New approaches to understanding the mechanism of nucleate boiling: Insights into an old problem.

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Nucleate boiling of a liquid on a heated solid surface exhibits distinct features such as a sharp rise in heat absorbed from the heater when vapor bubble nucleate and a later transition from individual vapor bubble to jets and columns of vapor departing the surface. This talk seeks to understand these phenomena by examining a vapor bubble in a liquid layer on the surface of a thin solid of much higher thermal conductivity than the liquid heated from below as a model system for nucleate boiling. A quasisteady continuum heat conduction-only model that treats the apparent three-phase contact line (CL) macroscopically shows that the CL is a major heat sink, in agreement with experiment and with more complex theories of liquid microlayers near the CL. This can explain the jump in heat flux upon nucleation. Quasisteady bubble growth under various models for CL motion yield heat flux scaling with system parameters in very good agreement with historic correlations. For the constant heater temperature, the bubble volume scales $\sim t^{3/2}$ for small bubbles, and a simple analytic model explains this scaling. Slowly growing larger bubbles grow at a lower power of t. For suitable detachment criteria, we examine bubble and residue volumes as functions of parameters and speculate as to its relevance of the transition from single bubble to jets and columns sub-regimes.

To improve on ad hoc CL motion models, we perform molecular dynamics (MD) on a nanoscale version of the three-phase system and find a P-T phase diagram that delineates the boundary between nucleate and film boiling. Under a uniform body force we follow as a vapor bubble nucleates on the solid surface and attempt to grow, deform and detach from it. Finally, a lattice-Boltzman study allows CL motion to be a calculated output. It considers both liquid and vapor as a single fluid of non-uniform density, and the dynamic location of the sharp density gradient represents liquid–vapor interface motion. We examine bubble growth and detachment, velocity and temperature profiles and CL motion first on a solid of zero thickness, and then on a finite thickness solid. We are currently looking at possible convective quenching of residue vapor bubbles after bubble detachment and its potential relevance to the single bubble/jets and columns transition.