The Lift Force from Vapor Layer under a Droplet in Leidenfrost Effect

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Introduction

When a water droplet drops on a hot surface, if the surface is hot enough, the droplet will levitate on the surface. To study the mechanics of the gap between droplets and surface, we give a model based on thermal dynamics to describe this phenomenon. In this work, we measure the thickness of droplets and gaps varying by temperature. And we use our model to predict the thickness of water and gaps.

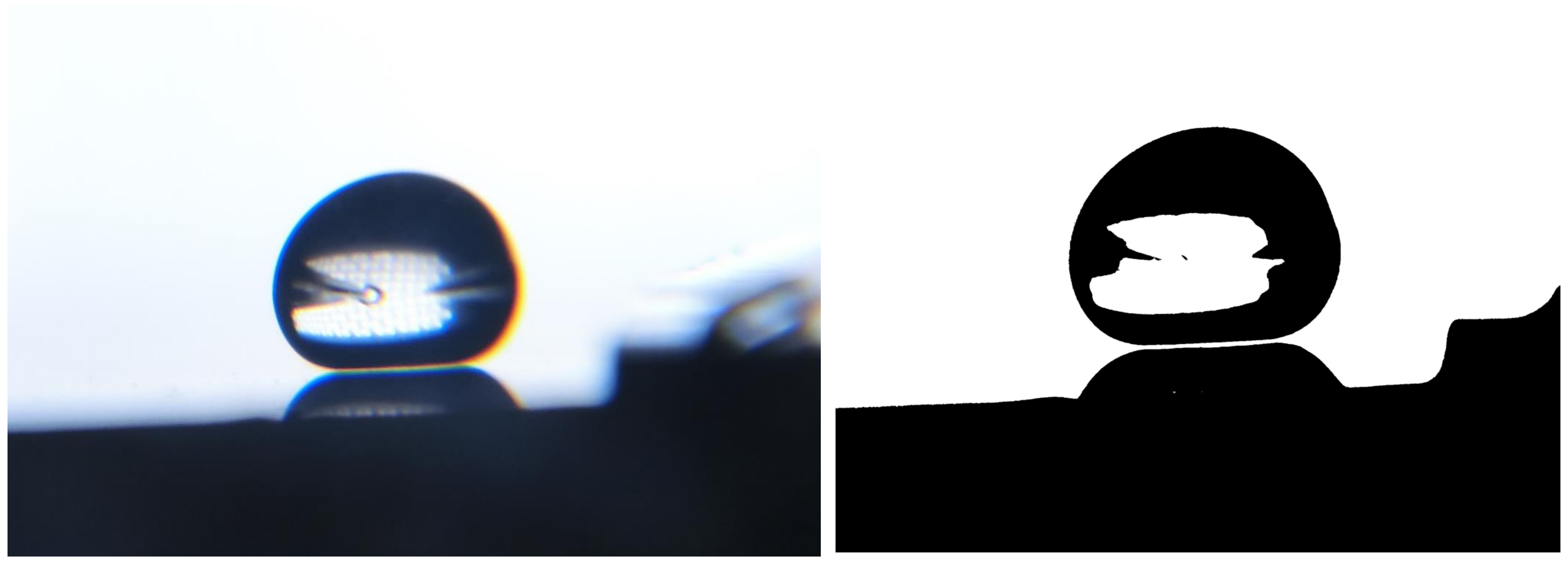

Figure 1. The droplets levitates on the surface. The right picture is the image with high contrast

Experimental Set Up

There is a heater sandwiched by two aluminum plates used to heat the surface. The temperature of surface of aluminum plate is controlled by a LabView program. To limit the motion area of droplets, we put two aluminum sheets on the center of plates. And to control the volume of droplets, we also use pipette to release our droplet.

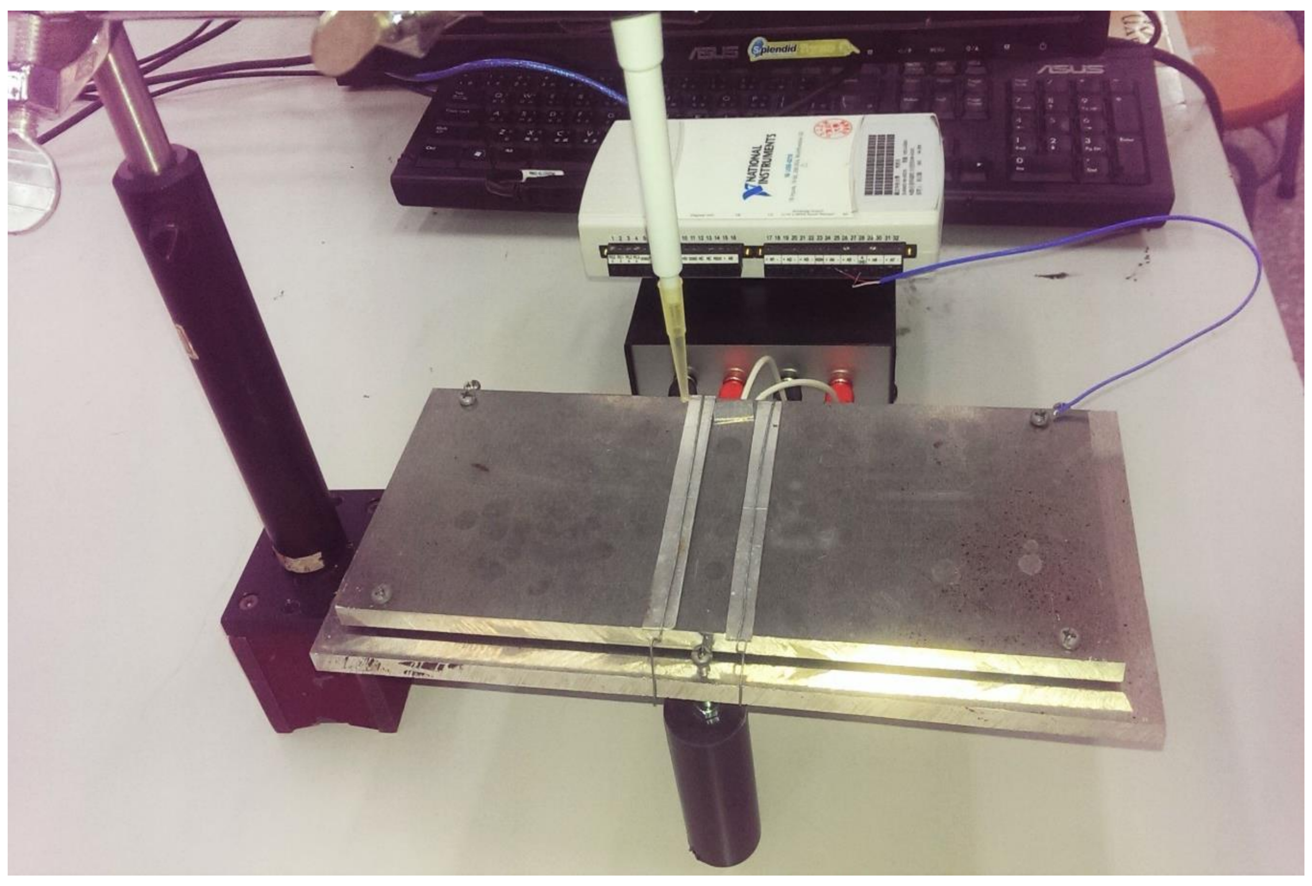

Figure 2.: Picture of experimental setup. Two aluminum plates with a heater between them.

Model

We assume the thermal transition in an unit area between aluminum plates and droplet should be constant at same temperature. Considering the collision of water molecules in the vapor form in an unit area of the gap between the droplet and metal surface, the lift force provided by water vapor can be written as:

$$\frac{F_v}{A}\uparrow=\frac{6k_bTN}{lA}=\frac{m_wg}{A}$$

By checking the number of N from our first few experiments, we can expect the thickness of the gap between metal surface and droplets in other experiments:

$$l=\frac{6k_bNT}{S_wHg}$$

l: the thickness of gap
T: temperature of surface, m_w: mass of droplet,
N: number of vapor molecules in the gap.
H: thickness of droplet. S_w: density of water.

Results

We found the thickness of droplet and gap have a reverse relation, and we compare the experiment result and theory. Figure 3 shows that the experimental data is in a good agreement with the predict trend, and the maximum deviation is less than 30%.

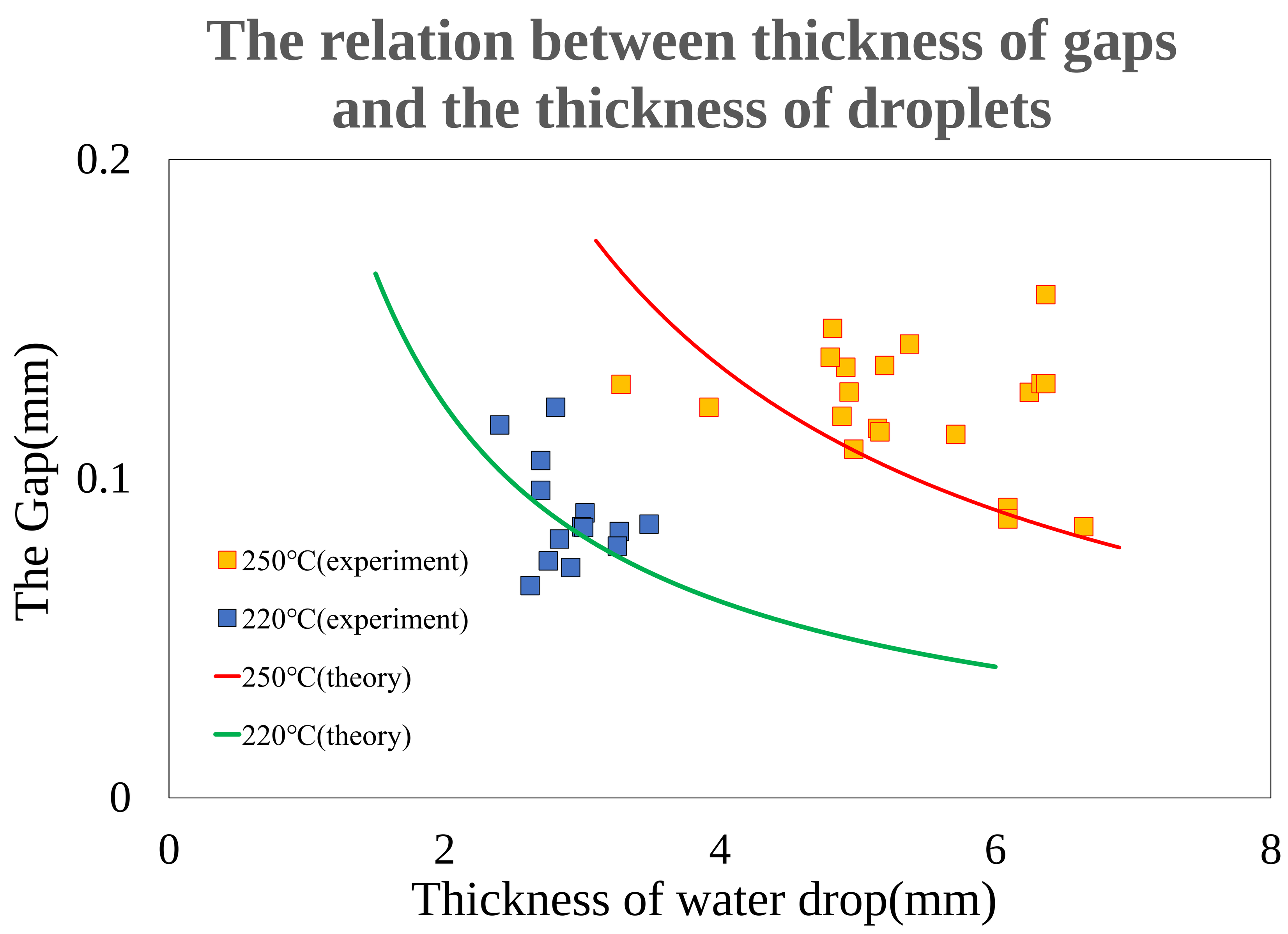

Figure 3 : The relation between thickness of gaps(l) and thickness of droplets(H)

Discussion

For a droplet, we find that the thickness of droplet decreases from the center, but the gaps beyond the droplet are the same. We thought it is because the cohesion of water molecules. That is to say, because we only consider the situation of the center of gap and neglect the cohesion, there is a discrepancy between experimental measurement and model predition.

Conclusion

Our model can predict the thickness of gaps if we know the thickness of water, but it is with about 30% deviation. The discrepancy may come from the effect of cohesion of water.

Reference

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