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Optimal Condition for Inkjet Fabrication of Soft-micro Gel Beads

インクジェットゲルビーズの生成条件に関する検討

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1. Introduction

Using inkjet technique, we have developed observation and measurement systems of micro liquid dynamics, in which, for example, the dynamic surface tension can be measured with quite high time resolution under 100 μs. In this technique, spontaneous break up of a liquid jet to homogeneous series of particles are driven by the ultrasonic vibration of the injection nozzle. It brought to us the successful observation of adsorption phenomenon of surfactant molecules to liquid surface [1]. Another application of our inkjet system is time slice view of wetting process of liquid on flat plate. We can observe the droplet shape on substrate with negligible gravity because of small amount of liquid and detect the surface conditions such as hydrophilicity and anisotropy [2]. A work to apply our inkjet system in progress is micro liquid fabrication. Inkjet droplets are uniform in size of ~ 30 μm in diameter typically and their shapes are spherical in traveling midair. The generation rate reaches 20,000 /s. It is expected to establish micro fabrication using inkjet droplets with these remarkable features in various fields such as electronics, medicine or food. We are constructing a system to fabricate soft gel beads of sodium alginate with two separately controlled inkjet nozzles and succeeded in obtaining micro-gel suspensions with interesting rheological property [3]. In this work, we improved our inkjet device to control the temperature of droplets and realized the collision of two droplets in midair with different temperatures for the future purpose of using gel materials with strong dependence on temperature.

2. Fabrication of Gel Beads

Edible materials as ingredients of droplets are good for widely usability of micro gel beads, and we chose sodium alginate solution in this work. This material forms gel with addition of calcium chloride quickly at room temperature and the softness of gel is controllable by the concentration of sodium alginate solution. **Figure 1** is the schematic view of the system for generating micro-gel beads using inkjet technique. Sample liquid is constantly ejected from a glass nozzle by air pressure and divided into small droplets due to frequently oscillation of nozzle by piezo actuators.

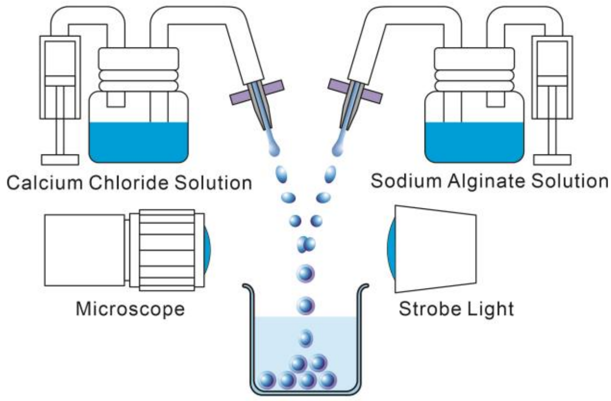

Fig. 1 Schematic view of our system for fabrication of soft-gel beads . Glass nozzle is sandwiched between two piezo actuators vibrating at suitable frequency to generate droplets continuously.

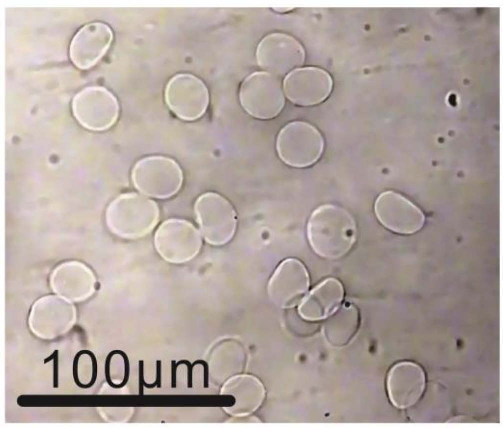

Fig. 2 Microscopic image of gel beads suspension in water. The concentration of sodium alginate was 0.125w% and the tip diameters of nozzles were 15 μm.

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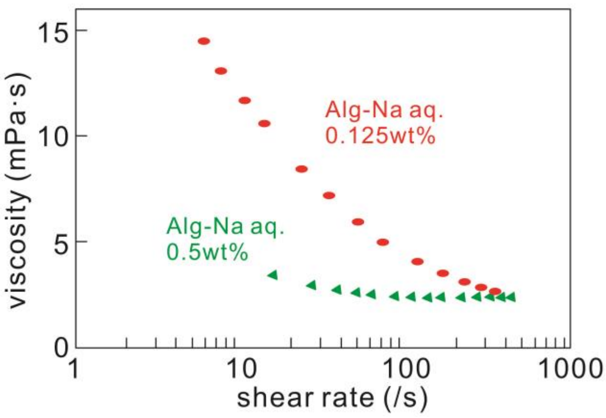

Fig. 3 Viscosity curves of gel beads suspensions. Convexity downward of this curve means that dispersed particles are soft and droplets of 0.125w% are softer than 0.5%.

This is so-called continuous type inkjet system, which is suitable for mass production of droplets. Two kinds of droplets of sodium alginate solution and aqueous solution of calcium chloride and small amount of ethanol are collided in the air with each other and a droplet of sodium alginate is wrapped up in a droplet of calcium chloride due to the difference in surface tension, and then gelation starts from the surface into the inside. **Figure 2** shows a microscopic image of aqueous suspension of micro-gel beads. Gel beads by our method have almost the same size of ~ 30 μm and roughly spherical shape. The reason for not perfectly spherical shape is that beads are soft and squashed at setting under microscope. We measure the rheological curve of this suspension as shown in **Fig.3**, from which we can also realize that our gel beads are soft. This suspension will be useful as mimic bio suspension such as blood.

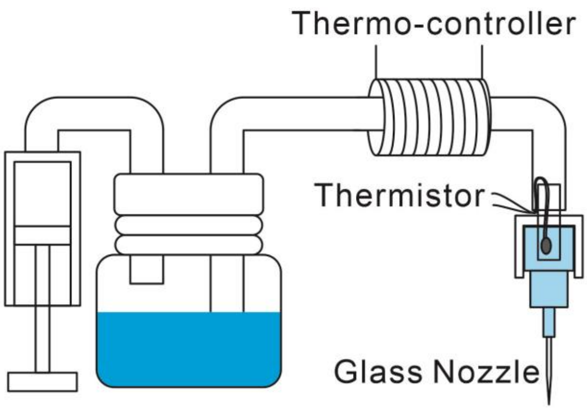

Fig. 4 Temperature measurement and control system. This figure shows one side of droplet collision setup shown in Fig.1. We use small thermistor with the top size of 1.5 mm in diameter.

3. Temperature-control System

It is hard to control and detect the temperature of inkjet droplets because of its small amount and high flight speed. We can manage the temperature of whole of the generation system of droplets relatively easily, but this way cannot make the temperature difference between two colliding droplets and we cannot cool down or heat up the travelling droplet in the air. In this work, we set up temperature control and measurement system at the location behind the nozzle as shown in **Fig.4**. We use a thin glass capillary with fine tip connected to syringe needle as an inkjet nozzle. A small thermistor is set in the connector between the needle and liquid supply tube to measure the temperature of liquid just before injection from the nozzle. Thermo-controller which is constructed with a Peltier cooling/heating system and water circulation system is put around the tube. Typical flow rate of liquid in the tube at this control system is about 10 mm/min, this is sufficient flow to control and detect liquid temperature. The temperature of generated droplet is not directly measured. However, it is almost the same value with controlled because we use droplets within 100 μs from the generation while the cooling time scale by evaporation is about 10 ms. Using a pair of these systems, we can make a temperature difference between two colliding droplets. It may be possible to cool down and gel a droplet in flight by covering a hot droplet with a cold droplet. We are now checking the controllable range of the temperature and exploring the other gelation material to be soft beads and show characteristic behavior like Fig.3.

References

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