Karlsruhe Institute of Technology

Institute for Thermal Process Engineering

Contact-Mediated Nucleation – A Possibility to Make the Crystallization of Melt Emulsions more Efficient and Sustainable

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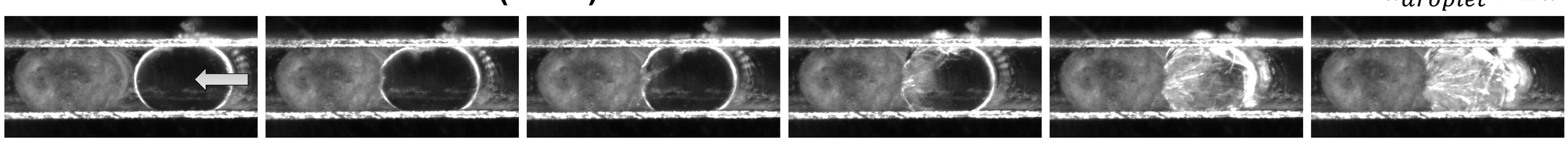
Contact-Mediated Nucleation (CMN)

$u_{droplet} \triangleq \Delta u$



Video

Motivation and State of the Art

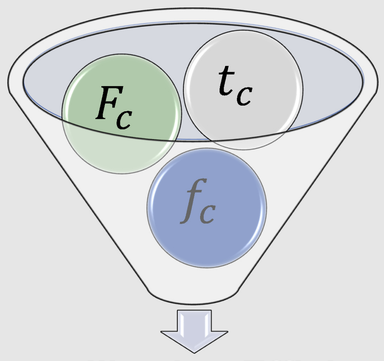
Process Parameters → Phys.-chem. Properties → Product Quality

- surfactant
- subcooling ΔT

- solid droplet fraction ξ

- shelf-life
- functionality

Coalescence theory[1] ⟷ CMN



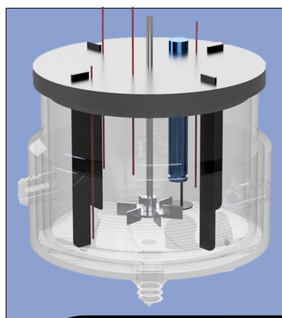
- contact force F_c (~ shear rate $\dot{\gamma}$)
- contact time t_c (~ $\dot{\gamma}^{-1}$)
- collision frequency f_c (~ $\dot{\gamma}$)

Crystallization Efficiency

$\eta_{CMN} = f(\dot{\gamma})$

Understanding of CMN →

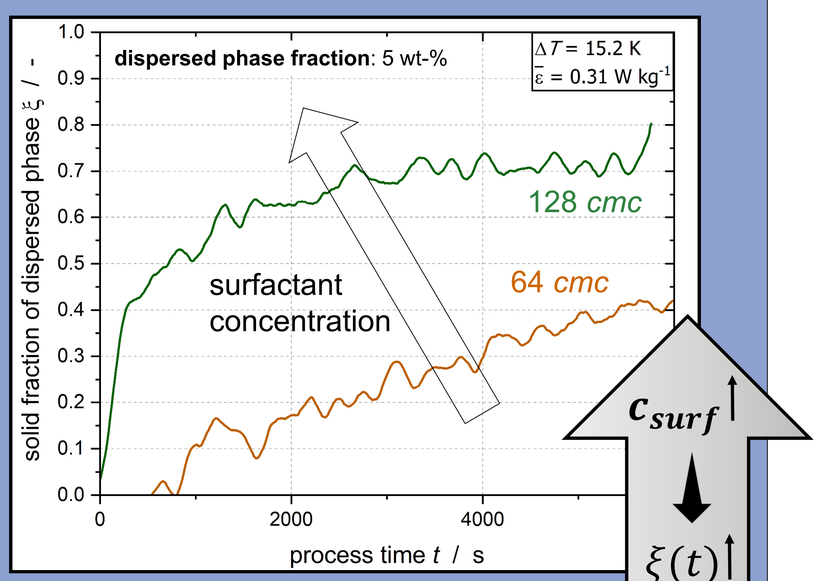
Stirred Vessel – Transfer to 'Industry-Like' System



- c_{surf} increased → higher nucleation rate
- no decrease of subcooling possible by increasing impeller speed (≙ energy dissipation)

- narrow droplet size distribution
- slow stirring speed

process acceleration

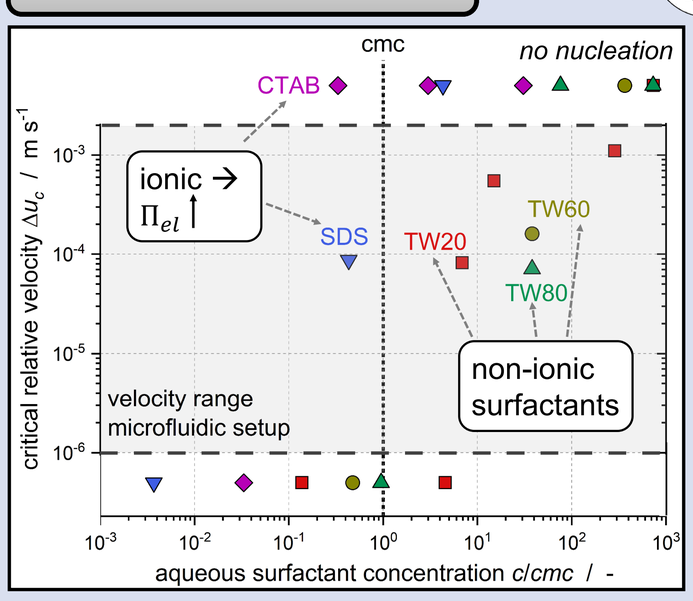


Microfluidics (µF) – General Understanding

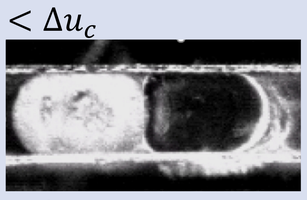
Impact of surfactant charge and concentration[2] on Δu_c

disjoining pressure: $\Pi_d = \Pi_{VdW}$ (Van-der-Waal) $+ \Pi_{el}$ (electrostatic) $+ \Pi_{osc}$ (oscillatory) $+ \sum \Pi_i$ (other)

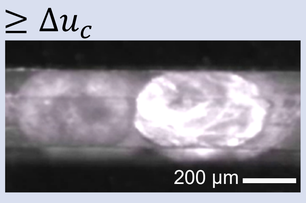
$\Pi_d \uparrow \rightarrow \Delta u_c \uparrow \rightarrow \eta_{CMN} \downarrow$



$\Delta u < \Delta u_c$

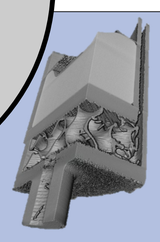


$\Delta u \geq \Delta u_c$



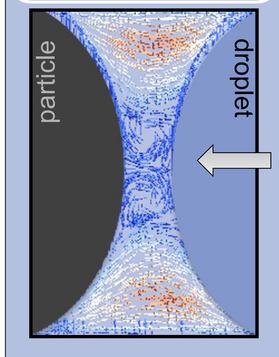
$t_c \geq t_{ind}$
$F_c \geq F_{CMN}$
$\rightarrow \eta_{CMN} = f(\dot{\gamma}, c_{surf})$

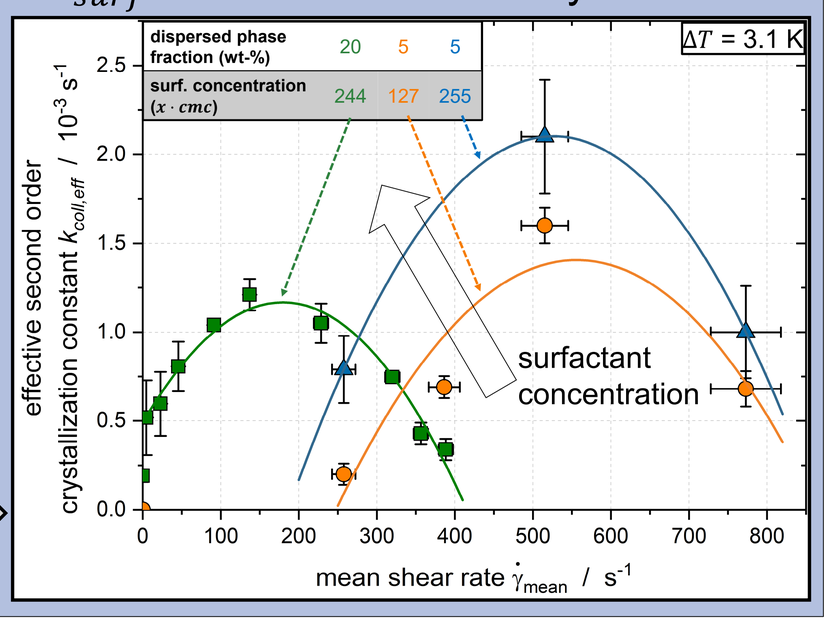
RheoNuclearMagneticResonance[3,4] – CMN in Laminar Flow Conditions



- no primary nucleation
- fraction of dispersed phase decreased → higher $\dot{\gamma}$ needed to induce CMN, as lower f_c
- c_{surf} increased → faster crystallization

laminar flow
µF[5] ≠ Rheo





References
[1] Chesters, A. K., Chem. Eng. Res. Des. 1991, 69, 259.
[2] Kaysan, G., Rica, A., Guthausen, G., Kind, M.; Crystals 2021, 11, 1471.
[3] Kaysan, G., Schork, N., Herberger, S., Guthausen, G., Kind, M., Magn Reson Chem 2022, 60, 615.
[4] Kaysan, G., Spiegel, B., Guthausen, G., Kind, M.; Chem. Eng. Technol. 2020, 43, 1699.
[5] Kaysan, G.; Hirsch, T.; Dubil, K.; Kind, M.; Colloids Interfaces 2023, 7, 12.

Special thanks to

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