Team project 2

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Boiling is normal phenomenon in daily life. Bubbles are the companions of boiling which indicate the occurrence of the strongest heat transfer—phase change heat transfer. The bubble cycle of generation, growth and departure contains rich heat transfer mechanisms. The video presented here records a complete bubble cycle. The heat transfer during the cycle will be discussed in this report.

A schematic of the image shooting system is shown in figure 1. A 95W red light-emitting-

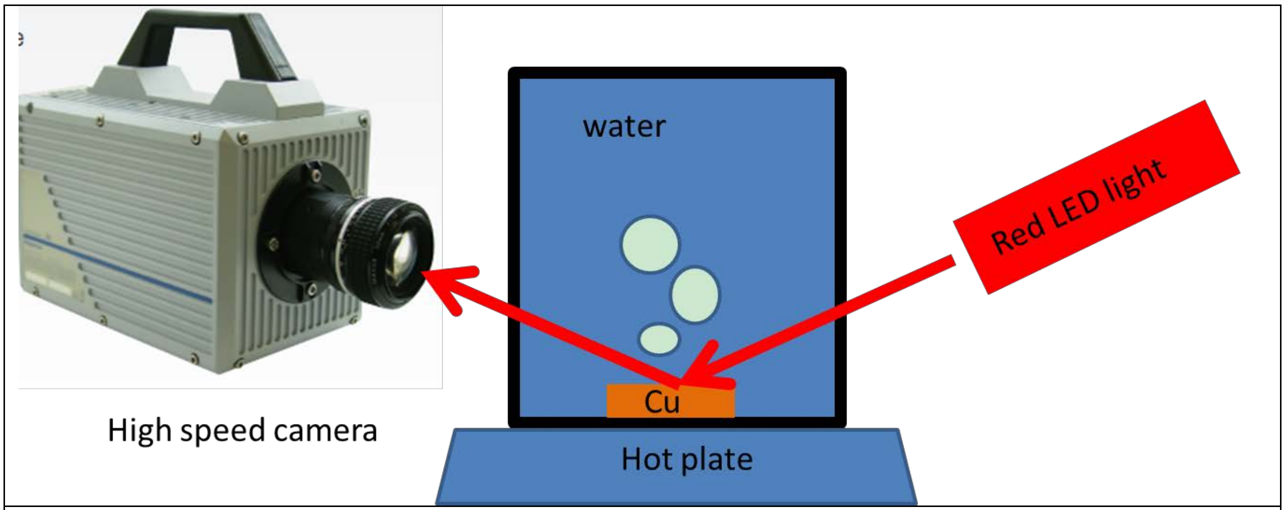

Fig. 1 schematic of the flow visualization apparatus and placement of the image

diode (LED) was selected as the illumination source. A Photron SA4 monochrome high speed camera was used to capture the fast bubble cycling. The bubbles were generated from a copper which was immersed into a Pyrex beaker. Hot plate was used as the heat source to heat up the copper as well as water. The copper was pre-polished by 2000 grit sandpaper and was pretty smooth. So the light had to be shined from the opposite position of the camera to deliver a mirror reflection. The speed of the camera was selected to be 500fps, which was enough to capture the bubble cycling as well as sufficient light to trigger the sensor in the camera. When the water is heated bubbles will form and grow in the water, which is the so called homogeneous boiling. However, the superheat, which is the temperature difference between the water temperature and the saturated water temperature under 1atm, is too high. So a copper piece was used in my image shooting process. The bubbles were generated from the heated surface, which is called heterogeneous boiling. Due to the cavities and the pre-existing gas/vapor in the cavities the superheat is greatly reduced[1,2]. The criterion for bubbles to first form is $\Delta T = \frac{4\sigma T_{sat}}{\rho_v h_{fg} D_c} K_{max}$, where ΔT is the superheat at the surface, σ is the surface tension of water, ρ_v is the density of water vapor, T_{sat} is the saturated temperature of water under 1atm, h_{fg} is the latent heat of water, and D_c is the cavity mouth diameter at the bubble generation spot. K_{max} is related to the contact angle of the surface. Since the pre-measured contact angle on this piece of copper is about 89.5°, K_{max} equals to 1[3]. The departure diameter of the bubble in the video is about 2mm (the field of view in this video is 1cm×1cm). Since the bubble departure diameter is usually twice the size of the diameter of the cavity mouth, D_c in this image is estimated to be 1mm[4]. So the superheat for this bubble is about 19.7°C. Considering the temperature of the hot plate was 150°C and the thermal conductivity of the Pyrex glass is low, this superheat is reasonable. Another thing worth noting is that the stem below the bubble which was in contact with the heating surface. It is quite clear that the wall of the stem has an about 90° angle with the copper surface. One of the most important heat transfer mechanisms in bubble generation is the macro-layer heat transfer, which is closely related to the contact angle. The macro-layer is a superheated liquid layer above the heating surface and below the bubble. The video of bubble cycle here somewhat support the macro-layer/contact angle relation[5].

The different reflection and refraction of water and water vapor in the system clearly depicted the outline of the bubble. The smooth copper in the system worked as a mirror to guide the light into the high speed camera. Due to the extremely short exposure time and fast shutter speed, the light intensity needed to be very high. That is another reason why the light couldn't be shined from the top of the Pyrex beaker. And the light intensity was also the limiting factor for higher speed.

The size of the field of view is about 1cm×1cm. Since the lens used here is a macro lens, the field of view is limited. The distance from the object to the lens is about 20cm. The focal length of the lens is about 7cm. The camera is the product of Photron corporate. The model is SA4. The resolution is 1024x1024 pixels. The shooting speed is 500fps. The aperture and the ISO were adjusted by the camera automatically. Movie maker in windows 7 was used to compose the video. 50 images were selected and the playback speed is 2fps.

The video clearly presents a complete bubble cycle and the flow/heat transfer during this process. I like the nice and clean view of that bubble. However, the speed is still too slow to capture the detail when bubble departure occurred.

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