MODULE-BASED MICROFLUIDIC DEVICES USING 3D PRINTERS

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ABSTRACT
Ever increasing demand in modulation and integration of microfluidic devices, new and advanced fabrication method are required for expanding their capability in microfluidic researches. We report three-dimensional (3D) printing technique for producing microfluidic modules and their assembly into functional microfluidic devices for non-expert users.

KEYWORDS: modules, 3D printing, biosensing, microfluidics

INTRODUCTION
Demands on integrated microfluidic devices have been increasing for chemical, biological, and medical applications [1, 2]. So far, PDMS-based assembly blocks for easy integrating multi-functional parts in a microfluidic device were developed to meet the requirements of non-expert user [3]. However, difficulties of conventional fabrication technique and the interconnection instability of PDMS-based components becomes an obstruction to operate the integrated device. Herein, we are firstly proposed an advanced fabrication and assembly method for modulated microfluidic devices. The general microfluidic components were made and assembled into functional microfluidic devices. Furthermore, non-expert users can easily access and utilize them into desirable microfluidic devices.

EXPERIMENTAL
Each functional modules were designed by assisting of AutoCAD computer software (Figure 1) and directly printed using 3D printer (ProJet HD 3500 Plus, 3D Systems, USA) with raw UV curable polymer (VisiJet M3 Crystal, 3D Systems, USA). During the printing, microchannels were occupied with wax supports to prevent potential structural changes. After printing is over, all the waxes were carefully removed from modules through ethanol washing. To assemble each module into a integrated microfluidic device, the rubber O-ring was inserted between the modules and secured using metal pins at each corners. The leakage test was manually performed under two cases as following: (1) without rubber O–ring, and (2) with rubber O–ring and the pressure changes were measured more than 10 times using digital pressure gauge and red ink solution. To confirm the functionality of the integrated devices, the immuno–reaction was performed using gold–deposited FITC–silica nanoparticles and carboxylated magnetic particles.

Figure 1. (a) Schematic illustration and pictures of modules. (b) Example illustration and (c) picture of customized integrated microfluidic device by assembly of individual modules using pins and O–rings by user scenario.
RESULTS AND DISCUSSION

Each module has different functionality and uses as basic building units for integrated microfluidic device (Figure 1). The outer dimension of module is $30 \times 30 \times 5$ mm$^3$ for width, height, and length, respectively. The concave and convex cone–shaped features were incorporated on the each side wall as mechanical alignment. The modules were directly printed from computer design using 3D printer. The module design for the customized microfluidic component was laid out in 3D using computer aided design program for preparing geometric coordinates. Based on the coordinates, the print head precisely moved and printed multiple layers of UV curable liquid polymer onto a flat surface. After printing liquid polymers, UV lamp solidified the liquid polymers into hard polymers and wax also printed to fill out the void for preventing potential collapse of main structures as illustrated in Figure 2.

![Module printing](Image)

Figure 2. Schematic illustration of direct fabrication modules through 3D printers.

The sealing and connectivity are a significantly important in this system to prevent potential liquid leakage and device malfunction. For non–expert users, we employed elastic O–rings as an alternative solution for perfect sealing between modules. It is also improved the mechanical stability under high pressure because of its elasticity (Figure 3). In addition, we applied alpha–fetoprotein (AFP) immuno–reaction as an example for liver cancer diagnosis to demonstrate potential application of integrated devices as biosensor [4]. Furthermore, the G–SNPs and magnetic particles complexes showed strong green fluorescent signal as shown in Figure 4. The proper overlap of fluorescent and optical images represented strong antibody and antigen interaction which confirm the proper functionality of integrated microfluidic device as biosensing platform.

![Fig. 3](Image)

(a) Without O-ring  (b) With O-ring  (c) Mechanical stability graph of modules without, with, and greased O-rings under various pressure.

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CONCLUSION

In summary, a rapid, straightforward, user-friendly and cost-effective fabrication of microfluidic modules were successfully realized by 3D printer. The designs were directly printed into functional 3D modules and different cases of module assembly can be possible. The variety designs of modules were firmly connected using metal pins and rubber O-rings and prevented any solution leakage. The simple and easy module assembly and reconstruction are suitable expand microfluidics to non-expert users. Moreover, these techniques can be widely applicable in microfluidic-related research including biosensing, biomedical, and biochemical devices.

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REFERENCES


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