INTRODUCTION

Recently it becomes more important to produce the microcapsule for such drug delivery system in medical application. For these years, many styles based on chemical reaction and micro fluid dynamics have been developed, although the accuracy of the microcapsule size is not good enough to control the activate time. In this report, a pair of the micro pipette injecters is developed and the liquid in the tube can be pushed out by the thin rod traversing in the tube. The contained liquid with higher viscosity in the tube can be pushed out in the solvent and then the small capsule can be generated when the thin rod is retracted quickly.

In this work, the experiments were designed and set up in order to check the performances. With the double tube pipette with the diameter of 50um, the small amount of two different liquids are preset in the pipette with the help of the surface tension force at first and then the thin rod can push out them into the solvent. Under the careful speed control of the thin rod, the single emulsion with the core and the shell can be generated in the solvent. This simple mechanical sequence can be repeated precisely and the accurate capsules with the size of 160um are able to be produced with the deviation of 10%. Another layout that two micro pipette dispensers are aligned with appropriate angle can allow to produce the capsule with the different core and shell materials. At first, the liquid for shell is pushed out from the right pipette injecter and then the second injecter can insert into the capsule from the left hand side and the core material can be injected. This unique and precise sequence can allow to produce such micro capsule with any kinds of materials although materials are limited with the chemical procedures. In the primary experiment, it is shown that the control system of the developed linear motor driven micro glass pipette injector, and several single or double layer capsules with different materials succesfully have been demonstrated with the high speed video motion pictures. Here the shell diameter of 500um with that of 200um core material of oil was succesfully made in the solvent by this unique micromechatronics technique.

SINGLE PIPETTE INJECTION

Principle of single pipette injection

The sequential view of the single pipette injection in the liquid is shown in Fig. 1. It is composed of a glass pipette and a thin needle. Here the glass pipette is filled with an inner liquid and the thin needle passes through the glass pipette. The glass pipette and the thin needle can be inserted into the base liquid. The inner liquid can be pushed out into the base liquid by the thin needle. The inner liquid becomes a sphere by the surface tension. The inner liquid gathers around the top of glass-pipette tip. When the thin needle is retracted from the glass-pipette tip, the inner liquid is parted from the thin-needle tip. Single emulsion can be generated in the base liquid.

Experiment of single pipette injection

In the experiments, the aqua purificata was used as the base liquid. The optimized diameters of the glass pipette and the thin needle were investigated from the primary experiment of single injection. In the experiments, the high speed video motion pictures were used to observe the generation process of the single emulsion. Here the shell diameter of 500um with that of 200um core material of oil was succesfully made in the solvent by this unique micromechatronics technique.
the inner liquid. Vegetable oil was used as the base liquid. The thin needle was made of tungsten. When single emulsion was generated by pushing out the aqua purificata to the vegetable oil, it was monitored by a high-speed microscope. At first the glass pipette tip was set at 1.5 mm above the vegetable oil. The thin-needle tip was kept on 0.4 mm above the glass-capillary tip. Fig. 2 shows an appearance of single emulsion generation. When the gap between the glass pipette tip inner diameter and the thin needle tip diameter was small, then the single emulsion could be generated. Several single emulsions were iteratively generated for checking the repeatability. The glass pipette tip inside diameter was 85 \( \mu \) m. The thin-needle-tip diameter was 70 \( \mu \) m. The aqua purificata was filled in the glass pipette. The aqua purificata was pushed out into the vegetable oil by the thin needle once three second. Single emulsions iterative generation can be monitored by a microscope instrument.

![FIGURE 2](image1.png)

**FIGURE 2** Experiment of single emulsions generation pushed out the pipette.

Fig. 3 shows the single emulsion iterative generation. The diameters of single-phase emulsions were measured by the images processing. Fig.4 shows the distribution of the diameters of 50 single emulsions. The average diameter was 163 \( \mu \) m, and the deviation of the diameters was within \( \pm 15\% \).

![FIGURE 3](image2.png)

**FIGURE 3** Continuous single emulsions in the base liquid.

**DOUBLE LAYER INJECTION BY SINGLE PIPETTE AND COAXIAL DOUBLE PIPETTE**

Principle of double layer injection

The double layer injection by single pipette and by coaxial double pipettes are shown in proposed in Fig. 5. A mechanism of the coaxial arranged pipettes method is composed of two glass capillaries, which are arranged coaxially, and a thin needle. The proposed method consists of an emulsion generation process and a liquids replenishment process. The emulsion generation process is shown.

![FIGURE 5](image3.png)

**FIGURE 5** Double layer emulsion by single pipette and coaxial double pipettes.

The first liquid and the second one are filled in the inner glass pipette. The inner glass pipette and the thin needle are gone down into the base liquid. At first, the first liquid is pushed out into the base liquid by the thin needle. The first liquid becomes a sphere by the surface tension. The first liquid is adhered the glass pipette tip. Then the second liquid is pushed out into the first liquid by the thin needle. The second liquid becomes also spherical by the surface tension. Then the second liquid is put in the first liquid. When the thin needle and the inner glass pipette
are gone up from the base liquid, the first liquid and the second liquid are parted from the thin-needle tip. Thus the double layer emulsion is generated in the base liquid. The first liquid in the pipette are consumed in the emulsion generation process. Therefore the liquid replenishment process is required as shown in Fig. 5. The inner pipette and the thin needle are gone up into the outer glass pipette. When the thin needle is gone up, the second liquid is raised into the inner glass pipette. Furthermore, the first liquid is gone down under the thin-needle tip. The inner glass pipette is gone down outside the outer glass pipette.

**Experiment of double layer pipette injection**

The coaxial arranged pipette method was checked by the experiment of double layer emulsion generation. In the experiments, chili oil was used as the first liquid. Aqua purificata was used as the second liquid. Vegetable oil was used as the base liquid. The inner glass pipette tip inside diameter was 100 μm. The outer glass pipette tip inside diameter was 150 μm. The thin needle tip diameter was 70 μm. The chili oil was filled in the inner glass pipette. The aqua purificata was filled in the outer glass pipette. The chili oil and the aqua purificata were filled in the inner glass pipette by the liquids replenishment process. The aqua purificata was sucked from the inner glass pipette tip to 1 mm above. The glass-pipette tip was set at 1 mm upper from the vegetable oil. The thin needle was put the inner glass pipette tip to 2 mm above. The inner glass pipette and the thin needle were gone down into the vegetable oil in the emulsion generation process. When double layer emulsion was generated, it was monitored by a digital microscope. Double layer emulsion could be generated as shown in Fig. 6. The aqua purificata sphere diameter was 500 um. The chili-oil-sphere diameter was 300 um. Double-phase emulsion generation was succeeded by the coaxial arranged pipette method.

![FIGURE.6 Experiment of capsule generation by double layer single pipette.](image)

**V-SHAPE LAYOUT TWIN PIPETTES INJECTION**

**Principle of V-shape twin pipettes injection**

A V-shape arranged pipettes method is shown in Fig. 7. The V-shape arranged pipettes method is composed of two single emulsion generation methods, which are aligned with V-shape. The first liquid is filled in a left-side glass pipette and the second liquid is filled in a right-side glass pipette. At first, the left-side glass pipette is gone down into the base liquid. The second liquid is pushed out into the first liquid by a left-side thin needle. The first liquid becomes a sphere by the surface density. The first liquid is adhered the left-side glass-capillary tip. Then the right-side glass pipette is inserted into the first liquid. The second liquid is pushed into the first liquid by a
right-side thin needle. When the thin needles and the glass pipettes are gone up from the base liquid, the double layer emulsion are parted from the thin needle tips. When the thin needles are gone up from the glass pipette tips, the double layer emulsion, the capsule can be generated in the base liquid.

**Experiment of V-shape twin pipettes injection**

In Fig.8, the experimental set up is shown. The thin rods and glass pipettes are aligned with V layout and they can driven by the linear stages. The positions and the speeds of them are controlled precisely by FPGA control unit. In the experiments, chili oil was used as the first liquid. Aqua purificata was used as the middle phase liquid. Vegetable oil was used as the outer-phase liquid. The thin needle was made of tungsten. The glass pipette tip inside diameter was 90 $\mu$m. The thin-needle-tip diameter was 70 $\mu$m. The aqua purificata was filled in the right side glass pipette, and chili oil was filled in the left side glass pipette. The glass pipette tips were set at 1.5 mm above from the vegetable oil. The thin needle tips were kept on 1.5 mm above from the glass pipette tips. The right side glass pipette and the thin needle were gone down into the vegetable oil. The left side glass pipette and the thin needle were gone down into the vegetable oil. Whether double-phase emulsion was generated was observed by a digital microscope. Double layerd emulsion, capsule could be generated as shown in Fig. 9. The aqua purificata sphere diameter was 500 um and the chili oil diameter was 200 um. Double layer emulsion generation succeeded in producing by the V-shape aligned pipettes method.

**CONCLUSION & FUTURE WORKS**

In this paper, micro encapsulation methods using glass pipette and thin needles for wide variety and small quantity production is proposed. Single layer emulsion generation and double layer emulsion iterative generation were succeeded. Double layer emulsion also succeeded in generating by the coaxial aligned pipettes method and the V-shape arranged pipettes method in the experiments. In the future, such chemical reactive and optical reactive materials can be used to produce the functional capsule.