Wetting dynamics with evaporation and condensation

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我々は dynamic van der Waal 理論[1]を用いて、蒸発と液化を伴う流体の濡れをシミュレーションによって調べた。その結果、気・液・固の接触線付近では特に蒸発・液化が激しくなっていることがわかった。また、床との長距離相互作用として van der Waals 力を考慮に入れたときの液滴の濡れ方についても調べた。

Wetting dynamics has not yet been well understood for volatile droplets or in the presence of evaporation and condensation. We present its theoretical study in the scheme of the dynamic van der Waals theory recently presented [1]. For a one-component fluid, Figure 1 shows the velocity field around a liquid droplet in its vapor spreading over a substrate in the complete wetting condition. The geometry is axisymmetric in 3D, with the vertical axis being at the droplet center. In the simulation, the initial temperature was at $T=0.875T_c$ throughout the system and the wall temperature was held fixed. As a remarkable feature, we can see growth of a thin precursor film ahead of the droplet [2]. It grows due to condensation at the edge of the precursor film. In the figure, we display also the heat flux on the wall, which is here negative because of the latent heat absorbed by the wall. On the other hand, when the wall is slightly heated, evaporation of a liquid droplet takes place most strongly at the contact line with a larger apparent contact angle. If the wall is strongly heated, a liquid droplet is eventually detached from the wall with a thin gas layer created between the droplet and the wall.

In these examples we notice relevance of convective velocity carrying latent heat. Generally, in one-component fluids, the temperature on the interface between gas and liquid is nearly on the coexisting curve $T=T_{cx}(p)$ at a given pressure p even under heat flow. However, this is not the case on the edge line of the advancing precursor film for the condensing case and on the receding contact line for the evaporating case. This means that the Marangoni effect is not operative away from the liquid-gas-solid contact and the hydrodynamics is very singular. In binary mixtures, on the other hand, the flow pattern is drastically influenced by the surface tension gradient even at extremely small impurity concentration.

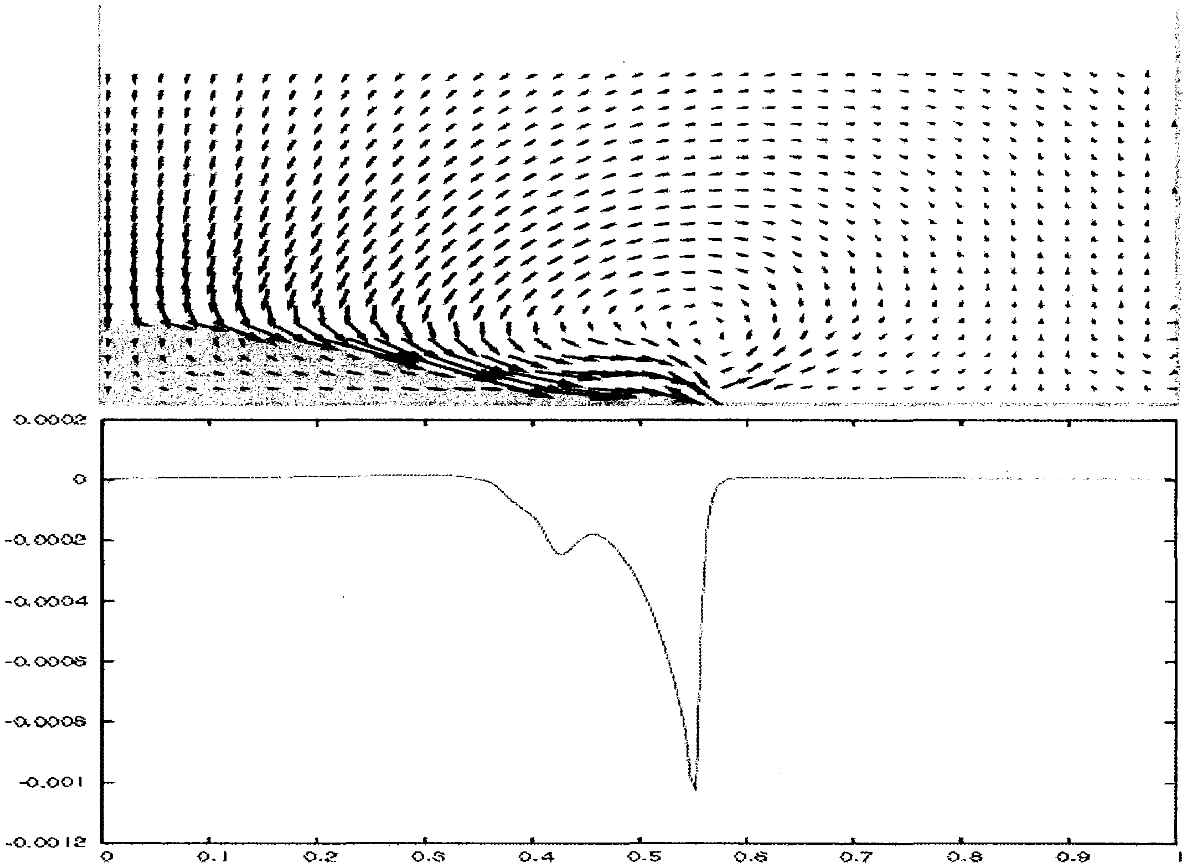

Fig.1 Spreading liquid droplet with a precursor film in the complete wetting. Shown are velocity (upper plate) and heat flux on the wall (lower plate) when the precursor film is advancing ahead of the droplet. The latent heat released at the film edge is absorbed to the wall.

[1]A. Onuki, Phys. Rev. E 75, 036304 (2007).
[2]P.G. de Gennes, Rev. Mod. Phys. 57, 827 (1985).