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Microassembly Support System with Controlled Liquid Bridge Force

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Abstract

We studied the micromanipulation support system that has been used in recent years. The system consists of a micromanipulation tool that utilizes a liquid bridge force and support system. The liquid bridge force is not affected by the material of the object but by the manipulation of the electrostatic properties. Unlike when a gripper is used for manipulation, a liquid bridge force is unlikely to damage the object. In this study, we improved the operability of the micromanipulation system. To improve the operability of the micromanipulation, we focused on the shape of the microcapillary tip and the pull-up speed. We experimentally investigated the basic characteristics of the new system and found that its operability was better than that of our previous system.

Keywords**: Micromanipulation, Liquid bridge force, Adhesive force**

1. Introduction

Many recently developed products such as pressure sensors and flow sensors contain semiconductors and microparts manufactured with the aid of MEMS (microelectromechanical systems) technology [1]. The number of microparts weighing less than 1 [mg] has grown owing to improved processing technologies that have enabled the production of smaller microparts [2]. Our goal was the development of an environmentally viable operation that enables the simple manipulation of objects, the fabrication of an inexpensive apparatus that does not require skill for its use, and the development of a modifiable environment that allows for the versatile manipulation of objects using the same apparatus [3]. See Fig. 1.

Fig. 1 Micromanipulation support system

2. System Composition

The proposed microassembly support system can be used to observe and operate objects of about 100 [μm]. The positioning accuracy of the object is 0.25 [μm] and the resolution of the XYZ positioning stage is 0.25 [μm]. The XYZ positioning stage comprises three positioning stages. All the three positioning stages are vertically integrated. The microassembly support system is composed of a typical PC, a microscope for observing microparts, a work area, a CMOS camera for capturing the view, an XYZ positioning stage for moving the liquid bridge force handling tool, and a vibration isolation table. This vibration isolation table is tapped at intervals of 25 [mm]. Fig. 2 shows the overall configuration and layout. The experiments were performed using the liquid bridge force work stage of the device [4].

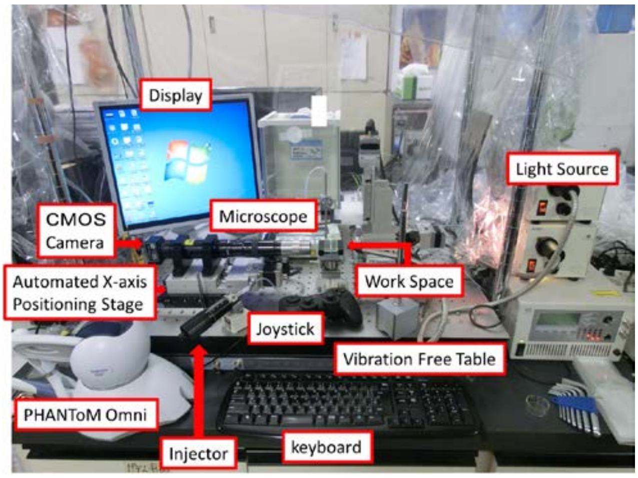

Fig. 2 Description of equipment

3. Handling technology utilizing liquid bridge force

In this study, we used a liquid bridge force to solve the problem of manipulating microparts [5]. A liquid bridge force is generated when a liquid exists between particles and the height of the liquid is less than the heights of the particles. The force pulls the particles toward each other (see Fig. 3.) In our study, we used a liquid bridge force for micromanipulation (see Fig. 4). The liquid used to generate the liquid bridge force was supplied by an air pressure capillary tube. The liquid bridge force was controlled by controlling the microinjected volume of the liquid. This method has some advantages. One is that no physical damage is caused to the object (see Fig. 5). Another is that the shape or material of the object is unimportant. Moreover, it depends on the liquid bridge force and the pulling speed [6].

The capillary pull-up speed and the size of the liquid bridge force are correlated. If the capillary is pulled up with a high speed, the liquid bridge force would decrease. If the pull-up speed is low, the liquid bridge force would increase. To use the capillary as a manipulator, it is important to control the liquid bridge force.

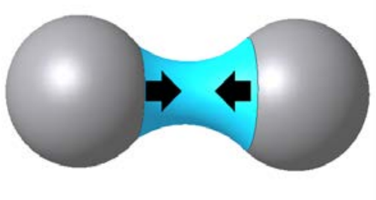

Fig. 3 Liquid bridge force

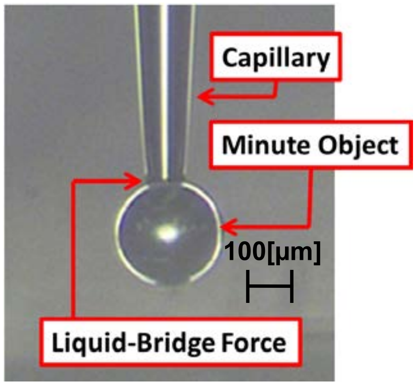

Fig. 4 Manipulation of liquid bridge force

Fig. 5 Pick method

4. Control of amount of discharged liquid

Controlling the liquid bridge force was a major challenge of the study. The discharge of the liquid using an empty pressure injector was regulated by eye measurement. This is one of the causes of failure in micromanipulation. The empty pressure injector (produced by NARISHIGE Companies, Fig. 7) was then changed to an electric injector (produced by MUSASHI Engineering Companies Fig. 6). The empty pressure injector is manually operated. The electric injector can discharge water automatically. It is also possible to control the quantity of the discharged water. Fig. 8 shows a photograph taken during the operation. The manipulation in Fig. 8(a) was done using a liquid bridge force. The formation of the bridge collapsed in Fig. 8(b). The water overflowed in Fig. 8(c). Because an electric injector was used for the case of Fig 8(d-1), continuous operation was possible. Because (d-2) in Fig. 8 is using the empty pressure injector, operation is interrupted. Efficiency of micromanipulation goes up by this. Moreover, because the electric injector can determine the quantity that discharges a liquid, its stable manipulation becomes possible.

Fig. 6 Electric injector

Fig. 7 Pneumatic injector

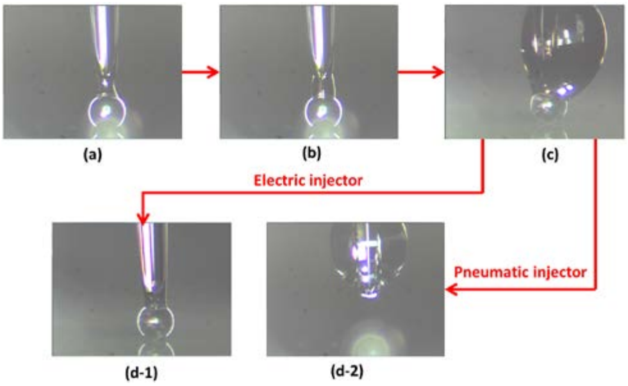

Fig. 8 Work landscape

5. Adhesive force for micromanipulation

In microscale studies, adhesive strength needs to be taken into consideration. Adhesive force exists between an object and the supporting surface (see Fig. 9). In the case in which an object is lifted, the liquid bridging force acts above the object. The adhesive force and gravity act on the opposite side (see Fig. 10). An object can be lifted if the liquid bridge force is greater than the resultant of the gravitational and adhesive forces. We conducted an experiment to measure the adhesive force. The prepared objects were a tiny globule and a microchip capacitor. The two different microobjects were measured because their ground contact areas differ. The tiny microobject (produced by UNION Companies, Fig. 11) was 600 [μm] in diameter [7]. The microchip capacitor (produced by Murata Manufacturing, Fig. 12) measured 600 [μm] × 300 [μm]. A double stick tape was stuck to the supporting surface. The microobject was fixed using the double stick tape. The adhesive force between the floor and an object was measured. Tiny globule: 0.353196 [μN]. Microchip capacitor: 0.376704 [μN]. The handling technology is expected to be improved by an understanding of the adhesive force.

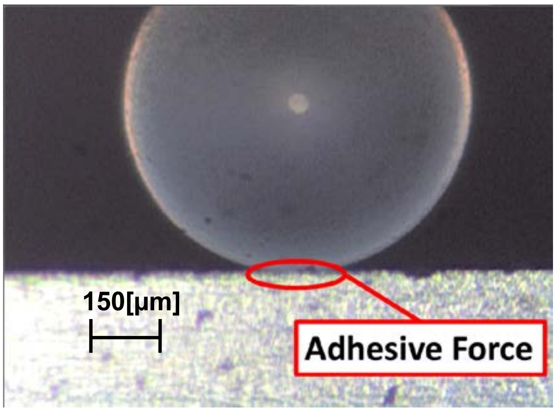

Fig. 9 Originating point of adhesive force

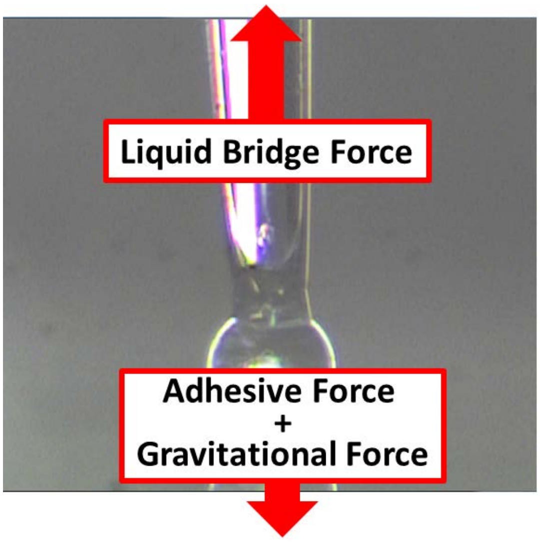

Fig. 10 Adhesive force and liquid bridge force

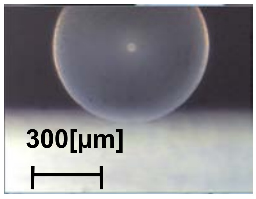

Fig. 11 Microobject

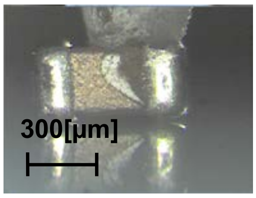

Fig. 12 Microchip capacitor

6. Basic experiments

A basic experiment was conducted to measure the liquid bridge force at the time of the micromanipulation. Fig. 13 shows the photograph of the experimental device. Fig. 14 is a schematic of the installation. The balance had a resolution of 0.00001 [g]. The diameter of the object was 200 [μm]. The experimental procedure was as follows:

1. The object was fixed to the balance. It was fixed with a double-stick tape.
2. The pulling was done by a liquid bridge force.
3. The balance was read (1 [data]/0.11 [s]).
4. The pull-up speed was increased from 1 [μm/s] to 25 [μm/s].
5. Five liquid bridge force were measured in each pull-up speed.

The tip of the capillary is shown in Fig. 15. The capillary pull-up speed was changed. When this was done, the liquid bridge force changed. It also changed the inside and outside diameters of the capillary tip. The experiment was conducted by changing the inside diameter, the outside diameter, and the capillary tip pull-up speed. Fig. 16 shows the results of changing the inside diameter and the speed. Fig. 17 shows the changes in the liquid bridge force with the outside diameter and the speed. When the pull-up speed was increased, the liquid bridge force decreased. When the inside and outside diameters were decreased, the liquid bridge force decreased.

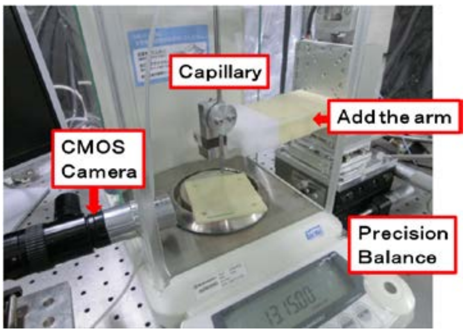

Fig. 13 Setup for measuring liquid bridge force

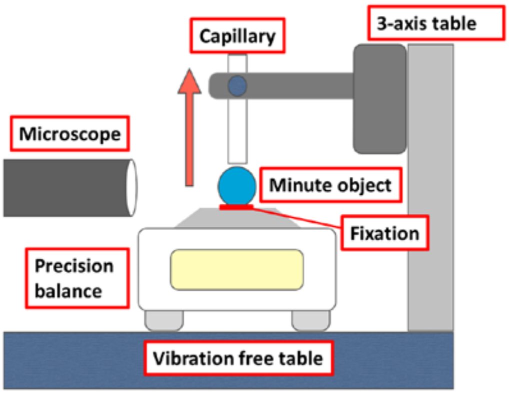

Fig. 14 Schematic diagram of experiment

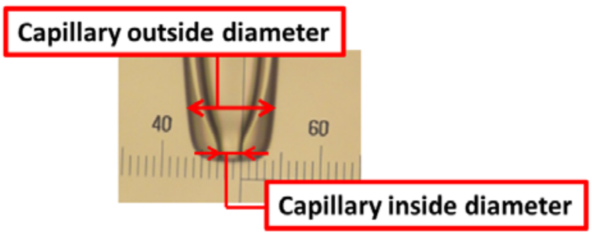

Fig. 15 Capillary tip

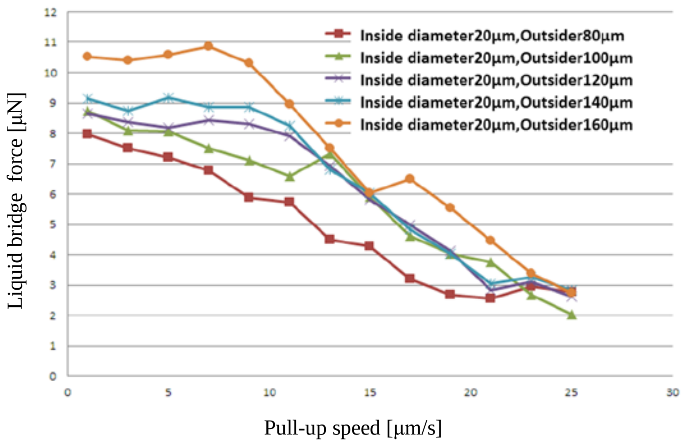

Fig. 16 Change in liquid bridge force with outside diameter and pull-up speed

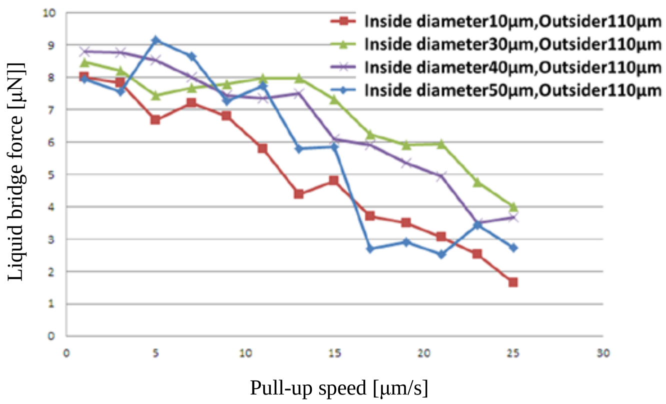

Fig. 17 Change in liquid bridge force with inner diameter and pull-up speed

The difference between the inside and outside diameters is required to be 70 [μm]. In our laboratory, when generating the capillary tip, the minimum diameter was 10 [μm]. Owing to experimental constraints, a capillary with outside and inner diameters of 80 [μm] and 10 [μm], respectively, was selected for our manipulation system.

In Fig. 18, the performance of the proposed capillary is compared with that of the old one. The maximum liquid bridge force decreased from 14.2 [μm] to 6 [μm]. The minimum liquid bridge force decreased from 3.1 [μm] to 0.8 [μm].

For the manipulation experiment, we used a microobject of diameter 200 [μm]. It was possible to generate a minute liquid bridge force of 0.8 [μN] by improving the capillary.

This force was sufficient for handling a 200 [μm] microobject, and the separation of the microobject was also easy. This improvement significantly shortened the time required to assemble the micropart.

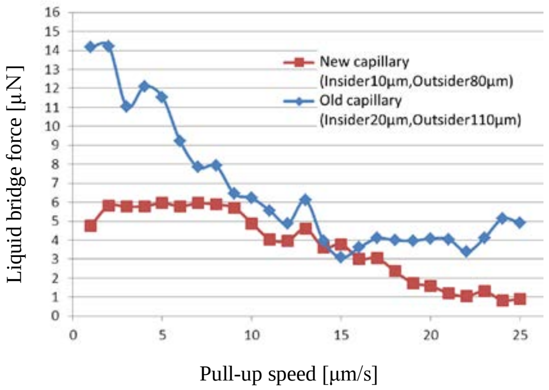

Fig. 18 Comparison of the liquid bridge forces

7. Conclusions

The inside and outside diameters of the apical portion of the capillary were changed. When the outside diameter of the apical portion of the capillary was changed, the shape of the bridge changed. When the shape of the bridge changed, the liquid bridge force was weakened. The results of the study revealed that the liquid bridge force changed with the speed. The adhesive force was also measured. Although the adhesive force was weak, it was definitely generated. The purpose of this study was achieved.

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