VISUALIZATION OF DROPLET BOILING ON THE HEATING TRANSPARENT SOLID SURFACE WITH DIFFERENT THERMAL PROPERTY

Shigeaki INADA

Dept. of Mechanical System Engineering, Gunma University,
1-5-1, Tenjincho, Kiryu 376-8515, Japan

The purpose of this research is to clarify the miniaturization boiling phenomenon, which intensely scatters with large number of minute liquid particles from the droplet surface to the atmosphere, when the droplet collides with a solid heating surface. Specifically, this behavior was photographed from the underside of the heating surface, with attention to the liquid-solid contact, which is generated after the collapse of the thin vapor film located between the heating surface and the droplet. As a transparent solid surface with different thermal property, sapphire, glass with ITO coating, quartz and quartz with chromium coating were used in this study.

EXPERIMENTAL APPARATUS

The schematics of the experimental apparatus is shown in Fig.1. Three types of heating surface were used: 1.artificial and white sapphires of 30mm diameter and 15mm thickness 2. ITO (Indium Tin Oxide) conductive film plane of the 0.15μm thickness sputtered on glass plate surfaces of 1.8mm thickness, and 3. a chromium coating plane of 0.15μm thickness sputtered on a quartz cylindrical of 40mm length and 50mm diameter. These heating blocks were inserted into the center of the heating cylindrical copper block, in which cartridge-type heaters are built in, at equal intervals in the direction of the circumference, so that the block could be uniformly heated from its periphery by conduction. The ITO-heating surface was heated by putting on the heating quartz cylinder. The upper surface of the heating block was maintained horizontally, onto which droplets were vertically dropped in the center. Degassed and distilled water droplets at a temperature of 16°C and 3.5 mm in diameter were dropped from a height of 65 mm. In this research, the Weber number of impingement was We=61, and the free vibration period τ_r was about 19 ms. The temperature of heating surface was measured by attaching the thermocouple with ceramic adhesive at two points on the surface. The behavior of droplets impinging on the heating surface was shot in real time with a high-speed video camera, from the underside of the heating block.

RESULTS

Figure 2 indicates the lifetime of vaporizing droplets in relation to the initial surface temperature of heating block (T_{w0}). The measurement of the lifetime was carried out in two methods using a stopwatch and the high-speed camera. In quartz plane with the small thermo-physical property, the period with the short lifetime expands to the high temperature region, and the maximum evaporation rate point has not appeared clearly. The broken line in Fig. 2 indicates the liquid-solid contact time (τ_t) at the nucleate boiling range, which calculated by Makino and Michiyoshi [1] in consideration of the thermal property of metals, diameter of droplet and heating surface temperature. We adopted this contact time as the lifetime (τ_e) in this research to apply to the diameter of droplet and surface temperature of quartz. Evaporation lifetime property of the nuclear boiling (boiling in the condition wherein the heating surface and the liquid film sufficiently contact each other) in ITO film plane and chromium coating plane is similar to the data in the quartz plane. As is evident from this figure, sapphire plane with the 4.9 times the thermal property value of the quartz closes in the lifetime curve in metal surface, and the heating surface temperature range shifts to the low temperature region. The solid line in Fig. 2 was applied to the sapphire plane by the same method as the dashed line.

Figure 3 shows the boiling behavior of the droplet on the ITO plane where the surface temperature is 202°C. Number shown under each photograph is the elapsed time after the drop impingement. The drop expands keeping the round shape after impingement, and it has reached the largest diameter at 12ms. A liquid film shows the crater shape that the circumference raises, while the drop expands in this interval. The large number of white spots, which are considered to be the generation of the minute vapor bubble in the liquid film, are observed.

Figures 4 shows the boiling behavior of the droplet on the sapphire plane where the surface temperature is 380.9°C. The picture of the left side at each elapsed time in Fig. 4 was photographed from the horizontal direction, and the right side from the underside. The part of the white ring is clearly projected in the top and right picture at 1ms after the drop impingement because the upper part lighting light was converged, and it was emitted to the visual field of the camera. The reason seems to be the lens effect with the result that a droplet projects the meniscus-like shape in the bottom. The pictures from the underside suggest that the droplet expands in the round shape, and the generation of comparatively big vapor bubble, which is observed in nucleate boiling, is not recognized. (However, such a big vapor bubble was recognized in case of the heating surface temperature of 320°C or less.) It seems to be a boiling phase in which a thin vapor film is formed and the droplet exists on the film. Judging by the photograph taken from the horizontal direction at 4ms, the minute liquid particles are rapidly scattering from the surface of a liquid film. According to this photograph from the underside, the some changes, which bring about the dispersion of these minute liquid particles, should have occurred.

Figure 5 shows the boiling behavior of the droplet on the chromium coating plane where the surface temperature is 531.7°C. In the case of 450°C or less, the nucleate boiling accompanied by a comparatively big vapor bubble is observed, and the droplet is divided and the divided droplets scatter. However, the boiling aspect changes, when the heating surface temperature exceeds 450°C. Part of the divided droplets keep the contact with the heating surface through the thin vapor film. The explosive dispersion of the minute liquid particle is generated in the moment of the collapse of the vapor film. Figure 5 shows the phenomenon at that instance, with one occuring between 26ms and 28ms, and the other generated between 122ms and 124ms. In the photograph from the horizontal direction, the radial explosive dispersion is projected. On the other hand, in the photograph from the underside, the picture is whitely projected because of the incidence of the irregular reflection light strengthened by the dispersion of the minute liquid particle.

CONCLUSION

The dispersion of the minute liquid particles originates from the generation of micro bubbles, which occur in the direct liquid-solid contact and the associated collapse of the thin vapor film between them.

REFERENCES

1. Makino, K. and Michiyoshi, I., The Behavior of a Water Droplet on Heated Surfaces, *Int. J. Heat and Mass Transfer*, Vol. 27, pp.781-791, 1984.

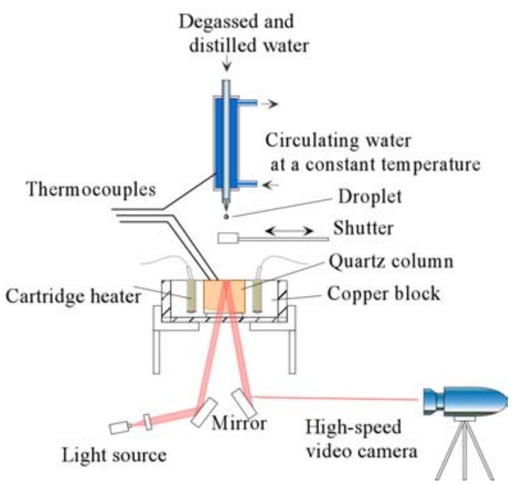


Fig. 1 Experimental apparatus

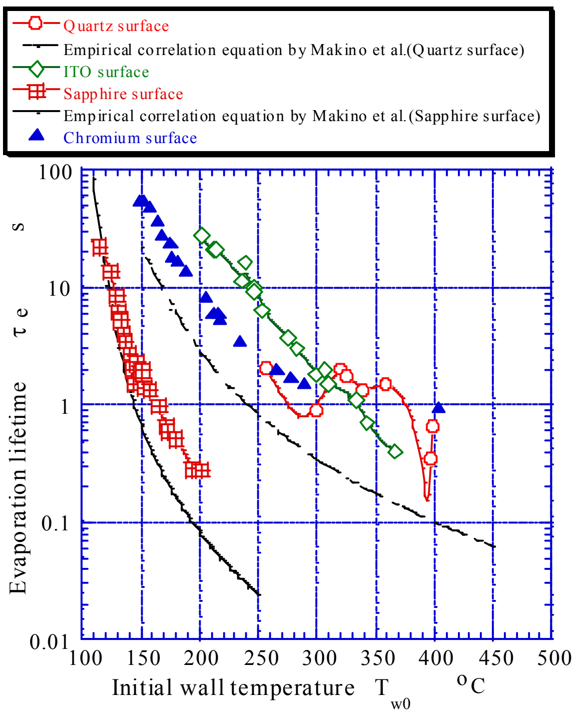
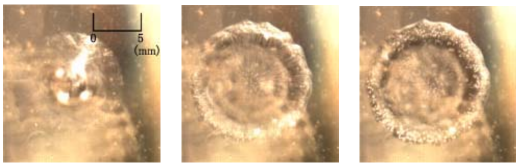
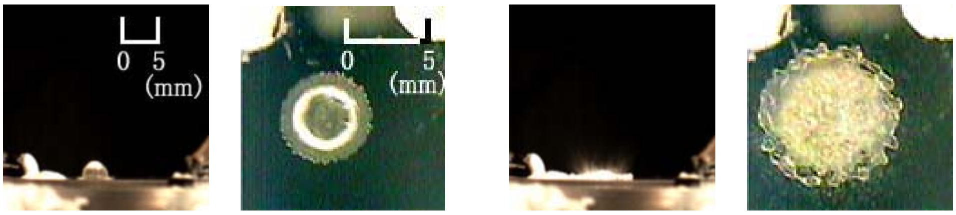


Fig. 2 Evaporation lifetime curve



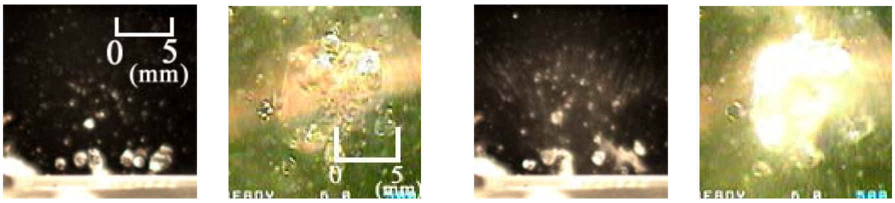
4ms 8ms 12ms

Fig. 3 Boiling behavior of a droplet impinging on the ITO surface (T_{w0}=202°C)

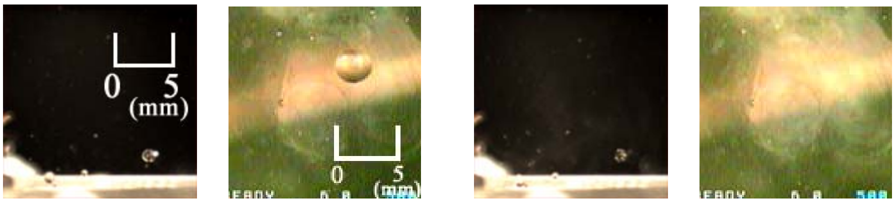


1ms 4ms

Fig. 4 Boiling behavior of a droplet impinging on the sapphire surface (T_{w0}=380.9°C)



26ms 28ms



122ms 124ms

Fig. 5 Boiling behavior of a droplet impinging on the Chromium surface (T_{w0}=531.7°C)