Shape-Controlled Synthesis of Degradable Polymeric Microfibers

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Introduction: Gelatin is an inexpensive, neutral, water-soluble, non-toxic, and FDA-approved biopolymer with excellent biocompatibility, biodegradability, and cell adhesiveness, which is extensively used in medical products, such as wound dressings, drug delivery systems, and tissue engineering. Recently, microfluidic device based fiber fabrication method has been recognized as an efficient method for the fabrication of micron-sized fibers due to its low-material consumption, conventional volume and size control, enhanced reaction rate, and inexpensive tooling costs. Comparing with other fiber fabrication methods, microfluidic method has a unique advantage that can create fibers with a range of cross-sectional shapes. The shape of the core is a function of the flow rates and the types and numbers of shaping elements in the channel walls, such as various grooves. However, to the best of our knowledge, there still has no study on fabrication of biocompatible gelatin fibers by microfluidic method.

Materials and Methods: A microchannel with four chevron-type grooves was utilized for fabricating the microfibers. The core solution is prepared as follows: 100 mL of DMSO was heated to 50 ^{o}C within 20 min, and then 8~12 wt% of gelatin powders were added into the DMSO solution under vigorous stirring. After stirring for 12 hours, the mixture was cooled to room temperature. Absolute ethanol was used as sheath solution in this work. The sheath-to-core flow-rate ratios were set to be 1500:5 µL/min (300:1), 1500:10 µL/min (150:1), 1500:20 µL/min (75:1), and 1500:50 µL/min (30:1).

Results and Discussion: The formation process of fiber can be explained as follows: firstly, the DMSO solution can be dissolved in ethanol by the mixing of core and sheath solution. Then, the gelatin is condensed into fiber structure due to its indissolubility in ethanol. In this work, to highlight the versatility of this fabrication process, we generated fibers using core solutions with various gelatin concentrations in DMSO solvent. The viscosity of core solution increases from 446 to 5140 cP by the increase of gelatin concentration from 8 % to 12 %, which significantly changes the fiber morphology from smooth to rough and cross section from round to square. Moreover, the mechanical properties of gelatin fibers are significantly improved by the increase of gelatin concentration, the Young's modulus and tensile stress at break of gelatin (12 %) fiber are raised about 2.2 and 1.9 times as those of gelatin (8 %) fiber. On the other hand, with the decrease of flow-rate ratio between sheath and core from 150:1 to 30:1, the ribbon-shaped gelatin fibers can be obtained, and the fiber dimensions (height × width) remarkably increase from 35 µm × 60 µm to 47 µm × 282 µm. The experiment results fit well with the simulation results in terms of shape evolution. The novel cross sections of gelatin fiber are beneficial to enhance the Young's modulus, tensile stress at break, and tensile strain at break.

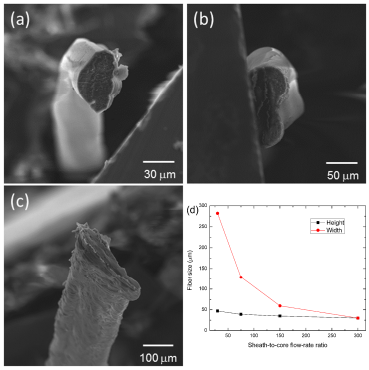

Figure 1. SEM images of gelatin (9 %) microfibers fabricated by sheath-to-core flow-rate ratios of (a) 150:1, (b) 75:1, and (c) 30:1. (d) Cross-sectional dimensions of the gelatin fibers as a function of the sheath-to-core flow-rate ratios in the microfluidic device.

Conclusions: The gelatin fibers with controlled size and shape are fabricated by microfluidic device using gelatin dissolved DMSO solution as core solution and ethanol as sheath solution. The viscosity of core solution increases from 446 to 5140 cP by the increase of gelatin concentration from 8 % to 12 %, which significantly changes the fiber morphology from smooth to rough and cross section from round to square. On the other hand, with the decrease of flow-rate ratio between sheath and core from 150:1 to 30:1, the ribbon-shaped gelatin fibers can be obtained, and the fiber dimensions (height × width) remarkably increase from 35 µm × 60 µm to 47 µm × 282 µm. The experiment results fit well with the simulation results in terms of shape evolution.

References: Z. Bai, JMM. Reyes, R. Montazami, N. Hashemi, J. Mater. Chem. A 2014, 2, 4878.