3P1-8

Observation of droplet landing on substrate from below

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1. Introduction

Using inkjet droplets with the diameter of about 50 μm, we are developing measurement system for investigation of picoliter liquid dynamics. In the past, we have succeeded in measuring the dynamic surface tension of water containing surfactant in short time region of less than 10ms,[1] and observing wetting and penetrating behavior of liquids on various substrates such as glass or paper.[2] Recently, we managed to directly observe colliding behavior of water and ethanol droplets in air.[3] In that work, we found that it takes ethanol about 30 μs to cover the surface of distilled water due to the difference in surface tension between water and ethanol, which is only 10^{-4} times the time scale of molecular diffusion. In the study, we also observed collisions of distilled water and ethanol on a glass surface, but the result was not as clear as those observed in air, due to poor ejection of dye-added ethanol and difficulty in optical observation as shown in Fig. 1. In this work, we reselected sample liquids that were easy to form droplets and observed its collision with distilled water droplets on a substrate using different way.

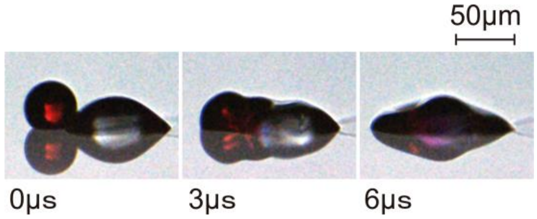

Fig. 1 Dye-doped ethanol droplet on the left colliding on a glass plate with distilled water droplet on the right. In this figure, we can see the mirror images of actual droplets reflected on the glass surface on the lower side of each photo.

2. Selection of sample liquids

In the previous study, we observed the collision of ethanol droplets with distilled water droplets. Since both substances were colorless and transparent, we added rhodamine B to ethanol to distinguish it from distilled water. However, this posed a problem as the dye solidified at the tip of the nozzle, making it difficult to eject the droplets. In the other work,[4] we succeeded to make highly viscous liquids with 1 Pa･s and some liquid foods such as oyster sauce into droplets. It was found that liquid foods without particles were more likely to form droplets. In this work, we used soy sauce as the counter material of water. Most commercially available soy sauces exhibit Newtonian behavior at 2 ~ 10 mPa·s. It is similar in properties to ethanol with added coloring in that it is easily soluble in water and soy sauce can be easily distinguished from water due to the coloring caused by the Maillard reaction. In addition, most Newtonian soy sauces contain ethanol to maintain their quality, and have lower surface tensions than distilled water. Figure 2 shows soy sauce ejected as droplets by our device. The viscosity of this soy sauce is about 7 mPa･s measured by EMS viscometer and the tail extending behind the main droplet is slightly longer than water, but there are no satellites and it is neatly formed into droplets. The diameter of the droplets is about 50 μm, and it is difficult to recognize the color of droplets in a microscope image when the color of the liquid is weak. However, as shown in Fig. 2, the color of this soy sauce is clearly recognizable, and it is possible to distinguish it from distilled water. Figure 3 shows photos of the collision of a water droplet and a soy sauce droplet in midair. The liquids are clearly distinguishable, and the interface between the water and soy sauce is clearly visible. Although soy sauce mixes well with water on a macroscale, it shows that no mixing or molecular diffusion is occurring at this size and time scale.

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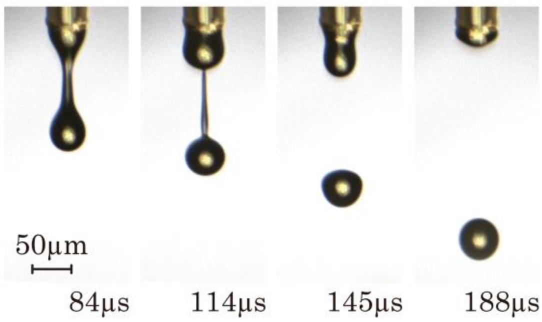

Fig. 2 Photos of generating a droplet of Yamami Brewery's Tamari Soy Sauce. The nozzle is φ50 μm.

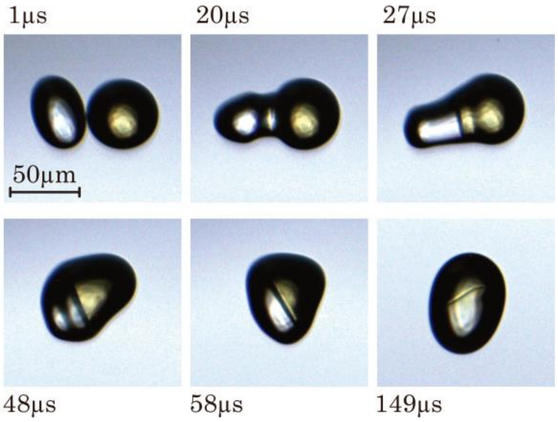

Fig. 3 Collision of a distilled water droplet from the left and a soy sauce droplet from the right. Each droplet is ejected from a nozzle with the diameter of 50 μm.

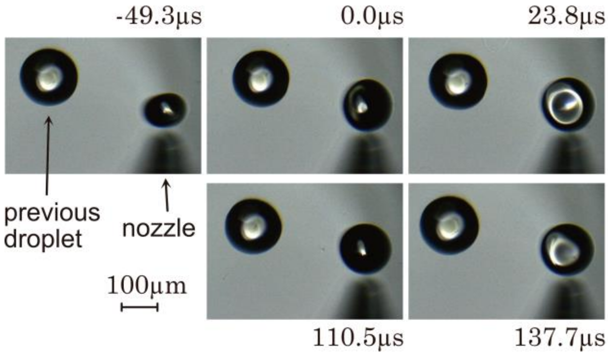

Fig. 5 Photographs of a droplet of distilled water landing on a glass substrate, taken from the back side of the substrate. The nozzle diameter is 50 μm. The time when the drop landed on was set as 0μs.

3. Observation system

In our previous study, we observed water and ethanol droplets colliding on a glass plate from the side of the droplets, as shown in Fig. 1. However, it was not possible to clearly observe the water-ethanol interface as was the case with droplets colliding in air due to the the surface roughness around the interface of water and ethanol. To observe flat cross section of the droplets, we observed the droplets from the back side of the glass substrate in this study. Our observation system is shown in Fig. 4. Strobe light illuminated droplets on a glass plate from above through a mirror. Because every droplet photographed with the strobe method is a new droplet, the plate is rotated so that each droplet always lands on a fresh surface. Figure 5 shows photographs of a water droplet landing on the substrate taken from below the substrate. The time when the droplet lands on the substrate is set as 0μs. The droplet flying in the air before it lands can also be clearly observed while the nozzle is out of focus. While the droplet that landed previously, seen on the left in the photo, shows no change, the brightness of the inside of the droplet that has just landed changes over time. This indicates that the droplet is repeatedly deforming in the direction perpendicular to the substrate. The contact area of the droplet barely changes, indicating that the wetting and spreading of water onto the glass surface is almost complete at the time of landing. In this way, observing the landing droplets from below the substrate makes it possible to investigate the behavior of droplets on the substrate in more detail. Currently, we are using this method to observe the impact and collision and mixing behavior of two droplets of water and soy sauce.

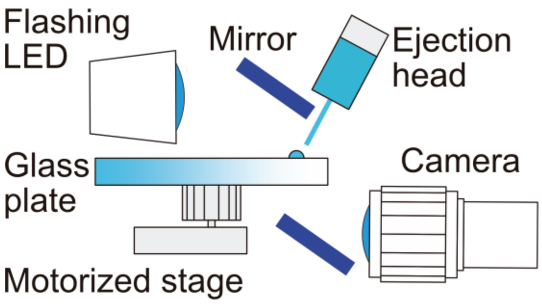

Fig. 4 Schematic view of our droplet observation system in this study using microscopic strobe technology.

References

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