Gas depletion through single gas bubble growth and its effect on subsequently growing bubbles

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We study the evolution of the gas-depleted area which develops around a specific site where bubbles nucleate and grow. In weakly supersaturated mixtures, bubbles are known to grow quasi-statically as diffusion-driven mass transfer governs the process, i.e. the growing time is of the order of ten minutes. In the last stage of the evolution, before detachment, there is an enhancement of mass transfer, which changes from diffusion to natural convection [O.R. Enríquez, C. Sun, D. Lohse, A. Prosperetti and D. van der Meer, The quasistatic growth of CO2 bubbles, Journal of Fluid Mechanics 741, R1 (2014)].

Once the bubble detaches, it leaves behind a gas-depleted area. The diffusive mass transfer towards the depleted area cannot compensate the amount of gas which is taken away by the bubble at the last stages in which natural convection governs its evolution. Consequently, the consecutive bubble will grow in an environment which contains less gas than for the previous one. This fact reduces the local supersaturation of the mixture around the nucleation site, leading to a reduced bubble growth rate.

Our experimental results support this hypothesis. There is an evident change in bubble evolution, since the expected behavior for diffusion-driven processes follows the square root of time, while due to the depletion this is not any more the case. We finally succeeded to theoretically model this depletion effect on the bubble growth rate.

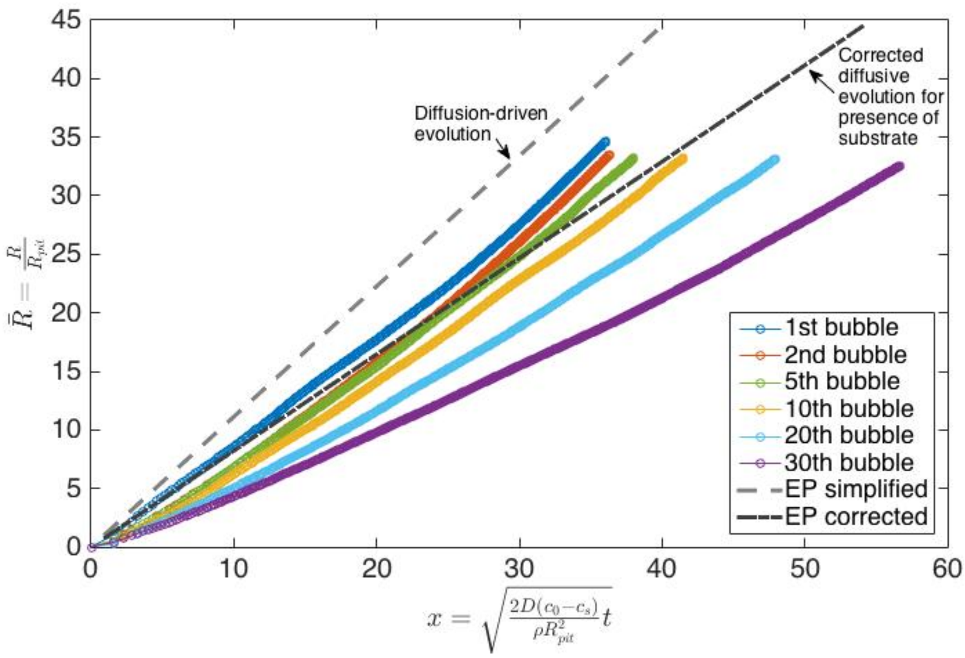

Figure 1. Non-dimensional bubble radius vs. non-dimensional time. The representation of Epstein-Plesset solution and the correction due to the presence of the substrate shows the evolution for a diffusion-driven process until reaching the theoretical detachment radius given by Fritz

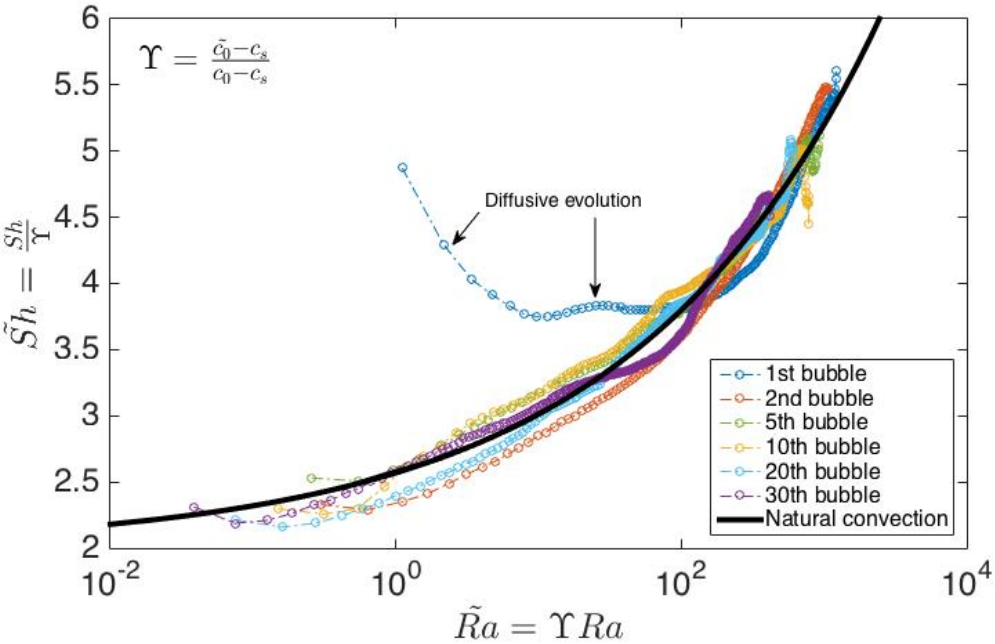

Figure 2. The rescaled Sherwood number (dimensionless mass transfer) vs. rescaled Rayleigh number (dimensionless density difference) shows an universal dependence. The rescaling factor can be derived from the ratio of effective concentration differences.