DEVELOPMENT OF A MICROFLUIDIC GAS GENERATOR FROM AN EFFICIENT FILM-BASED MICROFABRICATION METHOD

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Recently, tape&film based microfabrication method has been studied for rapid prototyping of microfluidic devices due to its low cost and ease of fabrication [1]. But most of the reported film-based microfluidic devices are simple single-layer patterned 2-dimentional (2D) designs, whose potential applications are limited. In this paper, we present the design, fabrication and testing results of a 3-dimentional (3D) structured microfluidic gas generator prototype. This gas generator is used as an example to introduce our new approach of film-based fabrication method towards lab-use microfluidic research, which usually requires constant change of design and prefers low fabrication cost and short fabrication period. The prototype is a film-based comprehensive microfluidic gas generator which integrates self-circulation, self-regulation, catalytic reaction, and gas/liquid separation. Time and economy efficiency are the biggest merit of this method. The only required facility during the whole process is a digital craft-cutter.

The working principle of the device is illustrated in Fig.1 [2]. The film-based prototype is an alternate version of the silicon-based self-circulating self-regulating gas generator developed by Meng [2]. Fig.2 shows the schematic of the film-based prototype. It consists of 15 layers of films, tapes, glass slide, tubing connectors, and cube supporting. As shown in Fig.3, the prototype device was obtained by sequentially aligning and stacking multiple layers of patterned films and double-sided Kapton tape. The patterns were obtained by a digital craft-cutter from CAD drawings. The 3D structure was made from both the pattern and the thickness of the layer material, as shown in Fig.4. Besides, functional features can be easily added into the device. For instance, Pt-black was partially sprayed on the tape layer for catalytic reaction using a shadow mask, and nanoporous membrane was cut in the desired shape and stack-placed in position as the gas/liquid separator. The self-circulating and self-regulating functions were achieved by capillary force difference in different channels as shown in Fig.4, which can be achieved by fabricating different channel depths and treating the surface of certain channel into hydrophilic and leave others hydrophobic. The treatment for polystyrene (PS) film was achieved by spraying Lotus Leaf® hydrophilic coating or using oxygen plasma machine [3].

The fabricated device was tested with H_2O_2 solutions (for O_2) and NH_3BH_3 solutions (for H_2) at different concentrations (Fig.5). A pressure difference (1 psi) was applied across the gas/liquid separation membrane to provide better venting. The gas generation profiles are shown in Fig.6 and the summarized characteristics is given in Table 1. The generated gas flow rate is measured by a gas flow meter, and liquid pumping rate measured by monitoring the movement of a liquid/gas meniscus. Fig. 6 shows that higher reactant concentration causes higher gas generation rate. The fluctuation of gas generation rate is due to the pulsatile pumping of this self-pumping mechanism. It is expected that designs with multiple parallel channels can make the gas generation profile smooth due to the interactions among the channels. Detailed characterization results and discussion on reaction kinetics and pumping dynamics in the microfluidic reactor will be reported.

Word Count: 498

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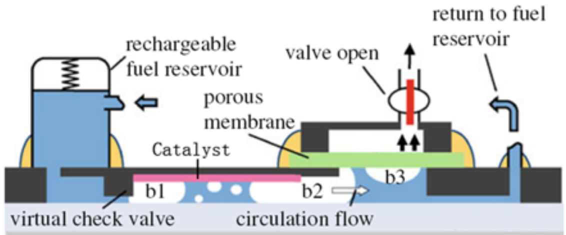


Figure 1. *Schematic of the device working principle* [2]. *When reactant solution comes into contact with the catalyst, the generated gas bubble (b1) will be pushed rightward due to the check valve, thus pushing everything in the reaction channel rightward. When the bubble (b2) reaches the hydrophobic porous membrane, it will be dragged rightward due to hydrophilicity difference and be vented out (b3) and collected. Therefore, self-circulation in the device is achieved and new reactant solution will be pumped into the reaction channel to react until the valve is closed which will cause a self-regulation.*

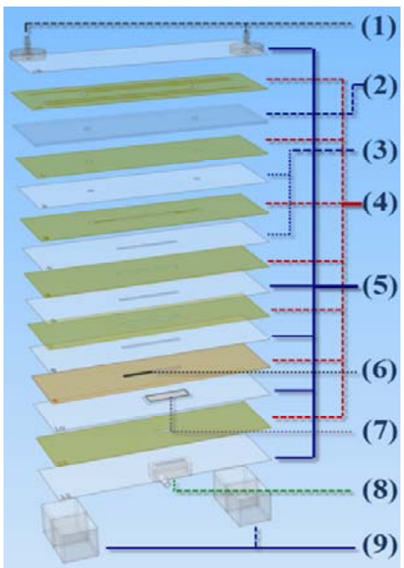
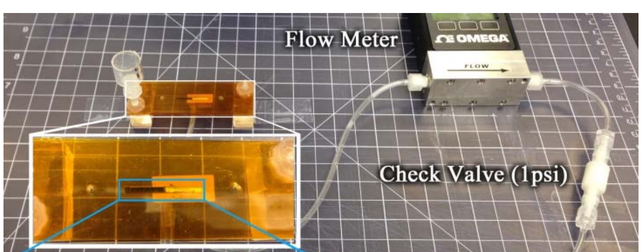


Figure 3. *BOM view of the design. (1)Tubing connector for inlet and outlet. (2)Glass slide with two drilled holes. (3)PS film (50 μm). (4)Double-sided tape (70 μm). (5)PS film (125μm). (6)Pt-black catalyst. (7)Nanoporous hydrophobic membrane for gas/liquid separation. (8)Gas collector. (9)Tube supporting*



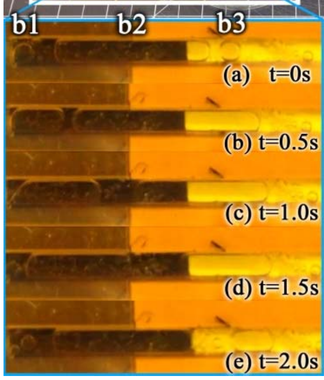


Figure 5. *Test setup and result (H_2O_2 8%). A reaction segment of 2s long is shown here. In the picture, the newly generated bubble (b1) expands and pushes b2 rightward, and at the same time, b3 is vented out which creates a rightward dragging force. This provides additional rightward pumping force which keeps the process going repeatedly.*

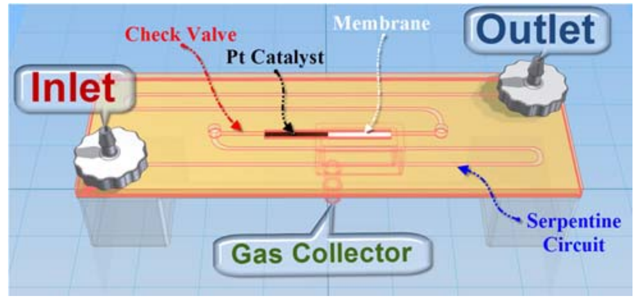


Figure 2. *Schematic of film-based microfluidic gas generator. The device is made by aligning and stacking multiple layers of patterned films and tapes, thus 3D structured channels are achieved. The serpentine circuit on the top layer is specially designed to visually measure the self-pumping rate of this single-channel gas generator. Pt catalyst layer and hydrophobic nanoporous membrane are imbedded in the device as well.*

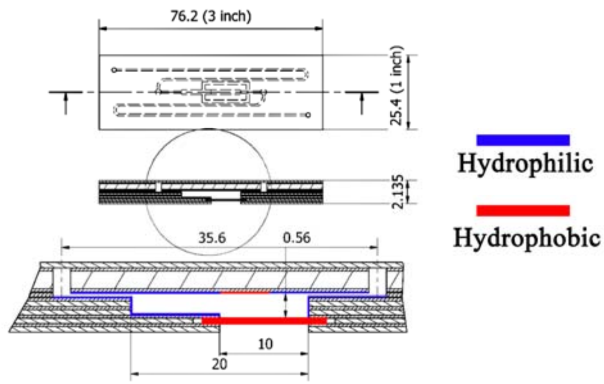


Figure 4. *Sectional schematic of the device. Overall dimension of the main body is 76.2×25.4×2.135 mm, the dimension of the Pt reaction channel is 1×10×0.585 mm . The interior of the reaction channel is specially treated to be partially hydrophilic and partially hydrophobic in order to achieve self-pumping.*

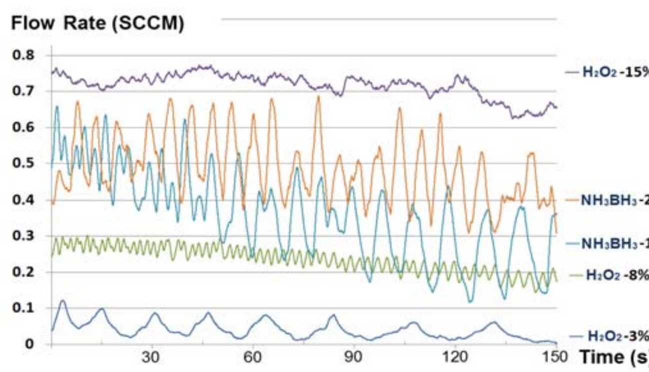


Figure 6. *Gas generation profiles for different reactants.*

Table 1. *Gas generation characteristics of the device*

Generated gas type	Reactant solution concentration (%)	Average gas generation rate in the first 150s (SCCM)	Liquid self pumping rate (μL/s)
O_2 (From H_2O_2)	3	0.038	0.075
	8	0.235	0.348
	15	0.720	0.819
H_2 (From NH_3BH_3)	1	0.361	0.512
	2	0.491	0.602
	4	0.525	0.623