ON-DEMAND FLUID CONTROL ON MICROCHIP
BY MICRO-PATTERNED LIGHT IRRADIATION
USING PHOTO-RESPONSIVE HYDROGELS

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ABSTRACT

Novel on-chip fluid control strategies, on-demand formation of arbitrary micro-channels and parallel control of multiple microvalves, were successfully demonstrated by PC-controlled maskless micro-patterned light irradiation onto photo-responsive hydrogel sheet. The programmed non-contact fluid control system presented in this study enabled the formation of microchannels with arbitrary pathway at desired time points. The system is expected to be used in various microfluidic applications.

KEYWORDS: Photo-responsive hydrogel, Micro-patterned light irradiation, On-demand fluid control, Microchannel formation

INTRODUCTION

Light irradiation is a useful and important control means since it can be applied to an object locally and instantaneously in a non-contact manner. Therefore, fluid control by light irradiation possibly provides a flexible and universal method compared to many other types of on-chip fluid control techniques: pneumatic fluid control; electric and piezoelectric fluid control; and chemical microvalves, including thermo-responsive and chemical-stimuli-responsive hydrogel microvalves.

Recently, we and the other research groups have reported microvalves controlled by light irradiation using volume change of hydrogel \cite{1, 2} and melting of paraffin plug \cite{3}. Most of these methods utilize light-to-heat energy conversion and temperature increase induces the volume change of the gels and phase transition of paraffin (heat mode). On the other hand, the photo-responsive hydrogel reported in our previous study changes the volume by photo-isomerization of photo-responsive chromophore (photon-mode) \cite{2, 4, 5}. Therefore, the microvalve was opened by light intensity as weak as 30 mW/cm\textsuperscript{2}, and no interference was observed between the closed microvalves.

This paper presents two types of novel on-chip fluid control strategies. We demonstrated on-demand formation of microchannels with arbitrary pathway by micro-patterned light irradiation onto photo-responsive hydrogel sheet. We also demonstrated independent and parallel flow control in a polydimethylsiloxane (PDMS) microchannel network by micro-patterned light irradiation onto photo-responsive microvalves composed of photo-responsive hydrogel.
EXPERIMENTAL

We constructed two types of microfluidic systems to demonstrate on-chip fluid control by micro-patterned light irradiation. In both systems, we used spiro-pyran-functionalized poly(N-isopropyl-acrylamide) (pSPNiPAAm) hydrogel, which is known to exhibit shrinkage in response to blue light irradiation (Fig. 1a) [4, 5]. A universal microfluidic system was constructed by mounting a glass plate with multiple inlet ports and outlet ports onto the hydrogel sheet attached to another glass plate (Fig. 1b). PDMS microchannel network equipped with multiple photo-responsive microvalves were constructed by stacking a glass plate with mechanically fabricated through-holes and a PDMS microfluidic chip onto the hydrogel sheet attached to another glass plate (Fig. 1c). The micro-patterned light irradiation onto a pSPNiPAAm hydrogel sheet was carried out by using a PC-controllable maskless micro-projection unit equipped on a microscope [4].

RESULTS AND DISCUSSION

Fig. 2 shows the “on-demand” microchannel formation by micro-patterned light irradiation. Microchannel formation and flow in the microchannel was visualized by fluorescent labeled latex beads. It was observed that microchannels were formed in the irradiated area within a few minutes and the latex beads suspension flowed through the formed microchannels. We also prepared 10 photo-responsive microvalves connecting PDMS microchannels (Fig. 3a). It was demonstrated to control a single microvalve independently (Fig. 3a and 3b) and multiple microvalves simultaneously by micro-patterned light irradiation (Fig. 3c and 3d).

CONCLUSIONS

In summary, the programmed non-contact fluid control on microchip was successfully demonstrated by micro-patterned light irradiation onto the photo-
responsive hydrogel sheet. The fluid control system presented in this study enables the formation of the microchannels with arbitrary pathway at desired time points. The system is expected to create novel opportunity of various microfluidic applications, such as particle manipulation and sequential chemical syntheses.

Figure 2. Formation of microchannels by irradiating micropatterned light. (a, c) Micro-patterned light irradiation. (b, d) Microchannel formation and latex suspension flow after micro-patterned light irradiation.

Figure 3. Independent and parallel control of multiple photo-responsive microvalves. (a, b) Single microvalve control by local light irradiation. (c, d) Parallel control of multiple microvalves by micro-patterned light irradiation.

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REFERENCES


