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The complete SmartBuild Plug-n-Play Modular Microfluidic System that comprises of a motherboard, fitting components, microchannel inserts with different configurations, modules with different functionalities including detection, heating and pumping, and a printed circuit board with integrated pin connectors, and ribbon cable and fiber optic connectors for system control, data collection and detection.
Microfluidic assembly blocks†

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An assembly approach for microdevice construction using prefabricated microfluidic components is presented. Although microfluidic systems are convenient platforms for biological assays, their use in the life sciences is still limited mainly due to the high-level fabrication expertise required for construction. This approach involves prefabrication of individual microfluidic assembly blocks (MABs) in PDMS that can be readily assembled to form microfluidic systems. Non-expert users can assemble the blocks on glass slides to build their devices in minutes without any fabrication steps. In this paper, we describe the construction and assembly of the devices using the MAB methodology, and demonstrate common microfluidic applications including laminar flow development, valve control, and cell culture.

Introduction

Microfluidic systems have proven to be an advantageous platform for biological assays.1–5 These systems benefit from reduced requirements for expensive reagents, short analysis times, and portability. However, the impact of microfluidics on science has not yet been fully realized. For microfluidic systems, a gap typically exists between the technology developers mostly in engineering and chemistry, and potential users especially in the life sciences. In general, significant time and expertise are required to develop customized microfluidic systems. The high cost and the level of expertise required for microfabrication deters such non-expert users from using microfluidic systems. Collaboration between microfluidic researchers and life scientists facilitate the advance of microfluidics, as does the existence of companies and academy-based microfabrication foundries where potential users may purchase customized microfluidic systems. However, such customized systems incur substantial initial costs and delays due to low volume production* and are less suited for prototyping or test set-ups.

Several researchers have addressed this gap between the developers and users of microfluidic systems, proposing simpler fabrication methods6–11 as well as construction of configurable systems.12,13 Duffy et al. introduced a method of using printed transparencies to replace the expensive chrome masks used in photolithography.7 Direct printing to fabricate microfluidic channel molds has also been demonstrated9 and obviates the need for photolithographical mold fabrication. The fluidic channels fabricated in such fashions have a maximum height of ~10 μm and they may not be suitable for some biological applications with large cells. Larger channels can be made with solid object printing (SOP) and thermoplastics10 although the minimum feature size is quite large (~250 μm). Recently, Grimes et al. proposed using thermally shrinkable polystyrene sheets to directly print master molds, a clever technique that holds promise for channels in the 50–100 μm range.9 Instead of addressing simpler fabrication, Shaikh et al. focused on design flexibility.11 They proposed a system-level microfluidic architecture that allows for easy customization. Similar modular microfluidic systems have also been proposed by Grodzinski et al.13

We demonstrate here an assembly approach for microdevice construction to facilitate the use of microfluidic systems by non-experts. Our approach involves fabrication of microfluidic assembly blocks (MABs) in PDMS followed by the construction of a full functioning microfluidic system by assembling the blocks. Assembly blocks act as basic building units to form custom devices. Each MAB has an own unique function including inlet/outlets, valves, straight/curved/bifurcated channels, and chambers. Mass production of identical blocks is also possible in a regular lab environment. Once the assembly blocks are fabricated, they can be delivered to non-expert users who can assemble devices with the blocks in minutes without the need for expensive design software or cleanroom facilities.

Materials and methods

Mold fabrication

The prototypical MABs were manufactured using the standard soft-lithographic technique.14 The overall fabrication process is depicted in supplementary Fig. S1.† The proposed SU-8 master mold for MAB fabrication consists of thin patterns (~75 to 150 μm) for channel network and thick patterns (~500 to 1200 μm) for grid walls. To fabricate the patterns for fluidic channels first, the SU-8 2025 (MicroChem) resist was spun on a bare silicon wafer and pre-baked on the hot plate for 5 min at the
<table>
<thead>
<tr>
<th>Block name</th>
<th>Schematic</th>
<th>Size</th>
<th>Function or purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet/outlet</td>
<td><img src="image" alt="Inlet/outlet schematic" /></td>
<td>1 × 1</td>
<td>To connect the device to external tubing. The size of a hole varies. The width of a connecting channel varies.</td>
</tr>
<tr>
<td>Straight channel</td>
<td><img src="image" alt="Straight channel schematic" /></td>
<td>1 × 1</td>
<td>To form a plain straight channel. The channel width and height may vary.</td>
</tr>
<tr>
<td>T channel</td>
<td><img src="image" alt="T channel schematic" /></td>
<td>1 × 1</td>
<td>To add a side stream to the main stream or divide an incoming stream into two outgoing streams at 90°. The channel width and height may vary.</td>
</tr>
<tr>
<td>Y channel</td>
<td><img src="image" alt="Y channel schematic" /></td>
<td>1 × 1</td>
<td>To merge two incoming streams to form a fused outgoing stream or divide a stream into two streams at 45°. The channel width and height may vary.</td>
</tr>
<tr>
<td>Psi channel</td>
<td><img src="image" alt="Psi channel schematic" /></td>
<td>1 × 1</td>
<td>To merge three incoming streams to form a fused stream or divide a stream into three outgoing streams. The channel width and height may vary.</td>
</tr>
<tr>
<td>Cross channel</td>
<td><img src="image" alt="Cross channel schematic" /></td>
<td>1 × 1</td>
<td>To merge or divide stream(s) The channel width and height may vary.</td>
</tr>
<tr>
<td>90° Curved channel</td>
<td><img src="image" alt="90° Curved channel schematic" /></td>
<td>1 × 1</td>
<td>To form a 90° turn in a stream. The channel width and height may vary.</td>
</tr>
<tr>
<td>Chamber (small)</td>
<td><img src="image" alt="Chamber (small) schematic" /></td>
<td>1 × 1</td>
<td>To collect samples or secure a reaction</td>
</tr>
<tr>
<td>Connector</td>
<td><img src="image" alt="Connector schematic" /></td>
<td>1 × 1</td>
<td>To connect two blocks with channels of different widths</td>
</tr>
<tr>
<td>Spacer</td>
<td><img src="image" alt="Spacer schematic" /></td>
<td>1 × 1</td>
<td>To fill blanks between blocks or obstruct one end of a channel.</td>
</tr>
<tr>
<td>Zigzag channel</td>
<td><img src="image" alt="Zigzag channel schematic" /></td>
<td>1 × 3</td>
<td>To enhance advective mixing in the stream. The channel geometry and width may vary. Used in molecular gradient generators.</td>
</tr>
<tr>
<td>Long channel</td>
<td><img src="image" alt="Long channel schematic" /></td>
<td>1 × 3</td>
<td>To form a long plain straight channel. The channel width and height may vary. Used as separation channels.</td>
</tr>
<tr>
<td>Culture bed</td>
<td><img src="image" alt="Culture bed schematic" /></td>
<td>2 × 3</td>
<td>To provide separate chamber for cell culture. The size of a bed may vary. Patterns in the chamber may vary.</td>
</tr>
<tr>
<td>Pneumatic valve</td>
<td><img src="image" alt="Pneumatic valve schematic" /></td>
<td>2 × 1</td>
<td>To control flow or separate an adjacent compartment. The valve is closed at the normal condition. When vacuum is applied to the inlet, the valve will open. Dark blue represents the upper layer and light blue represents the bottom layer.</td>
</tr>
</tbody>
</table>
65 °C and for 20 min subsequently at the 95 °C. Approximately 75 μm thick patterns could be obtained when the spin coating was done once. After the exposure to 365 nm UV light, the coated wafer was post-exposure baked for 1 min at the 65 °C and for 10 min subsequently at the 95 °C The successive development in SU-8 developer solution (MicroChem) resulted in the channel patterns with desired thickness. The thickness and width of the patterns were analyzed on a surface profiler (Alpha-Step 500, KLA-Tencor). After cleaning the surface of the silicon wafer with the channel patterns on it, the same SU-8 resist was spun and pre-baked repeatedly until the desired thickness was obtained. The wafer then was carefully aligned to a chrome photomask patterned with grid walls as well as cross alignment marks. The size of the grids was chosen from 4 mm by 4 mm up to 8 mm by 8 mm that corresponds to that of fabricated blocks. The thickness of grid walls was measured with a mechanical height gauge (Mitutoyo).

**Block fabrication**

Once the SU-8 master mold was prepared, a mixture of PDMS prepolymer and curing agent (9 : 1 w/w, Sylgard 184, Dow Corning) was cast against the multi-layered master mold. We slightly tilted the mold and scratched the excessive PDMS solution off, using a commercial razor blade. The mold was then moved to a flat surface and cured at 150 °C for 15 min. Each cured PDMS block was carefully removed with a sharp aluminium syringe needle from individual cells separated by the grid walls. For inlet blocks and modules, injection holes were drilled by a luer stub. To fabricate the bottom layer, 100 μm PDMS layer on the glass side. In accordance with the design to be realized, we first selected proper blocks out of the lot of MABs. The selected blocks then were carefully aligned and assembled together on the chosen substrate. Using a pair of tweezers, we put a block together as tightly as possible by horizontally pushing and releasing it toward the block that had been already placed on the substrate. Visual aids such as a high magnification stereoscope were utilized to further facilitate the alignment procedure.

When necessary, liquid adhesive substances were used to strengthen overall bonding. A small volume (~1 μL block−1) of the adhesive solution was placed around the already assembled device in order to initiate adhesive spreading by capillary action. Excessive adhesive that occupied the main channel was carefully aspirated. For PDMS mixture filling, the device was moved to a flat surface and cured at 150 °C for 15 min. The same curing process was applied for PDMS curing agent filling. For the UV-curable glue bonding, the device was transferred in the UV crosslinker immediately after the capillary action took place and cured for 10 min. The devices treated with such adhesives were immediately used for tests and experiments without extra wait time.

**Fluid control and image acquisition**

Each injection port in the inlet blocks was connected through syringes to a computer-controlled set-up, which consisted of sets of two-way solenoid valves (Numatech). Each solenoid valve could perform a pulsed air pressure injection or a pulsed vacuum suction. The switches to pressure and vacuum were programmed and operated by LabView (National Instruments). Liquid reagents were also loaded via the syringes with aid of the computerized pressure control. The experiments were performed on the device oriented on a stage of a stereomicroscope (Olympus SZX12). For evaporation tests, the inlets and outlets were sealed with glass slits (Dow Corning). To exclude any effects of humidity and temperature, all devices were kept at the same location throughout the experiments. During the demonstrative fluidic experiments such as mixing and pneumatic valve operation, in situ imaging was recorded using a digital camera (Nikon Coolpix 4500) with a capture rate of 30 frames s−1 and then transferred to the computer for further analysis. A blue dye (Trypan blue 0.4% solution,
Sigma–Aldrich) and an orange liquid (fluorescein) were used to characterize the mixing performance in the study. The luminance intensity images were recorded and transferred to the computer for evaluation. The RGB images captured were converted into grayscale images. The grayscale images were further corrected from the background intensity. A computer program was written to analyze the luminance levels of the pixels along a line drawn at the center across the mixing channel.

Cell culture

To perform the cell culture in the microdevice, we prepared green fluorescent protein (GFP) expressing *E. coli* cells induced by arabinose. The GFPs were inserted into pET24a plasmid. The prepared bacteria cells were mixed with the culture media (Luria-Bertani, 20 g L$^{-1}$) containing ampicillin and inserted into the microculture system by a syringe. The microculture device was then brought and kept in the reactor at the constant temperature of 36 $^\circ$C. The fluorescent cell images recorded from the microscope (Olympus BX51) were moved to a computer for further analyses.

Results and discussion

Microfluidic assembly block concept

We have constructed microfluidic assembly blocks (MABs) that can be selectively assembled into a custom microfluidic device within minutes at the site of use. To construct a microfluidic device, MABs are selected from a standard set of components (Table 1) and then assembled to form the desired channel network, as shown in Fig. 1. Note that the block fabrication and the device assembly can be done at different locations. While the MABs are fabricated by trained engineers who have expertise on sophisticated microfabrication processes, the custom devices are readily assembled by non-expert users. Noticeably, the majority of recent microfluidic needs in the life sciences requires a very simple design of channel network and relatively wide channels. A variety of standard MABs can be produced at low cost and in large quantities, and the custom devices can be rapidly designed, assembled, and tested.

Fabrication of the MABs involves a multi-step lithography to construct the SU-8 master mold. The mold consists of thin channel patterns and thick grid patterns up to 1200 μm in height. To achieve this thickness, multiple repetitions of spin-coating and pre-baking were incorporated$^{15}$ (supplementary Fig. S2).† The MAB mold is then used to form the individual PDMS assembly blocks. Fig. 2a–c show a photo of the constructed SU-8 master mold, the resulting square MABs, and a simple exemplary device assembled on a glass slide. The MABs are designed such that they can be rotated in 90$^\circ$ increments if a different orientation is needed. Since the coated SU-8 layer was very viscous and thick, the spin coating tended to produce slight variations in thickness around the entire wafer. This non-uniform thickness of the grid walls resulted in fabricated blocks with a small variation in thicknesses (supplementary Fig. S3).† However, the variation in block thicknesses does not affect the assembly process.

Bonding and sealing

The mixing ratio of PDMS prepolymer and curing agent is crucial to be able to smoothly peel the blocks from the mold. A mixing ratio much greater than 10 : 1 resulted in elastic and flimsy blocks that ruptured during peeling. In contrast, 5 : 1 or smaller mixing ratios caused the blocks to tightly adhere to the SU-8 mold, resulting in block damage during forced extraction. However, when such an exceptional ratio is required, silanization of the mold may help facilitate the removal process.$^{16}$ Note that, since the SU-8 grid walls are very robust, the removed PDMS blocks have clean and flat vertical edges on their sides.

To assemble MABs into a working microfluidic device, the selected blocks are aligned on a substrate in accordance with the user’s design. We investigated two types of substrates; a bare glass slide and a PDMS-coated glass slide. While PDMS-coated substrates may allow for slightly stronger bonding, they tend to get dirty easily when exposed to non-cleanroom
Table 2 Various bonding strategies for assembly of MABs

<table>
<thead>
<tr>
<th>Bonding methods</th>
<th>Difficulty level</th>
<th>Bare glass substrate</th>
<th>PDMS coated glass substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inherent adhesion only</td>
<td>Easiest</td>
<td>Reversible weak</td>
<td>Reversible very weak</td>
</tr>
<tr>
<td>Application of PDMS mixture (10:1)</td>
<td>Easy</td>
<td>Irreversible moderate</td>
<td>Irreversible moderate</td>
</tr>
<tr>
<td>Application of PDMS curing agent</td>
<td>Easy</td>
<td>Irreversible moderate</td>
<td>Irreversible strong</td>
</tr>
<tr>
<td>Application of UV-curable glue</td>
<td>Medium</td>
<td>Reversible strong</td>
<td>Reversible strong</td>
</tr>
<tr>
<td>Oxygen plasma treatment</td>
<td>Difficult</td>
<td>Irreversible moderate</td>
<td>Irreversible very weak</td>
</tr>
</tbody>
</table>

environments. Note that it is crucial to minimize the unavoidable gaps. With simple tweezer manipulation, fairly good contact between blocks (inter-block gap less than 5 μm) could be repeatedly achieved within seconds (Fig. 2d). Visual aids such as a stereoscope are not necessary but may facilitate the alignment procedure.

In addition to the bonding between the blocks and the substrate, the inter-block bonding should be hermetic to prevent liquid loss. Since the side interfacial area of each MAB available for bonding is small, the inherent adhesion on the sides of each MAB is not the major component for block-to-block adhesion, even if two adjacent blocks may have formed gapless contact. The substrate–block bonding and the elastic nature of the PDMS combine to add an additional horizontal compressive force to seal the component connections.

The loss of liquid from the channels is an important consideration in this and all PDMS devices. Even if every connection between blocks is hermetic, evaporation will still occur by diffusion through the top membrane of the channel. To address the time elapsed in evaporation through the PDMS, we introduced a dimensionless diffusion time to directly compare the evaporation results from various devices with different device thicknesses. The dimensionless time, $\tau$, is defined as,

$$\tau = \frac{t D}{h^2}$$  (1)

In the above equation, $t$ is the elapsed time, $D$ is the estimated diffusion coefficient of water vapor through PDMS membrane ($D \sim 10^{-3}$ mm$^2$ s$^{-1}$), and $h$ is the membrane thickness corresponding to the difference between the device thickness and the channel thickness ($h$ ranges from 300 to 1100 μm). To address leakage out of imperfections in block-to-block bonding, we used a ratio of exposed interface area per fluid volume (IF) as a parameter:

$$IF = \frac{\sum A_i}{V} \text{ where } A_i = g_i \times (w + 2d) \text{ and } V = hwd$$  (2)

In this equation, $A_i$ indicates the interfacial area exposed to air at the $i$-th junction and $V$ represents the total volume of fluid sample. $A_i$ is calculated using the average gap distance ($g_i$), the channel width ($w$), and the channel thickness ($d$). Likewise, the fluid volume is calculated from the drop length ($l$) of fluid sample and the channel dimensions. Larger IF values indicate more exposure to air at junctions. Fig. 3a shows the effect of inter-block gaps on the evaporation rate and confirms that the gaps introduced by the MAB assembly procedure have only a minor effect on the evaporation rate.

The inherent adhesion to the afore-mentioned substrates is reversible and can withstand inside pressures up to 5 psi, a pressure high enough to perform pneumatically driven flow...
Table 3 Various block shapes and the characteristics of their assembly

<table>
<thead>
<tr>
<th>Fabrication</th>
<th>Plain Squares</th>
<th>Hexagons</th>
<th>Tabbed Tabs and indents</th>
<th>Jigsaw profiles</th>
<th>Pre-defined Alignment keys</th>
<th>Channelled base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block removal from the mold</td>
<td>Easy</td>
<td>Easiest</td>
<td>Medium</td>
<td>Difficult (narrow necks)</td>
<td>Medium</td>
<td>Medium (roof)</td>
</tr>
<tr>
<td>Base structure</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Cross alignment posts</td>
</tr>
<tr>
<td>Assembly</td>
<td>Square tile</td>
<td>Honeycomb</td>
<td>Non-square tile</td>
<td>Jigsaw puzzle layout</td>
<td>Pre-defined polygonal slots</td>
<td>Pre-defined square slots</td>
</tr>
<tr>
<td>Block alignment</td>
<td>Square tile layout</td>
<td>Honeycomb layout</td>
<td>Non-square tile layout</td>
<td>Jigsaw puzzle layout</td>
<td>Pre-defined polygonal slots</td>
<td>Pre-defined square slots</td>
</tr>
<tr>
<td>Interface</td>
<td>Short</td>
<td>Short</td>
<td>Medium</td>
<td>Long</td>
<td>Medium</td>
<td>Long</td>
</tr>
<tr>
<td>Sealing</td>
<td>Good</td>
<td>Good</td>
<td>Medium</td>
<td>Poor</td>
<td>Medium</td>
<td>Best</td>
</tr>
</tbody>
</table>

Fig. 4 Photos of (a) the fabricated mold for the cross alignment key system, (b) the assembled device, and (c) a fluidic test. Photos of (d) the fabricated mold for the roofed blocks (left) and the channeled base (right), (e) roofed blocks and (f) a fluidic test on an assembled device. The black dashed line in (f) represents the square roof of one aligned block while the white dashed line indicates the interface between a base and a block under the roof.

Fig. 5 (a) Demonstration of the valve module working in an assembled device. A drop of an orange solution is placed at the left inlet while a blue drop is placed at the right inlet. When both valves are closed, both the orange and blue drops will not move. (b) When the right valve is open in the presence of applied vacuum, the blue solution passes through the valve to the outlet where the suction exists. As the valve is closed, a portion of the fluid will stop and not be drawn further. (c) After the left valve opens, the orange solution is drawn to the outlet. (d) When both valves are open, both solutions are aspirated.

experiments in typical biochemical studies. The bonding to bare glass slides and PDMS-coated slides could withstand 3–5 psi and 4–6 psi, respectively. In addition to such inherent adhesion, we also investigated a number of other bonding techniques (Table 2). We used three adhesive substances (the PDMS mixture used to fabricate the blocks, the PDMS curing agent, and a UV-curable glue) to increase the block-to-block bonding. When placed around the device in contact with the blocks, the adhesive substances flow into the interfacial gap between the device and the substrate due to capillary action. Curing the adhesive then resulted in strong bonding between the surfaces (Fig. 2e). All of the devices treated with those adhesives could withstand inside pressures of >30 psi for 30 min. Interestingly, using the curing agent as the adhesive appeared to exhibit another advantage of further reducing the evaporation rate as shown in Fig. 3b. Apparently, the curing agent produced denser cross-linking during polymerization than the 9 : 1 PDMS mixture.

Block shapes

Modifications in block shapes can further change their fabrication and assembly characteristics. The square block system proposed in this study has several obvious strengths in its application, the greatest of which is that the fabrication, mold design, and block removal is straightforward. Moreover, since there are no features added to the block for such purposes as alignment, the entire block surface area can be used for fluidic structures, thus minimizing dead volume. Additionally, these square blocks are designed to have minimal interface area when two blocks are connected. As the interface area decreases, the assembly will be more straightforward and thus require less elaborate techniques to bond. The sides of square blocks are easy to clean, minimizing the effects of residual polymer and common dust.

Nevertheless, one drawback of the assembly methodology with plain square blocks rather comes from the lack of alignment keys. Slight deviations in just a few blocks may cause an overall alignment problem, especially for a large assembly task. Another applicable method for improved assembly is to constrain the blocks in pre-defined areas. The areas are created in PDMS by separately constructing a base structure that can carry a certain number of blocks. Fig. 4a–c show one of the block-and-base approaches using cross-shaped alignment posts in PDMS. Such alignment posts tightly confine the block position to enhance alignment.
Fig. 6  *E. coli* cell culture in the MAB assembled device. (a) Plot of cell concentration versus culture time. (b) Photos of the grown cells in the device at different culture times. (i) 0 min, (ii) 20 min, (iii) 65 min, and (iv) 100 min, respectively.

Fig. 7 Exemplary systems for complex biochemical assays. (a) A conceptualization of a molecular gradients generator using the zigzag channel modules and other MABs that can generate five different concentration levels of the two-sample mixture. (b) Demonstration of a simpler system that mixes the blue dye and water into the outgoing stream with three different concentration levels. (c) The cross-sectional profile of blue dye concentrations at A-A' showing the concentration gradients.

Applications

We have used MABs to prototype a variety of microfluidic devices. In addition to fluidic channels, a common component used in microfluidic systems is a PDMS pneumatic valve to control fluid flow.\(^\text{18}\) We developed an MAB of two square-block size containing a microvalve that was designed according to previous reports.\(^\text{19,20}\) Fig. 5a–d demonstrate the use of working valve blocks; the valve in this MAB is closed at rest and open when vacuum is applied. Since the valve always accompany a connection port to a vacuum source, a valve and an inlet have been modularized together (see the electronic supplementary information).\(^\text{†}\) To verify its function when embedded in a device, we demonstrated a simple mixing channel network consisting of three inlet/outlet blocks, a Y-channel block, and two valve modules. When the valve is open, fluid passes through the valve to the outlet where a vacuum is applied. With the valve closed, no fluid flows, although a portion of the fluid sample will remain since the closed valve will not prevent complete liquid evacuation. After the valve opens again, the fluid resumes to the designated areas, the blocks will not be properly inserted; on the other hand, if the blocks are smaller, inter-block gaps will be problematic. More block shapes such as hexagons and jigsaw puzzles were also tested and analyzed in the electronic supplementary information.\(^\text{†}\) Various block shapes and their assembly characteristics are summarized in Table 3.
be drawn to the outlet. Such valve modules can be assembled with any components in the device where precise fluid control is needed and thus provide flexibility in designing complex custom devices.

As another example, we used MABs to construct a microculture system for bacterial cells. The system used two inlet blocks for sample/media injection and a cell culture module occupying the space corresponding to six square blocks. Fig. 6a shows the successful culture results of E. coli cells in the assembled microculture system. Increases in the number of grown cells were clearly shown in Fig. 6b.

In a microscale environment, the addition of two streams in laminar flow results in a clean boundary between streams. A complex system using the zigzag modules to generate molecular gradients is conceptualized in Fig. 7a. To show the working principles of such assembly, a simpler system is illustrated in Fig. 7b. The cross-sectional profile in Fig. 7c shows a distinct gradient of blue dye concentrations at A-A′. For the device, two inlet MABs were used in conjunction with a Y-channel block for merging two streams, zigzag channel modules, and an outlet block. The use of MABs can also be extended to complex biochemical assays. The conceptualized large-scale integration in Fig. 8a illustrates a system that can perform twenty independent assays simultaneously from one sample. An independent assay unit similar to that in the above integrated device is shown in Fig. 8b. Each unit device can perform reagent mixing, PCR, restriction digest reaction, and a separation.

Conclusions

The MAB system provides a simple way for non-fluidic researchers to construct custom, complex microfluidic devices. There are several unique advantages of the MAB approach for microfluidic device constructions. The MAB approach is ideal for selective surface modification or treatment limited to a specific section of the total device. Besides, there are no intrinsic limits in the channel thickness and the feature size. The MABs fabricated in PDMS exhibit enough durability that the blocks could be used multiple times. Most importantly, the developers of MAB can manufacture a standard set of MABs that can be assembled into various custom devices. The MAB allows for full flexibility in planar configuration. The exemplary assembled devices demonstrated that the technology can be able to be used in a wide variety of applications. Non-expert users can practically mix and match the blocks to build their device with any configuration. Consequently, the proposed MAB methodology would be suitable for the recent needs since such devices with a simple configuration can be constructed within minutes in a regular laboratory environment.

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