

## DIFFUSE INTERFACE METHOD FOR DIRECT NUMERICAL SIMULATION OF NUCLEATE BOILING

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Boiling is an efficient mechanism for heat transfer in several industrial applications due to its excellent heat transfer coefficient. These systems are difficult to describe accurately, due to the complex coupling of the hydrodynamics, heat transfer, mass transfer and non-equilibrium phase-change thermodynamics. Recent development of high performance computating with parallelised numerical simulations enables a detailed study of nucleate boiling phenomena.

We are developing a direct numerical simulation framework using our in-house TPLS solver [1] using the diffuse interface method [2] which solves the Cahn-Hilliard equation to describe evolution of the liquid-vapour interface. This method removes the stress singularity at three-phase contact line, thereby allowing imposition of a contact angle boundary condition to prescribe surface wettability [3]. This approach is important in order to understand the role of surface wettability on nucleate boiling heat transfer coefficient, bubble growth and departure.

The growth rates and departure of nucleating single bubbles as a function of substrate wettability have been obtained through simulations. The modelling framework has also been extended to simulate multiple bubbles to analyse the bubble interaction, the superheat and bubble size for different wettabilities, as shown in Fig. 1.

Our analysis shows the importance of surface tension on the departure conditions, suggesting a better heat removal in high wettability cases. Conversely, we have found a limited growth rate in low wettability surfaces, which might promote the growth of subsequently forming bubbles.

In order to account for the thermodynamics and hydrodynamics of the liquid microlayer formed beneath a growing vapour bubble, we are currently developing an improved hybrid-pseudopotential lattice Boltzmann method applied to a nucleate boiling system [4,5].

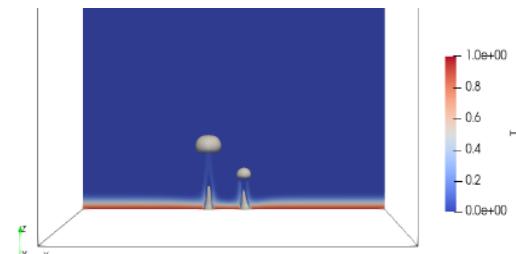


Figure 1. 2D section of temperature profile in a two-bubble simulation.

## REFERENCES

[1] TPLS, <https://sourceforge.net/projects/tpls/>.

- [2] P. J. Saenz, K. Sefiane, J. Kim, O. K. Matar, and P. Valluri, Evaporation of sessile drops: a three-dimensional approach, *J. Fluid Mech.* Vol. **772**, pp. 705-739, 2015.
- [3] H. Ding and P. D.M. Spelt, Wetting condition in diffuse interface simulations of contact line motion. *Phys. Rev. E* Vol. **75**, 046708, 2007.
- [4] Timm Krüger et al. *The Lattice Boltzmann Method*, Springer International Publishing, 2016.
- [5] Q Li, Y Yu, and Z. X Wen. How does boiling occur in lattice Boltzmann simulations? *Phys. Fluids* Vol. **32**, 093306, 2020.