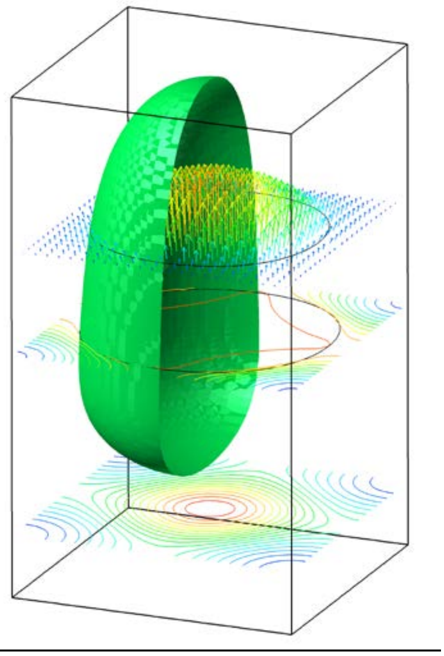
Hydrodynamics and mass transfer in Taylor flow

Background: In small channels, slug flow often occurs in the form of Taylor flow or segmented flow. In this flow pattern, elongated bullet-shaped gas bubbles that almost fill the channel cross-section (Taylor bubbles) are separated by liquid slugs which are free from gas entrainment. Taylor flow is attractive for multiphase micro process engineering (e.g. in monolith reactors) because the high interfacial area per unit volume and the thin liquid film combine very efficient gas/liquid/solid heat and mass transfer with reduced axial dispersion.



Numerical simulation of gas-liquid mass transfer in co-current upward Taylor flow in a square mini-channel

Project: Chemical processes in multiphase systems such as Taylor flow are characterized by the occurrence of various length and times scales and a complex interaction between two-phase hydrodynamics, heat and mass transport and chemical kinetics. Our work aims on the development of rigorous numerical methods/models and advanced computer codes in order to gain new physical insight in such multi-scale multiphase processes. In this context, a novel numerical method for first-principle simulations of mass transfer in two-fluid flows with deformable interfaces is under development. The approach is based on the single-field formulation of the governing equations in the sharp interface limit and a hierarchical grid. It considers conjugate mass transfer with resistance in both phases and shall be valid for arbitrary values of the Henry number (distribution coefficient) and species with low to intermediate Schmidt numbers. The method is implemented in our in-house computer code TURBIT-VOF and is validated by experimental data for fluid flow and mass transfer in Taylor flow, which are provided by cooperation partners within the DFG priority program SPP 1506.

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Selected publications: A. Onea, M. Wörner, D.G. Cacuci. A qualitative computational study of mass transfer in upward bubble train flow through square and rectangular mini-channels. Chemical Engineering Science 64 (2009) 1416; S. Kececi, M. Wörner, A. Onea, H.S. Soyhan. Recirculation Time and Liquid Slug Mass Transfer in Co-current Upward and Downward Taylor Flow. Catalysis Today 147S (2009) S125; Ö. Keskin, M. Wörner, H.S. Soyhan, T. Bauer, O. Deutschmann, R. Lange. Viscous co-current downward Taylor flow in a square mini-channel. AIChE Journal 56 (2010) 1693; M. Wörner. Numerical Modeling of Multiphase Flows in Microfluidics and Micro Process Engineering: A Review of Methods and Applications. Microfluidics and Nanofluidics 12 (2012) 841