SPECIFIC FLOW CONTROL SYSTEMS USING IR LASER INDUCED SOL-GEL TRANFER OF HYDROGEL

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ABSTRACT

IR laser induced sol-gel transfer of hydrogel is applied for the microfluidic controls. High performance biomolecules sorting systems using T-shaped microchannel including Ti absorbers to enhance the heat generation were realized. Mebiol Gel^{TM} whose critical temperature 32 C was used as the carrier and high speed sorting of about 30 msec was achieved by optimizing the channel structure. We also apply sol-gel transfer to realize 2-D specific flow control in the microcavity by projecting near-IR light using a Digital Mirror Device (DMD).

Keywords: sol-gel transfer of hydrogel, biomolecules sorting system, 2-D specific flow control system

1 INTRODUCTION

Flow control in micro chemical/biochemical analysis systems is one of the key technologies. Various types of micropumps and microvalves have been studied and developed.[1] But most of the micro valves need multi step fabrication processes and have dead space due to their complicated structures. Even for the simple cell sorting systems including flow switches, the microchannel structures must be complicated when the microvalves are integrated. To avoid this problem, micro cell sorters using seath flow control were reported.[2,3] We proposed novel biomolecules sorting systems using sol-gel transfer of hydrogel.[4,5] Further studies on the switching characteristics, the sorting time is reduced by efficient IR absorbing procedure using metal thin film absorber as indicated below.

Flow control using sol-gel transfer of hydrogel can be applied to 2-D specific flow control in a free space glass microcavity, since the efficient heat generation is realized with metal thin film IR absorbers. First prototype of the 2-D specific flow control system by near-IR projection using DMD is also described.

2 BIOMOLECULES SORTING SYSTEM

2.1 Principle of Biomolecules Sorting System

Fig.1 shows the principle of the biomolecules sorting system using T-shaped microchannel, the sorting system has one inlet and two outlets of recover and waste ports. At initial state, IR focused laser (1480nm) is illuminated at the Ti absorber of the recover branch. Since the gelled layer is formed to block the channel, all molecules flow to the waste port. When the target molecule is detected, the illumination point is shifted to the Ti absorber of waste branch. Ti absorber and water are heated by the laser. Sol-Gel transfer of the Mebiol Gel^{TM} occurs when the temperature exceeds the critical point (32 C). The formed gel blocks the flow. The target molecule is sorted to the recover port.

2.2 Design and Optical Setup

Fig.2 shows the structure of biomolecules sorting chip. The device consists of two quartz glass plates. A 5 μm wide and 5 μm deep channel is formed in the lower quartz plate. The channel is fabricated by femto-second laser ablation, and Ti thin films are formed close to the junction. The through holes of an inlet and two outlets are drilled with a diamond

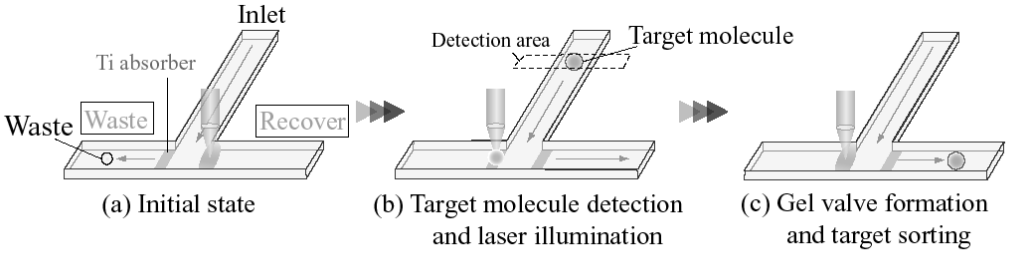


Fig.1 Principle of the biomolecules sortingsystem

tool. Then the two plates are bonded by HF bonding[6].

Schematic of the optical setup is shown in Fig.3. The fluorescent signals are detected at 10um upstream from the junction. Wavelength and power of the used laser are 1480nm and 0.2W. PC controlled two scanner mirrors are used for switching of the focued IR beam (Mirror 1) and scanning (Mirror 2).

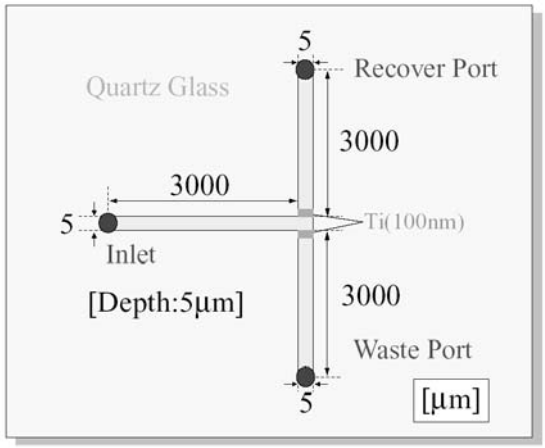


Fig.2 Structure of the T-shaped biomolecules sorting chip

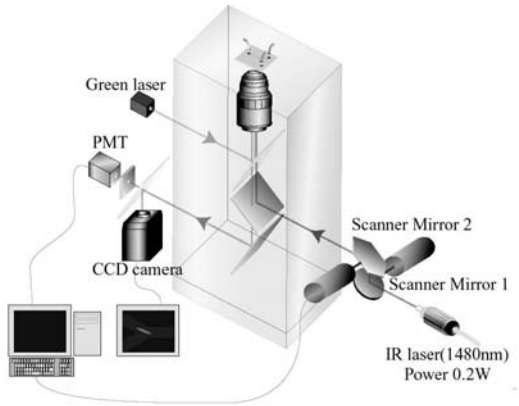


Fig.3 Optical setup of the T-shaped biomolecules sorting system

2.3 Experimental Results

We estimate the temperature distribution around the IR laser illumination point by monitoring the fluorescent intensity decrement of the Rhodamine due to the temperature increase. Fig.4 shows the temperature distribution around the near-IR laser illuminated, (a) water including Rhodamine on the glass and (b) that on the Ti (100nm) membrane formed on the glass. The IR energy necessary for elevating the certain temperature on the Ti film is about 30 times smaller than that on the glass. The results show the Ti membrane is useful for the efficient IR absorber.

Fig.5 shows the sorting feature using fluorescent bead as the sample. Fig.5 (a) is streamline of the beam after detecting the target bead at the detection point and IR focused laser is illuminated at the left Ti absorber, while (b) is after switching the illumination point to the right absorber at 33 msec later. This result indicates that the sorting time is faster than 33 msec.

Fig.6 shows the relative velocity of the trapped beads and free beads around the sol-gel transfer measured by the high speed camera. By moving the illumination point, the trapped one is released while the free one is trapped. The transient time indicates the sol-gel transfer speed. The results indicate that the transfer is completed within 3 msec. By employing the Ti IR absorbers, necessary IR power for sol-gel transfer is reduced about 1/30 and the sorting time was improved 4 times faster.

The proposed system is now going to apply actual sorting of biological cell, DNA and RNA. Recovery ratio of 95 % is already achieved in the case of λ–phage DNA sorting.

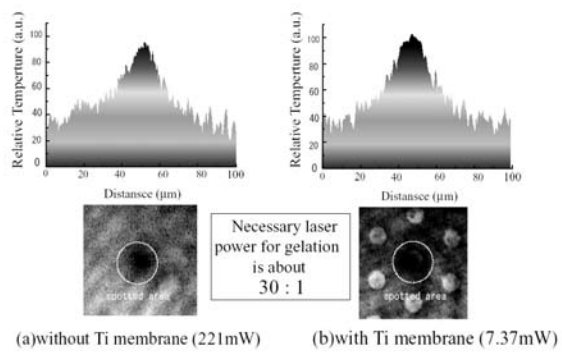


Fig.4 Temperature profile where the spotted IR laser illuminated

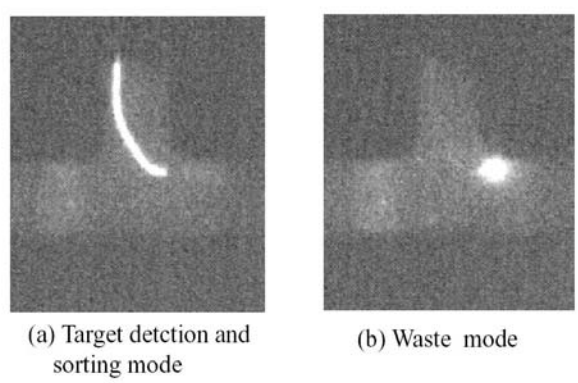


Fig.5 Sorting feature using fluorescent beads

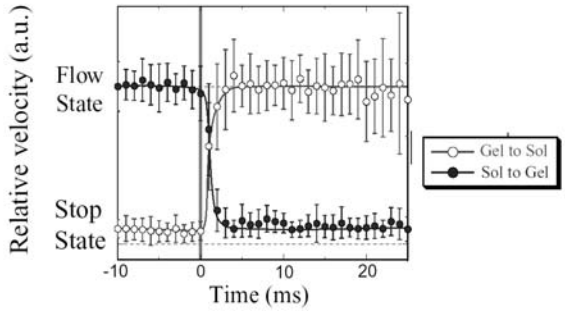


Fig.6 Relative velocity of the trapped beads and free beads around the sol-gel transfer area

3 2-D SPECIFIC FLOW CONTROL SYSTEM

3.1 Principle

The schematic principle of the 2-D specific flow control system is illustrated in Fig.7. A multi-inlets and outlets glass microcavity having the arrayed Pt IR absorbing spots on the bottom glass. At initial state, low viscosity Mebiol Gel^{TM} is introduced into the inlets and flows out from all outlets. By projecting near-IR light patterns to the Pt absorbers using the PC controlled DMD. Mebiol Gel^{TM} are heated and sol-gel transfer occurs when the temperature around absorbers exceeds the critical point (32 C). Then gelled patterns are formed and limited flow passes are formed in the microcavity (Fig.7(b)). The patterns of limited flow passes can be designed freely by PC programming.

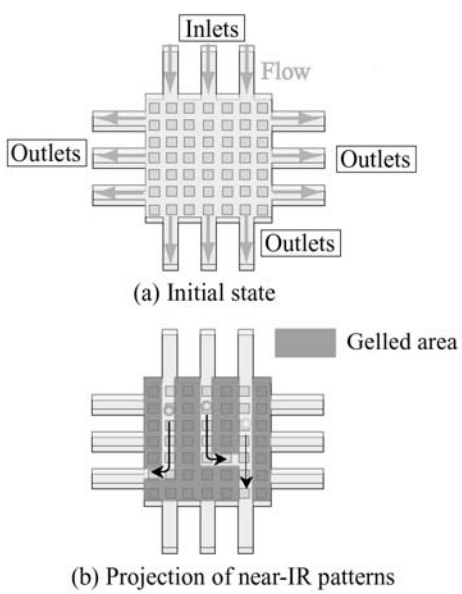


Fig.7 Principle of the 2-D specific flow control system

3.2 Design and Optical Setup

Fig.8 shows the structure of the 2-D specific flow control chip. A microcavity and channels are fabricated on upper Pyrex glass substrate by the HF etching. Thickness of the upper substrate is 170μm. Cr/Pt near-IR absorbers are formed on the lower substrate. Size of the absorbers is 10 μm square and distance between the absorbers is 20 μm Thickness of the lower substrate is 500 μm. The through holes of inlets and outlets are drilled with a diamond tool. Both substrates are aligned and bonded by the thermal bonding.

Fig.9 shows the optical setup of the 2-D specific flow control system. Wavelength of the near-IR laser is 808nm. Maximum laser power irradiated to the DMD is 10W. Maximum incident power into the microcavity is 40mw. In the present stage, the IR projection area is limited within 100 μm x 80 μm.

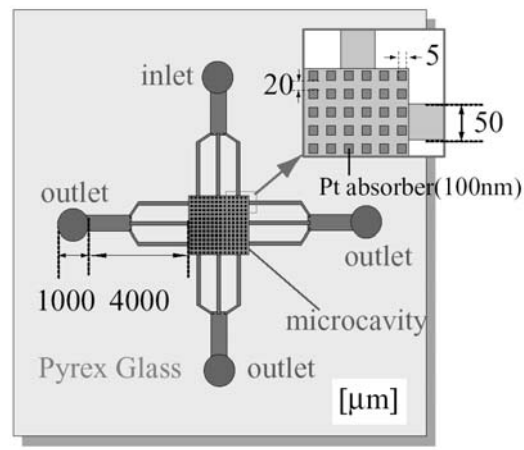


Fig.8 Structure of the 2-D specific flow control chip

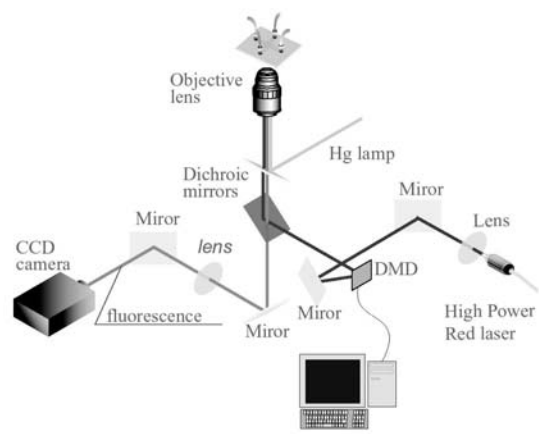
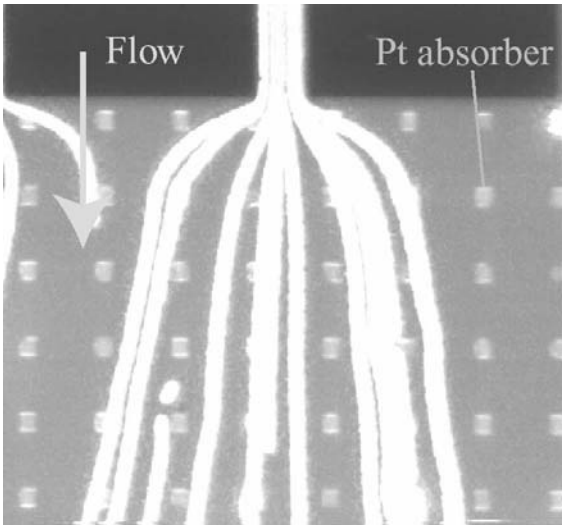


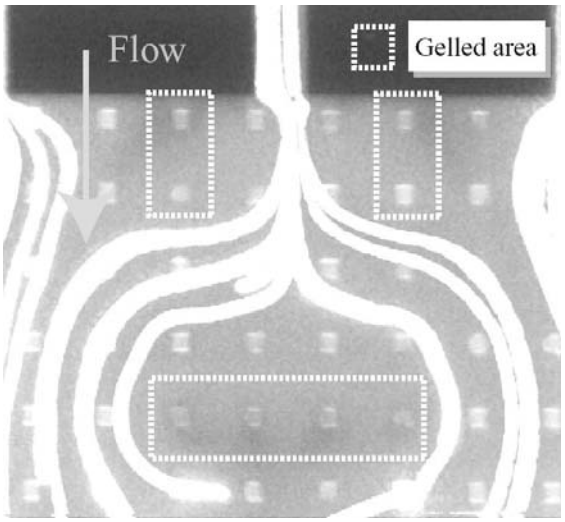
Fig.9 Optical setup of the 2-D specific flow control system

3.3 Experimental Results

Fig.10 shows the integration of the fluorescent beads streamlines (4.0sec) with and without IR projection to the microcavity. Fluorescent beads flow into the microcavity without control at initial state (a). By projecting near-IR light of two vertical patterns and one horizontal pattern with DMD, the beads flow passes are limited as shown in Fig.10(b). This result indicates that the 2-D specific flow control is available by this method. We are going to expand the projection area by improving the optical setup.



(a) Initial state



(b) Under gel walls formation by near-IR light projection

Fig.10 Fluorescent beads streamlines with and without IR projection

4 CONCLUSIONS

IR laser induced sol-gel transfer of hydrogel is applied for the microfluidic controls. High performance biomolecules sorting systems using T-shaped microchannel including Ti absorbers to enhance the heat generation were realized. Mebiol Gel^{TM} whose critical temperature 32 C was used as the carrier and high speed sorting of about 30 msec was achieved by optimizing the channel structure.

We also apply sol-gel transfer to realize 2-D specific flow control in the microcavity by projecting near-IR light using a Digital Mirror Device (DMD). Wide area 2-D specific control will be realized by improving the optical setup.

ACKNOWLEDGEMENTS

This research was partly supported by "Nanotechnology Support Project" of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

This research was partly supported by Grants-in-Aid for COE Research of Waseda University, Scientific Research Priority Area (B) No.13124209, Scientific research (B) No.12450167, and 13558088 from the Ministry of Education, Culture, Sports, Science and Technology of Japan

We would like to thank Prof. H. Yoshioka for providing Mebiol Gel^{TM}.

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