GENERATION OF MULTI-HELICAL MICROFIBERS AND MARBLE MICROBEADS USING ORBITAL-ROTATION AND AXIAL-SPIN CENTRIFUGE

Shoya Yasuda[1], Masayuki Hayakawa[1], Hiroaki Onoe[2], and Masahiro Takinoue[1, 3*]

[1]*Department of Computational Intelligence and Systems Science, Tokyo Institute of Technology, JAPAN*

[2]*Department of Mechanical Engineering, Keio University, JAPAN*

[3]*PRESTO, JST, JAPAN*

ABSTRACT

We developed a centrifugal microfluidic method for the construction of multi-helical hydrogel microfibers and marble hydrogel microbeads. In this method, we used a centrifugal mixer that can rotate a capillary-based microfluidic device by both 'orbital rotation' and 'axial spin'. By the axial spin, hydrogel fibers were twisted in their generation. We demonstrated this system was also applied to construction of marble microbeads. We believe that this method will promote the construction of complex three-dimensional micro-materials and will be applied to cell manipulation, material synthesis, etc.

KEYWORDS: Hydrogel, Helical microfiber, Centrifuge-based device, Centrifugal mixer

INTRODUCTION

Recently, hydrogel microfibers have attracted much attention because of the advantages of stability, modifiability, encapsulation ability of molecules and cells, biocompatibility, etc. Especially, a remarkable application of hydrogel microfibers is three-dimensional (3D) tissue engineering[1]. To fabricate and control complex 3D structure of tissues, an easy-to-use construction method to generate hydrogel microfibers with complex structures is desired. Here, we report a simple centrifugal microfluidic method for the construction of multi-helical hydrogel microfibers.

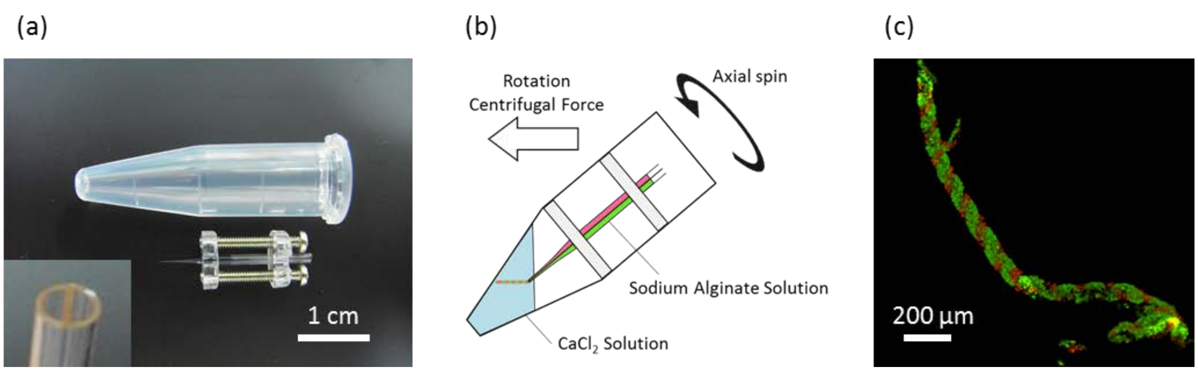

Figure 1: Device pictures, schematic illustration of the method, and generated helical microfibers. (a)1.5 mL micro tube and θ capillary inserted holder. Inner box is the enlarged picture of cross section of a θ capillary. (b)Schematic image of centrifuge-based fiber extruding system. (c)3D reconstructed fluorescence image of double-helical microfibers.

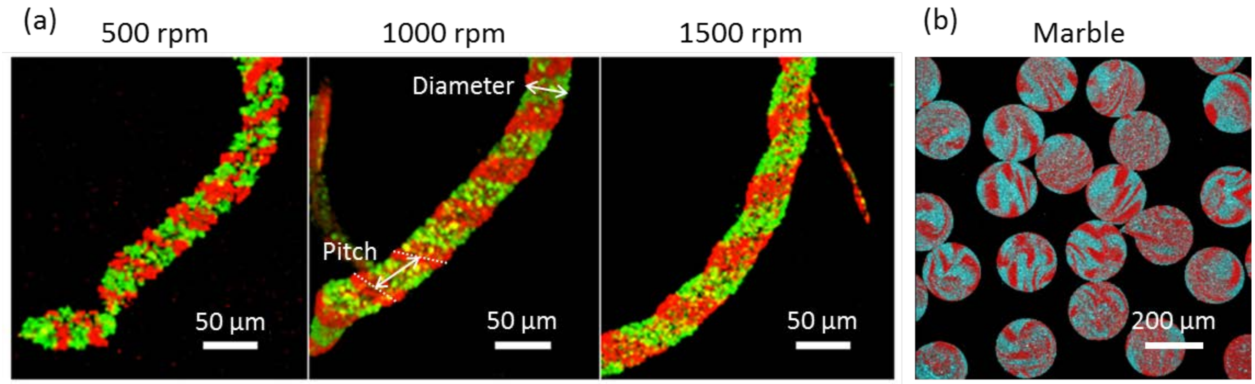

Figure 2: (a)Control of helical pitch by the angular speeds of orbital rotation and axial spin. Definition of the pitch p is shown in the picture of 1000 rpm. (b)Generated marble microbeads. In this experiment, the tip of glass capillary was not soaked in $CaCl_2$ solution.

EXPERIMENTAL

The method is based on a capillary-based centrifugal microfluidic device[2] (Fib.1a). We applied the device to a centrifugal mixer that can rotate the device by both orbital rotation and axial spin (Fig.1b). By the orbital rotation, a sodium alginate solution in a capillary was pushed out; simultaneously, the axial spin relatively twisted the flow-out solution against the capillary. Centrifuging step was finished in 10 minutes and generated microfibers were observed by fluorescence microscope; since different colored fluorescence nanobeads were contained in each sodium alginate solution.

RESULTS AND DISCUSSION

As a result, we obtained double-helical microfibers (Fig.1c). To investigate the generation mechanism, we quantified the diameter and helical pitch of the fibers; you can see the diameter and the definition of the pitch in Fig.2a. The diameters of the generated microfibers were approximately the same as the inner diameters of capillaries. In addition, the pitches of the generated microfibers increased with angular speeds of the orbital rotation (Fig. 2a). By using this system, we obtained triple-helical microfibers from a triple-barreled glass capillary, and sextuple-helical microfibers from a septuple-barreled glass capillary. These results suggest that arbitrary multi-helical microfibers can be generated in principle. Finally, we applied this system to the construction of marble microbeads (Fig.2b). In this experiment, the tip of the glass capillary was not soaked into the gelation agent ($CaCl_2$ solution); thus, at the tip of the capillary, a highly-viscous sodium alginate droplet like starch syrup was twisted many times, and hydrogel microbeads with a marble pattern were generated.

CONCLUSION

We developed a simple generation method for multi-helical microfibers and marble microbeads. We believe that these hydrogel materials with complex 3D structures will be applied to more sophisticated tissue engineering and highly-functional micromachines such as molecular robots.

ACKNOWLEDGEMENTS

We thank Dr. Ken Nagai (JAIST), Dr. Masamune Morita (Tokyo Tech.) and Mr. Hao Li for helpful discussions. This work was supported by a Grant-in-Aid for Scientific Research on Innovative Areas "Molecular Robotics" (No.24104002) to M.T. from The Ministry of Education, Culture, Sports, Science, and Technology (MEXT), a Grant-in-Aid for Challenging Exploratory Research to M.T. and H.O. (No.24651159), a Grant-in-Aid for Scientific Research (B) to M.T. and H.O. (No.26280097) from the Japan Society for the Promotion of Science (JSPS).

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CONTACT

*Masahiro TAKINOUE, Department of Computational Intelligence and Systems Science, Tokyo Institute of Technology, 4259-G3-53 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8502, JAPAN
Tel/Fax: +81-45-924-5680, E-mail: takinoue@dis.titech.ac.jp