MICROFLUIDIC FABRICATION OF BIO-ACTUATORS DRIVEN BY ARTIFICIAL MUSCLES MADE FROM MOLECULAR MOTORS

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ABSTRACT

In this paper, we developed a microfluidic chip based method for fabrication of bio-actuators driven by artificial muscles made from molecular motors. Different from conventional complex methods, we integrates the fabrication and actuation of bio-actuators into a single microfluidic chip using UV-induced projection printing with a maskless optical system. A micro-gripper was fabricated and actuated in a microfluidic chip as an example of application. This low-cost and easy-operated method is able to make different kinds of bio-actuators for microfluidic devices.

KEYWORDS: Microfluidics, Bio-actuator, Molecular motor, Artificial muscle

INTRODUCTION

Actuators are very important components in microfluidic systems to regulate fluid flow or perform manipulation tasks. Over the past decades, micro-actuators based on various actuation mechanisms have been developed. As one of the most rapidly emerging technologies, bio-actuators which are driven by biological material such as living cells and tissues, have shown their unique advantages [1]. However, such bio-actuators suffer from high-cost and complex fabrication due to the strict environmental requirements of biological materials, limiting their practical application. Recently, molecular motors, which convert chemical energy into mechanical work with better robustness than cells, were considered as potential materials to make low-cost bio-actuators for microfluidic devices.

THEORY

In our previous research, we succeeded in assembling molecular motors into contractive artificial muscles in designed shape through UV lithography [2]. The principle is presented in Figure 1: Two genetically-modified proteins, CaMLMM, a fusion protein of calmodulin (CaM) and light meromyosin (LMM), and K465m13, a fusion protein of kinesin-1 and calmodulin binding sequence m13, are used to enable the optical activation. Upon UV irradiation, Ca^{2+} is released by photolabile chelator, making K465m13 incorporated into the CaMLMM filament to form filaments similar to myosin filaments, which bridge microtubules and make them self-assemble together. As a result, a muscle-like contracting network of motor proteins are formed in UV irradiated area, which can wrap around the pillars in this area and generate a considerable tension between them.

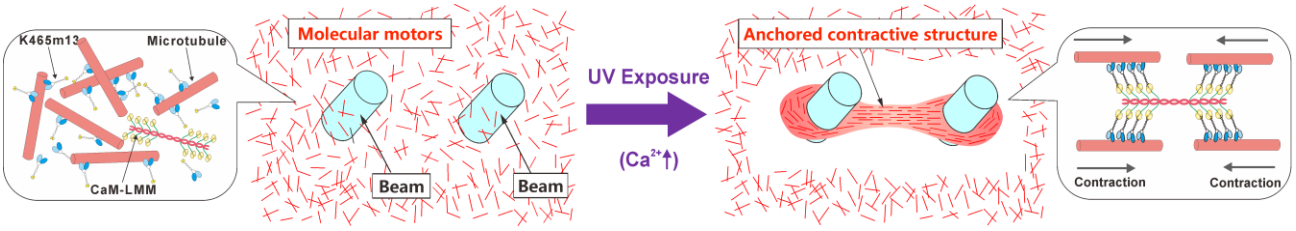

Figure 1: Schematic view of artificial muscles assembled from motor proteins.

EXPERIMENTAL

Based on this printable artificial muscle, we developed a new method and system to easily make bio-actuators for microfluidic devices. The system was composed of a railed microfluidic chip and a maskless UV lithography system using digital micromirror device (DMD), as shown in Figure 2. Bio-actuators could be fabricated and actuated in microfluidic chip through the following processes: First photocurable hydrogel preplymer was introduced into the fabrication area. By aid of the custom-designed micro channel, 3D hydrogel microstructures, with a thin forced part and a fin in the rail, was printed by UV lithography (Figure 2(a)). Then the fabricated structure was rail-guided to the actuation area, where extra space was designed between the forced part and the

micro channel to make the forced part better anchored with artificial muscles. Molecular motors, CaMLMM, K465m13 and microtubule, were mixed in the micro chan nel and introduced into the actuation area. Finally, artificial muscles were printed in certain area and drove the structure to perform specific functions (Figure 2(b)).

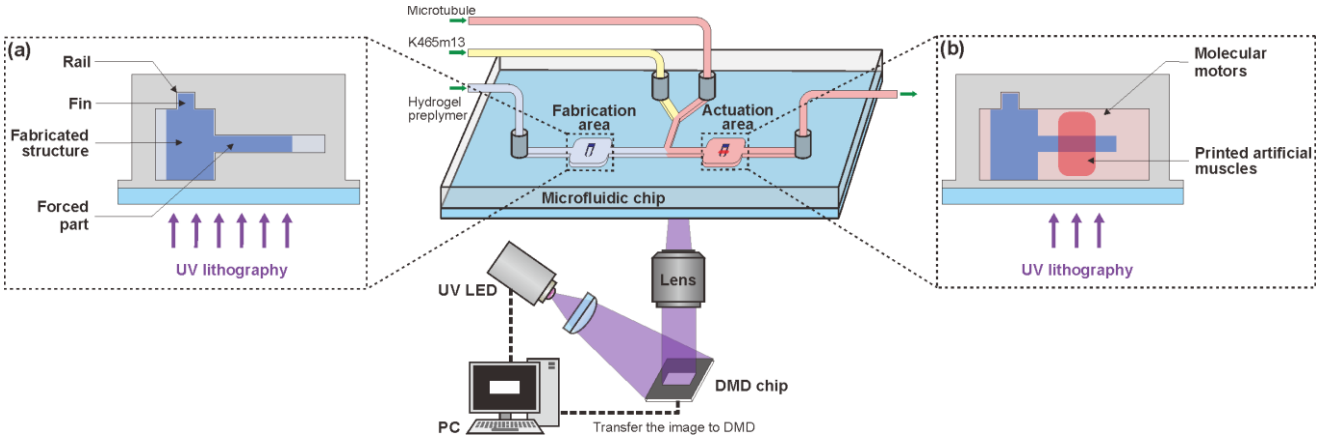

Figure 2: Fabrication and actuation of bio-actuators in microfluidic chip.(a) Polymerization of 3D hydrogel structure in multi-layered micro-channel. (b) Assembling of artificial muscles after rail-guided delivery of fabricated actuator.

RESULTS AND DISCUSSION

Micro grippers are always used in microfluidic devices for micromanipulation of mechanical and biological objects. The proposed method and system were demonstrated by fabricating and actuating a micro gripper in microfluidic chip. Figure 3(a) shows the design size of the micro gripper, which had two notched arms to be anchored with artificial muscles and a fin in the rail. Figure 3(b) is the SEM image of the fabricated micro gripper. The actuation process of the micro gripper is described in Figure 5(c): After UV illumination, artificial muscles were soon formed in the rectangle area and drove the arms to approach. The gap between arm tips was reduced to the minimum within 30s. Therefore, micro objects can be caught by the arm tips and delivered with the micro gripper. The results demonstrated that through this method, various kinds of bio-actuators could be easily fabricated and actuated in microfluidic chips. We believe this technology will contribute a lot to the development of microfluidics.

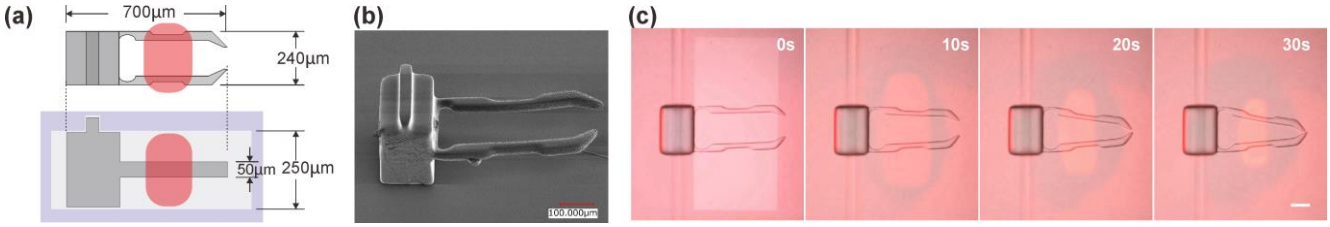

Figure 3: (a) Schematic design of the micro-gripper and the actuation channel. (b) SEM image of the fabricated micro-gripper. (c) Actuation of the micro-gripper by printed artificial muscles. Microtubules were stained by Rhodamine dye and fluorescence images and bright-field images were merged (scale bar = 100 μm).

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