# Team project 3

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Condensation is the phenomenon that vapor gives out heat and returns to liquid state. It is also quite common in daily life. The indicator of condensation is the formation of liquid droplet on the cooling surface. The coalescence of the droplets forms a large enough droplet to depart from the surface and result in high heat transfer efficiency. The video of the work presents the coalescence of droplets and the movement of the large droplet.

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

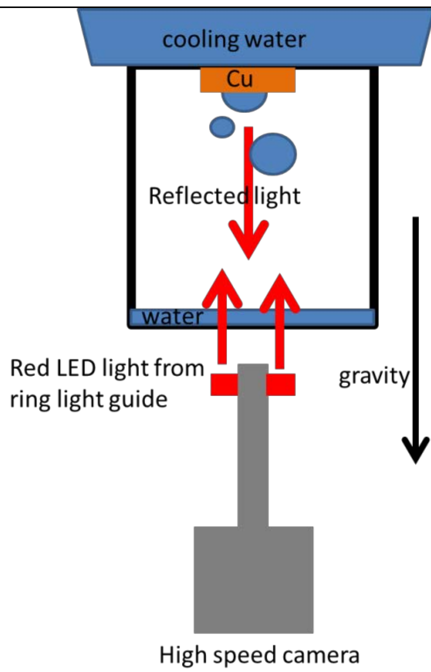


Fig. 1 schematic of the flow visualization apparatus and placement of the image

diode (LED) was selected as the illumination source. A ring light guide was used to distribute light uniformly on to the surface. A Photron SA4 monochrome high speed camera was used to capture the fast droplet movement. The droplets formed on copper which was mounted in a stainless steel chamber. Cold water was supplied to flow over the back of the copper to cool the vapor. The copper was pre-polished by 2000 grit sandpaper and was pretty smooth. The speed of the camera was selected to be 500fps. Vapor was generated by heating the DI water in the chamber. Vapor condensed on the cool copper surface and returned to liquid phase. More and more condensed water accumulated together at the droplet nucleate site which is usually at the scale of tens of nanometers[1]. The droplet nucleate site absorbs more water and grows. When the weight of the droplet exceeds the attaching force the droplet falls off the copper surface. The attaching force comes from the surface tension at the liquid/solid interface. According to our measurement of the contact angle on this copper surface before mounting it into the chamber, the contact angle is 89.5°. The forces that act on the droplet are gravity ($mg=g\times\rho\times2/3\pi R^3$) and surface tension ($f=\sigma\times2\pi R\cos\theta$). During the growing stage of the droplet, surface tension is larger than the weight. When a critical radius is reached, the surface tension equals to the weight and then the droplet falls off the surface. So the critical radius is $R=(3\sigma/\rho g)^{1/2}$=4.24mm. The largest droplet in our video has a diameter of 4mm which is far away from the critical radius. There was no falling off during our video. Another interesting phenomenon worth noting is the coalescence of the droplets. The nucleate sites on the surface are distributed randomly. The consequence is that droplets could meet each other during the growing process before falling off. This is very clear in the video. However, the strong vibrating after the coalescence is more attractive. This is probably the result of the momentum change during the coalescence. The gravitational force act on the two droplets is perpendicular to the vibrating direction. So it didn’t contribute to the momentum change. By a close check of the coalescence process we could see that there was a short stem first appeared between two droplets before the coalescence. It indicates that the viscous force, which is the capillary force that results from the surface tension affects the momentum change. The larger droplet has a larger surface tension than that of the smaller droplet. So the net force on the combined droplet was on the larger droplet side and resulted in a momentum pointing to the larger droplet side. Then the surface tension became the dragging force to calm down the combined droplet and finally the droplet stabilized and stayed still[2].

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 10cm. 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. 13 out of 100000 images were selected and the playback speed is 1fps.

The video clearly presents the droplets' coalescence and the droplets movement during this process. I like the strong vibration and the little stem in between. However, the speed is still too slow to capture the detail and the focus needs to be further carefully adjusted.

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[1] V.P.Carey, Liquid-Vapor Phase-Change Phenomena 2nd edition, Taylor & Francis Group LLC, New York, 2008
[2] Dirk G.A.L.Aarts, *et al.*, "Hydrodynamics of Droplet Coalescence", Physical Review Letters, Vol 95, pp. 164503(1)-164503(4)