Bubble dynamics and heat transfer on biphilic surfaces

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Abstract

Wettability is known to play a major role in bubble dynamics and subsequently in pool boiling heat transfer. In recent studies, several authors argue for the use of biphilic surfaces (hydrophilic surfaces with superhydrophobic spots) to maximize pool boiling heat transfer, although they were not yet able to fully describe the fluid dynamic and heat transfer processes occurring under these extreme wetting conditions. In line with this, recent works recommend deepening the study of the fundamental fluid dynamics and heat transfer processes occurring during the growth and detachment of a single bubble.

In this context, the present work focuses on the numerical and experimental description of single bubble dynamics and heat transfer on biphilic surfaces. Averaged values are used together with a specific analysis of the heat fluxes exchanged with the surface during bubble formation and detachment, to evaluate the relative importance of various heat flux contributions, based on a mechanistic approach. The heat fluxes are evaluated based on extensive post-processing of images taken with a high-speed thermographic camera. Then, a detailed analysis of the temporal evolution of the bubble growth, obtained by high-speed imaging is performed together with the heat flux and temperature fields evaluated at different instants during bubble growth. This experimental characterization based on the evaluation of the temporal evolution of several quantities (e.g. bubble size, dynamic contact angles, bubble shape, contact line velocity) is compared with the results obtained from a numerical model. An enhanced volume of fluid (VOF) model was specifically prepared within the platform OpenFOAM 2.2.1 to describe bubble growth and detachment process under these specific boundary conditions (e.g. extreme wetting conditions). The proposed enhancements include a special treatment for dampening spurious velocities at the interface, the addition of the energy equation and coupling with a phase-change model for boiling and/or condensation.