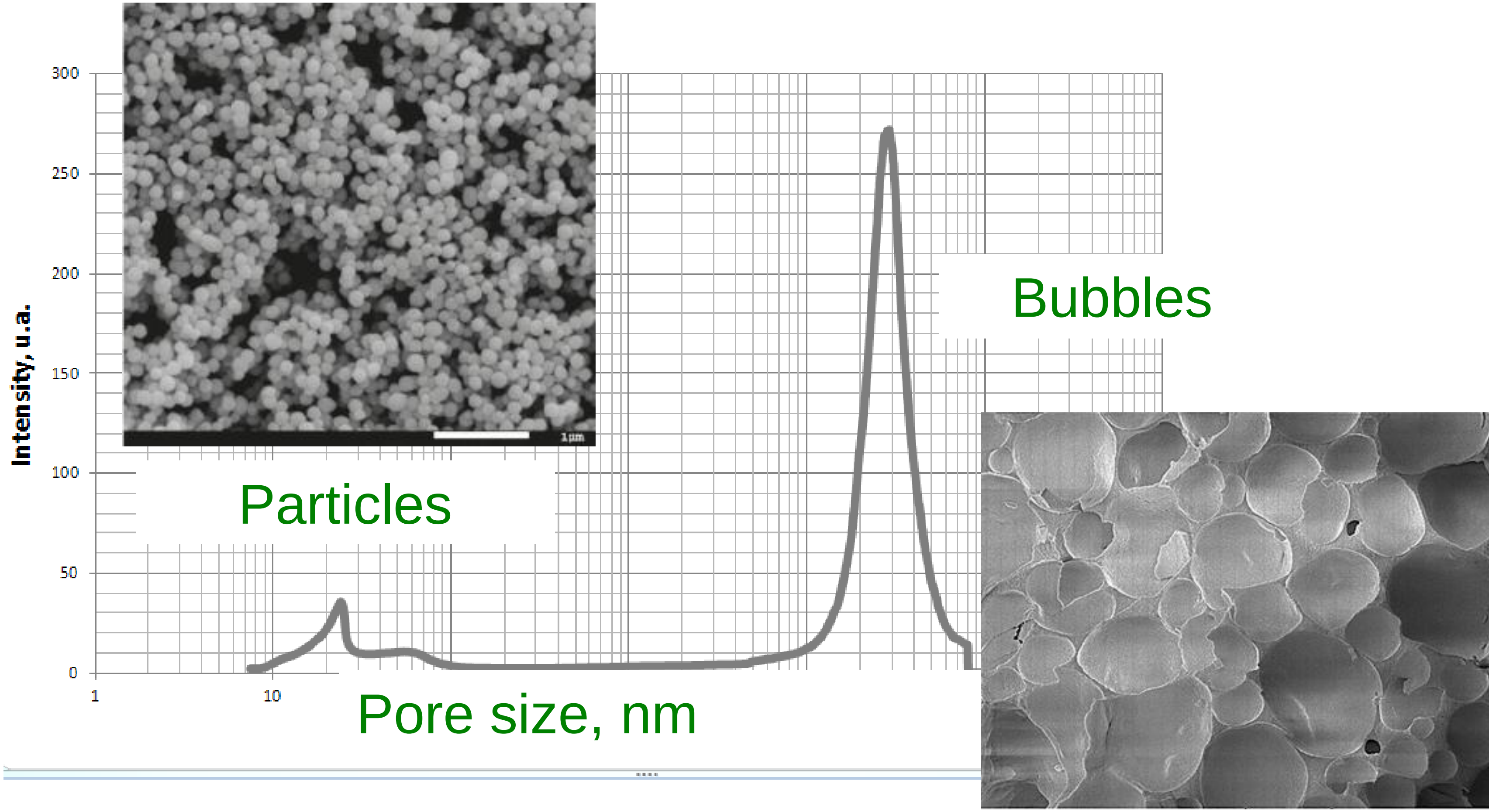
Hierarchical structure of the foams



<u>Three characteristic length scales:</u>

particle (×nm), aggregates (×10 nm), bubbles (×10 μm)

Summary

1. The formation of foams and their stability against drainage and Ostwald ripening depend significantly on the rheological properties of the surfactant-particle mixtures.

2. The stability of the wet foams against drying depends on the level of aggregation of the particles, upon adding the surfactant

3. The foams shrink isotropically (the suspension and the bubbles shrink simultaneously) during the process of drying, which has been explained in details in a newly developed theoretical model.

1. A. Dekoninck et al., WIPO Patent "High-performance Thermal Insulation Materials". WO 2013/007958 A1.

2. I. Lesov, S. Tcholakova, N. Denkov, Factors Controlling the Formation and Stability of Foams, Used as Precursors of Porous Materials, *J. Colloid Interface Sci.* **426** (2014) 9-21.

3. I. Lesov, S. Tcholakova, N. Denkov, Drying of Particle-Loaded Foams for Production of Porous Materials: Mechanism and Theoretical Modeling. *RSC Adv.* **4** (2014) 811-823.

Acknowledgments

SAINT-GOBAIN
RECHERCHE

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Thank you for the attention!