MICRO INJECTOR BASED ON DIGITAL DRIVE AND CONTROL FOR BIOMEDICAL ENGINEERING

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Abstract: This paper reports a novel microfluidic system, by which microfluidic delivery, transport and control can be digitally realized in femtoliter scale. Microelectronic grade N_2 from a pressurized canister was passed through HPLC tubing into a micro injector. The micro injector was driven and controlled digitally by the control system that can apply various control parameters such as pulse frequencies. A front-end of micro nozzle was inserted the dyed oil to collect droplets injected. The diameter of a droplet was measured by a microscope and a CCD camera, and then its volume can be calculated on the assumption that the droplet is spherical. The micro nozzles were simply pulled in glass capillary tubes by the micro puller self-made, and the geometry parameters of the micro nozzles can be adjusted easily. Experiments have successfully been carried out, and the results demonstrated that the proposed digital micro injector possesses three significant advantages : precise ultra-small liquid volume in femtoliter scale, digital microfluidic control and micro devices fabricated by simple glass process, not based on IC process.

Keywords: digital drive; microfluidic control; micro injector; microfludic systems; DNA injection

1. INTRODUCTION

Microfluidic delivery, transport and control have grown in importance for life science, chemistry, medicine, and biomedical engineering applications. Microinjection for biomedical engineering can be considered as a kind of transport of micro liquid volumes and low Reynolds number flow. For many of these applications, decrease of flow resistance, increase of drive force on microfluidic flow, precise ultra-small liquid volume, digital microfluidic flow, and microfluidic devices or equipments fabricated by simple process and low cost are several essential problems in the microfluidic technologies.

Much effort is being dedicated to developing microfuidic systems for a variety of applications [1]. Of all microfuidic systems, micro pumps with low power consumption, able to handle small and precise volumes, are of great scientific and practical interest, including valve-less diffuser pump designed for gases [2-6].

Digital microfluidic circuits based on electrowetting on dielectric actuation are mainly applied to control move of micro droplets [7]. A kind of femtoliter injector, fabricated with a silicon plate and a structured Pyrex glass plate, for DNA mass spectrometry was recently reported [8].

In this paper, we introduce a novel micro injector based on digital drive and control. Performances and characteristics such as low flow resistance, large drive forces, precise micro liquid volume, easy fabrication processes are expected on the microinjection system to be proposed in the paper.

2. PRINCIPLE OF DRIVE MECHANISM

The presented concept applies a new principle of microfluidic drive and control. **Fig.1** shows a schematic illustration of the microfluidic drive and control mechanism.

Microfluidic systems based on the drive principle presented are very simple in mechanism. There are neither micro pumps nor micro valves, which are moving parts of microfluidic systems, in the micro fluid channel (that is the inside of the solid wall shown in Fig.1). The actuator connected to the solid wall drives the solid wall; in consequence the solid wall gets a movement *s* along to the arrow.

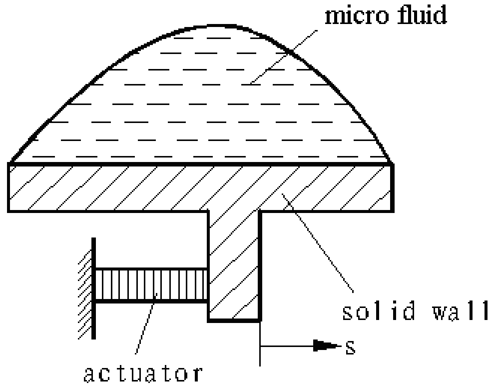

Fig.1 Pricinple of driven mechanism

Micro fluid flow in the micro channels shown in Fig.1 will suffer viscosity forces (shearing forces) between the solid wall (body) and micro fluid that be driven and controlled. The motion of the solid wall with plus or minus acceleration in moving direction will accompany inertia forces. When the absolute value of acceleration of the solid wall is high, the inertia forces of the solid wall are greater than the viscosity forces between the solid wall and the micro fluid. On the contrary, we get inertia forces, being smaller than the viscosity forces, when the absolute value of acceleration is low.

According to this analysis, by changing the absolute value of the acceleration of the solid wall, we can drive and control the micro fluid flow without moving parts such as micro pumps and micro valves inside micro channels. Furthermore, the micro fluid flow can be digitally driven and controlled by varying control parameters such as direction, waveform, amplitude, frequency, phase angle and wave number of the acceleration.

3. EXPERIMENTS

3.1 Experimental system

A schematic drawing of the experimental setup is shown in **Fig. 2**.

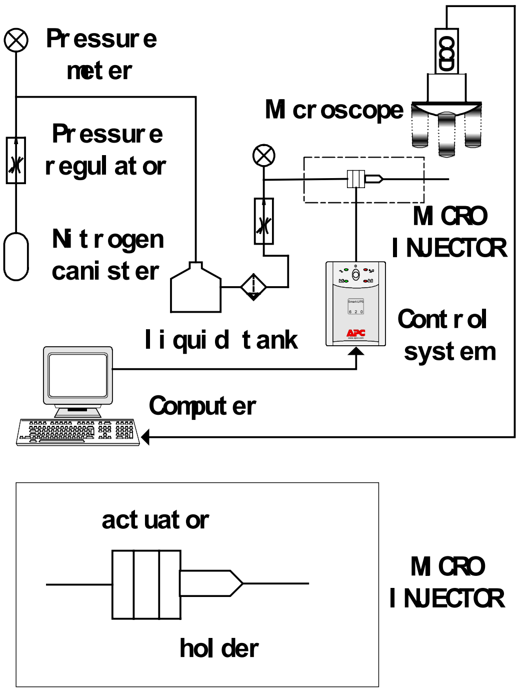

Figure 2 A schenatic drawing of the experimental setup

Microelectronic grade N_2 from a pressurized canister was passed through HPLC tubing into a micro injector. A PPD-01AKN pressure meter was used to monitor the exit pressure.

The micro injector body is simply constructed by a micro nozzle (needle) holder and a micro nozzle, and there are no moving parts such as micro pumps and micro valves inside the micro injector. An actuator, connected to the micro injector supplies driving forces for the micro injector. Thus, the micro nozzle was driven and controlled digitally by the control system that can supply various control parameters such as direction, waveform, amplitude, frequency, phase angle and wave number of the acceleration of the micro injector.

A front-end of micro nozzle was inserted the dyed oil to collect droplets injected. The diameter of a droplet was measured by a microscope and a CCD camera, and then its volume can be calculated on the assumption that the droplet is spherical. The micro nozzles were simply pulled in glass capillary tubes by the micro puller self-made, and the geometry parameters of the micro nozzles can be adjusted easily.

3.2 Fundamental Experiments

3.2.1 Microfluidic Flow in Micro Channels

Experiments of micro fluid flow in micro channels were carried out with the digital micro injector. Pure water was used as micro fluid, and micro channels are $30-70\mu m$ in diameter. **Fig.3** illustrates momentary microfluidic injection in a micro channel. The velocities of the micro fluid flow in the micro channels are $10-20\mu m$ /s, so Reynolds numbers are $0.001-0.0001$ in range.

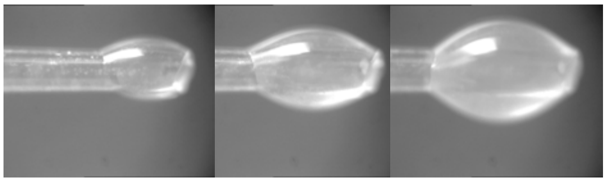

Fig. 3 momentary microfluidic injection in a micro channel

3.2.2 Diameter of Micro Nozzles versus Pressure drop

In order to decide N_2 pressure drop applied on micro nozzls, fundamental experiments on relationship between the pressure drop and the inside diameter of micro nozzles are carried out, and the result is shown in **Fig. 4**.

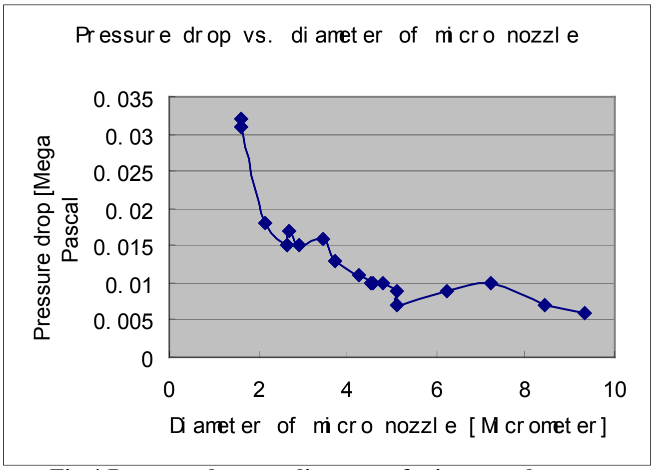

Fig.4 Pressure drop vs. diameter of micro nozzles

3.3 Digital Micro Injection

Fig.5 shows one micro droplet injected from a micro nozzle by generated at a frequency of 1Hz. From experiments at this frequency, we observed the diameter of the droplets are $3.0-6.0\mu m$, so their

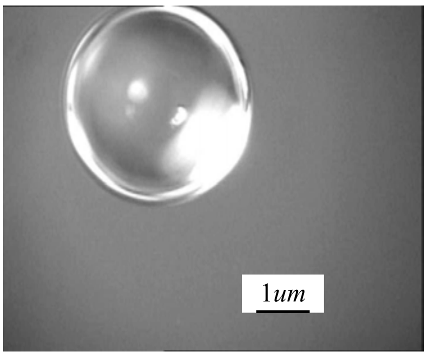

Fig. 5 One micro droplet injected from a micro nozzle at 1Hz

No.ABST658 Liya Hou

volume are 113.0 − 905.0 *fl* ($1fl = 1\mu m^3$)

Two micro droplets and three micro droplets generated at 2Hz and 3Hz are shown in **Figure 6** and **Figure 7** respectively. The higher the frequency, the smaller the diameter is.

And at a frequency of 20Hz, we get a stream of micro droplets. **Table 1** shows volume of micro droples with defferent frequencies.

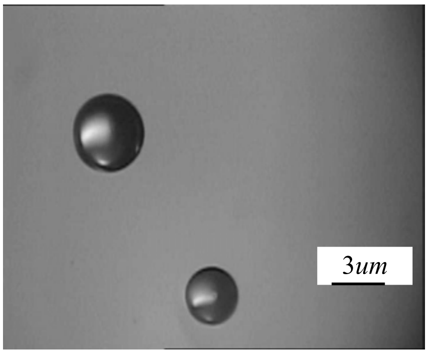

Fig. 6 Two micro droplets injected from a micro nozzle at 2Hz

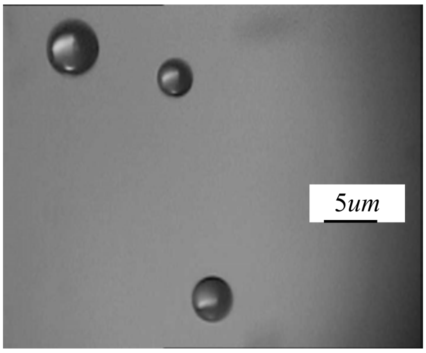

Fig. 7 Three micro droplets injected from a micro nozzle at 3Hz

Table 1 Volume of Micro Droples with Defferent Frequencies

Frequency (Hz)	Diameter of micro droplets (*um*)	Volume of micro droplets (*fl*)
1	3.0 − 6.0	113.0 − 905.0
2	2.4 − 4.8	57.9 − 463.0
10	1.5 − 3.0	14.0 − 113.0
20	0.6 − 1.2	0.9 − 7.2

4. CONCLUSIONS

The presented micro injector based on digital drive and control has better performances and characteristics of low flow resistance, large drive forces, and precise micro liquid volume. In addition, the fabrication process of the micro injector is very simple because it has no need to set moving parts inside.

Experiments have successfully been carried out, and results demonstrated that the proposed digital micro injector possesses three significant advantages : precise ultra-small liquid volume in femtoliter scale, digital micro fluid flow control and micro devices fabricated by simple glass process, not based on IC process.

The proposed digital micro injector, as its advantages mentioned above, can find its applications for DNA injection, dispensers for mass spectrometer, precision drug injection, delivery for micro total analysis systems and so forth. Furthermore, the digital femtoliter injector can be expected for making nano particles.

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