Fine Bubbles For Biochemical Transformation

B. Thomas[1], D. Ohde[1], S. Mattes[2], P. Bubenheim[1], K. Terasaka[3], M. Schlüter[2], A. Liese[1]
[1]Hamburg University of Technology, Institute of Technical Biocatalysis, Denickestraße 15, 21073 Hamburg, Germany
[2]Hamburg University of Technology, Institute of Multiphase Flows, Eißendorfer Straße 38, 21073 Hamburg, Germany
[3]Keio University, Department for Applied Chemistry, Tokyo, Japan

What are Fine Bubbles?

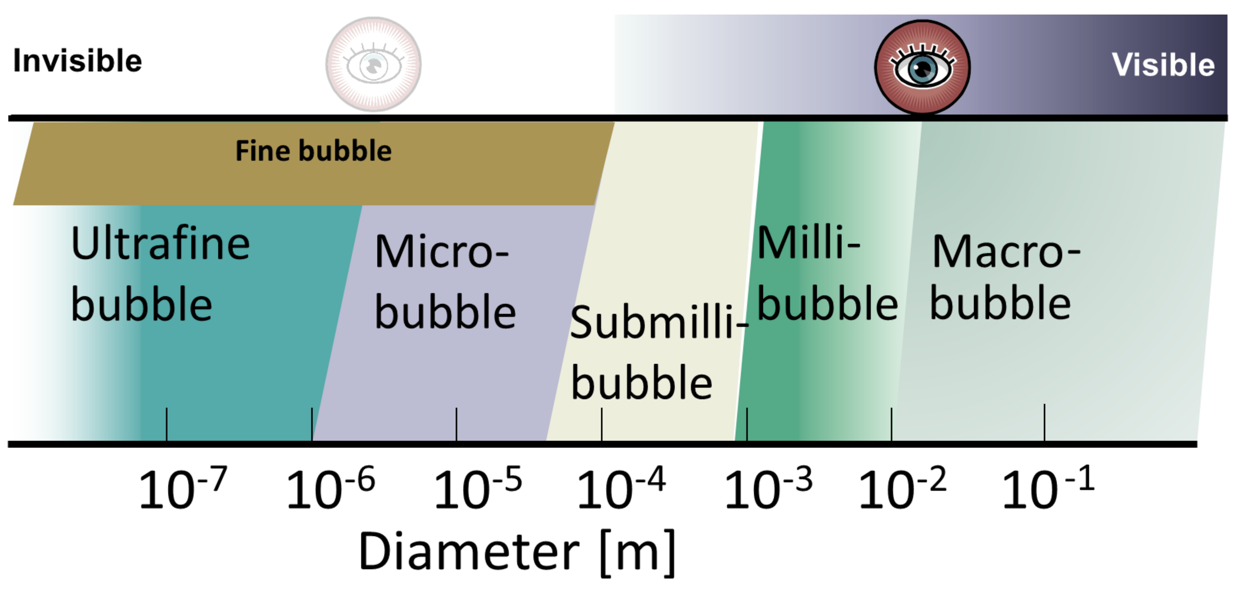

Fig. 1: Definition of fine bubbles size classes [1]

- Perception of gas/liquid reactions in view of mass transport phenomena is of major importance in chemical and biochemical applications [1]
- The demand for new technologies with elevated mass transfer performance is high [1,2].
- One option to achieve this goal is the aeration with fine bubbles, whose diameter is typically less than 100 micrometers [2,3]
- Application of different bubble size classes by three sparger types
  - Submilllibubbles: 1 µm shirasu porous glass (SPG) membrane
  - Millibubbles: 2 µm sinter stone
  - Macrobubbles: 5 holes, d_{hole} = 0.5 mm bubble pipe

Enhancement of Reaction Rate by Fine Bubble Technology

- Detailed investigation of the influence and effect of bubble size on β-D Glucose consuming enzymatic model reaction
- The aim is the improvement of mass transfer regarding oxygen consuming enzymatic reactions to overcome limitations of conventional aeration systems

➢ Gas to liquid mass transfer is the key!

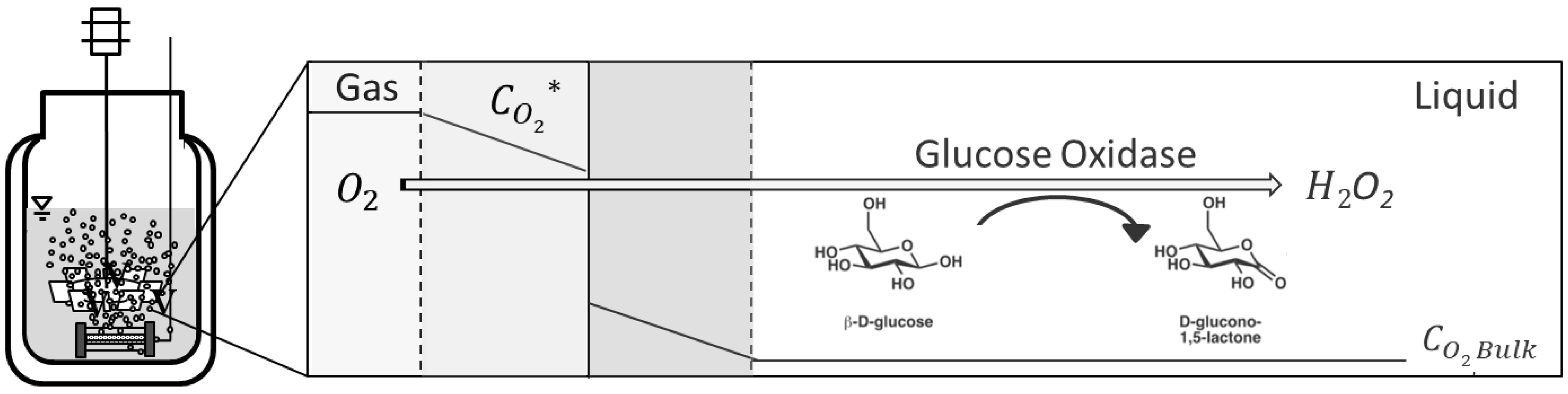

Fig. 2: Enzymatic D-glucono-1,5-lactone formation in a multiphase system (two phase system with indication of boundary layer, dashed lines)

Comparison of Aeration Systems

- Feasibility study of fine bubble technology
- Study of glucose oxidase catalyzed model reaction in presence of macro- and microbubble aeration
- Investigation of mass transfer, foam formation and enzyme stability

Submillibubbles	Millibubbles	Macrobubbles
SPG Membrane	Sinter Stone	Bubble Pipe
d_{bubble} = 0.2 - 1 mm	d_{bubble} = 1 - 10 mm	d_{bubble} = 10 - 100 mm

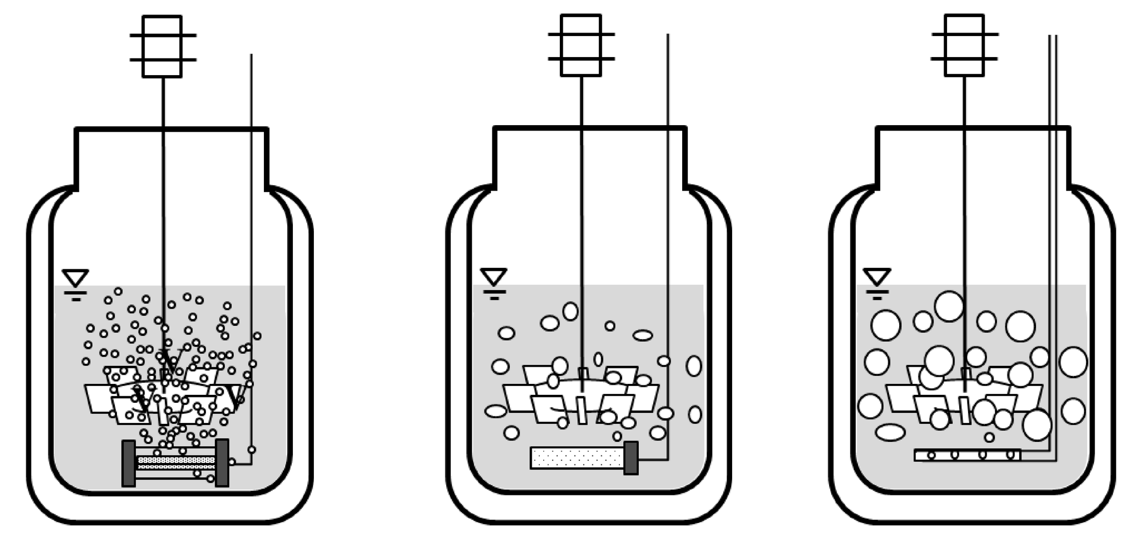

Fig. 3: Comparison of three different aeration systems

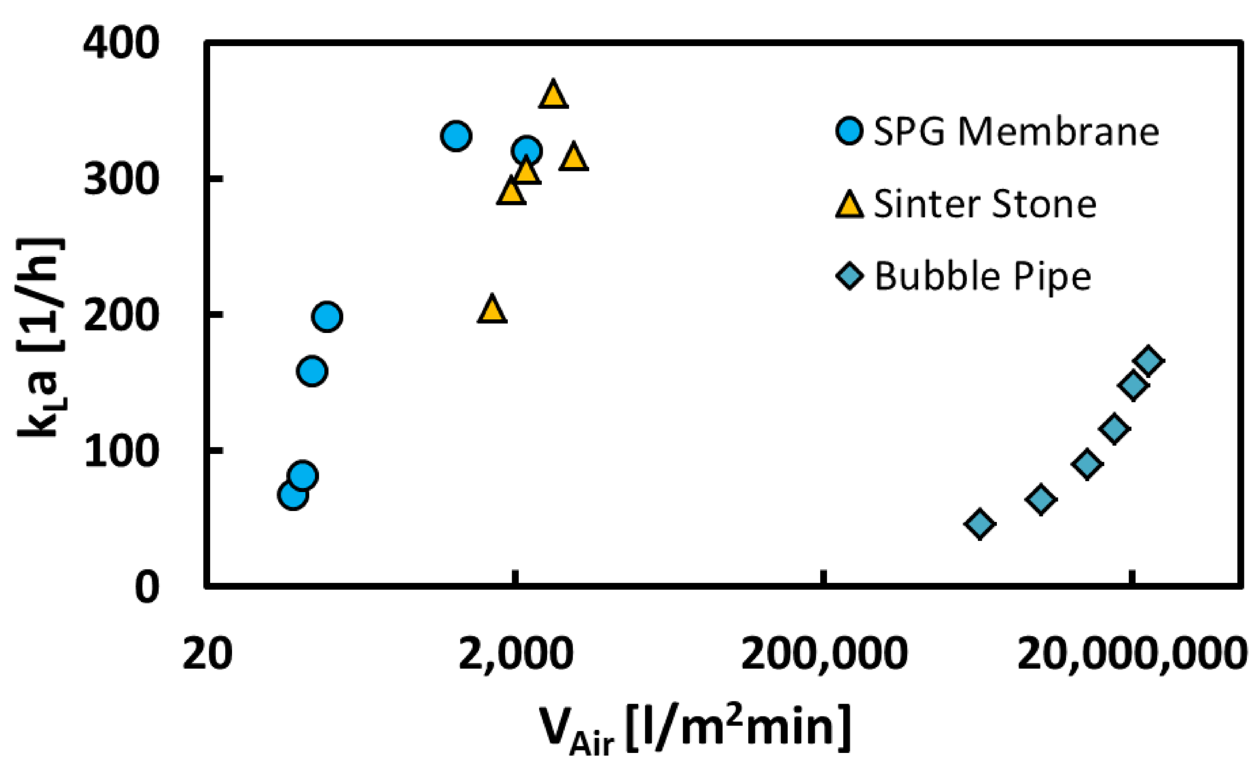

Fig. 4: Investigation of mass transfer performance (dynamic k_La determination with O_2 PrenSens Fibox 4, conditions: T = 35°C, V = 300 ml in 500 ml glass double walled reactor, 12.08 g (0.04 mol) D (+) glucose, 8.3 mg GOX (25 U/mg), 0.5 mg catalase (2000 U/mg), stirrer speed Rushton turbine = 436)

O_2 Mass Transfer Performance

- SPG membrane shows the highest mass transfer performance at low gassing rates
- Less foam formation with fine bubble aeration was observed

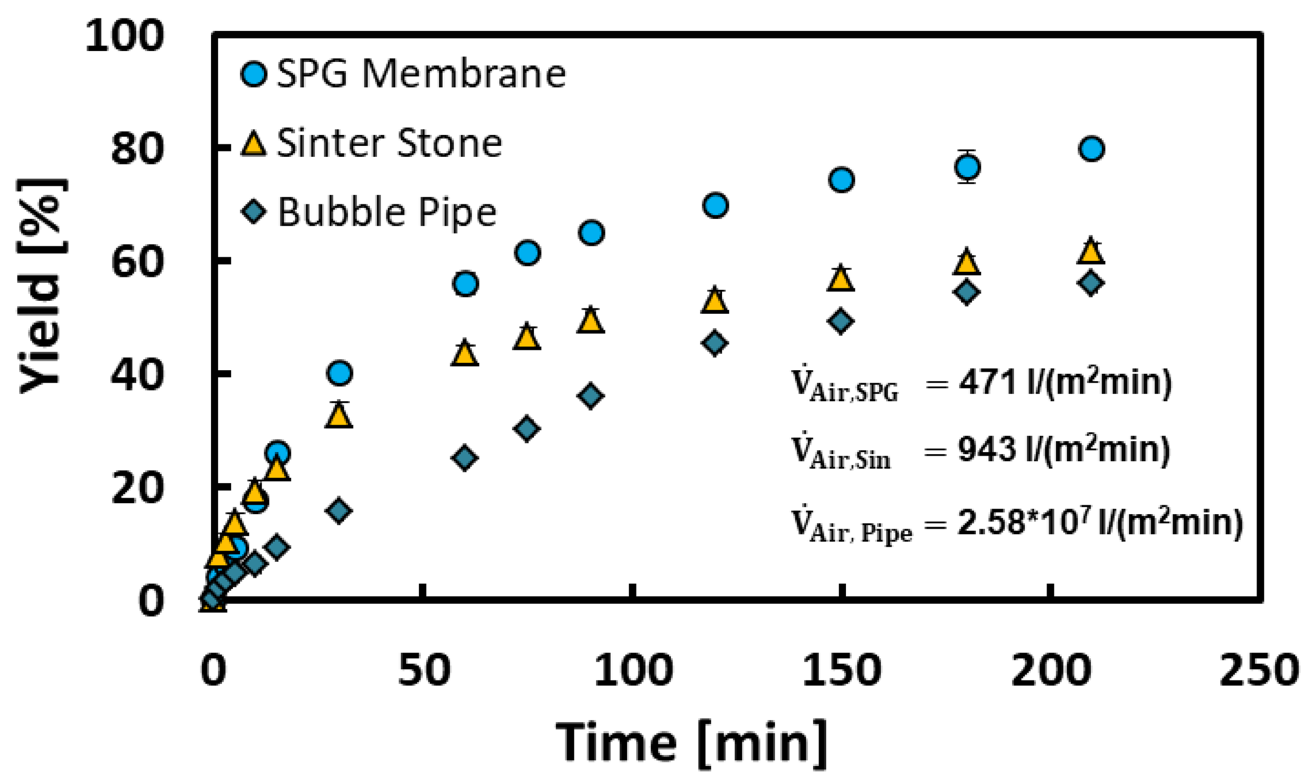

Fig. 5: Glucose oxidase reaction (T= 35°C, V = 300 ml in 500 ml glass double walled reactor, 12.08 g (0.04 mol) D (+) glucose, 25 mg GOX (25 U/mg), 0.5 mg catalase (2000 U/mg), SPG Δp = 2.6 bar), pH stat. titration with 1 M KOH in water, stirrer speed Rushton turbine = 436 rpm, titration with 0.01 mM KOH in water, 1 ml sample in 4 mL water: ethanol (1:1), indicator bromothymol blue 0.1 % in ethanol)

Reaction Productivity

- Investigation of reaction rates was carried out
- Aeration with submillibubbles results in higher yield

Summary

- Comparison of conventional and submilllibubble aeration systems
- Glucose oxidase catalyzed model reaction showed higher yield with submilllibubble aeration
- SPG membrane shows the highest k_La by low gassing rates

Contact:
Benjamin Thomas
Institute of Technical Biocatalysis
Hamburg University of Technology
Denickestr. 15; 21073 Hamburg
Office: DE15, 2504
Tel. +49-40-42878-4171
E-mail: benjamin.thomas@tuhh.de

References:

[1] Tsuge, Hideki. Micro- and nanobubbles. Boca Raton, Florida : CRC Press; Pan Stanford Publishing, (2015).
[2] Terasaka, Koichi, et al. Development of microbubble aerator for waste water treatment using aerobic activated sludge. Chemical Engineering Science. 2011, Bd. 66, 14, S. 3172–3179.
[3] Khuntia, Snigdha, Majumder, Subrata Kumar und Ghosh, Pallab. Microbubble-aided water and wastewater purification. Reviews in Chemical Engineering. 2012, Bd. 28, 4-6.

Acknowledgement:
We are grateful to the Deutsche Forschungsgemeinschaft (DFG) for financial support (DFG, LI 899/10-1) and to all our cooperation partners, especially c-LEcta for the supply of the NADH oxidase.