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Supporting Information

On-Chip Development of Hydrogel Microfibers from Round to Square/Ribbon Shape

Zhenhua Bai,[a] Janet M Mendoza Reyes,[b] Reza Montazami[a] and Nastaran Hashemi*[a]

[a] Department of Mechanical Engineering, Iowa State University, Ames, IA 50011, USA.E-mail:

nastaran@iastate.edu

[b] Department of Computer Engineering, University of Puerto Rico, 00681, Puerto Rico

Experimental Section

Chemicals and materials: Type-A gelatin, dimethyl sulfoxide, and absolute ethanol were purchased from Sigma-Aldrich. The channel component, poly(methyl methacrylate) (PDMS) was made from Sylgard 184 Elastomer Base and Curing Agents that were purchased from Dow Corning Corporation, Midland, MI.

Microfluidic channel device design: A microchannel with four chevron-type grooves was utilized for fabricating the microfibers. The channel has a symmetric geometry with a single core inlet and two inlets for the sheath flow. The channel is made in two halves of PDMS. Briefly, PDMS pre-polymers were poured over two silicon wafers with defined channel geometry, and cured at 85 ^{o}C for 20 min. Then the PDMS layers were lifted off and one of them was punched holes for inlets and outlets of the fluids. Finally the two PDMS chips were bounded to each other by plasma-cleaning. As shown in Fig. S1, the channels were 130 μm in height and had a width of 390 μm. The chevron-shaped grooves were 100 μm wide by 65 μm deep and intersected the channel wall at 45 degrees.[1-3] The holes for core and sheath solutions were punched on the top layer to allow the solutions to flow into channels.

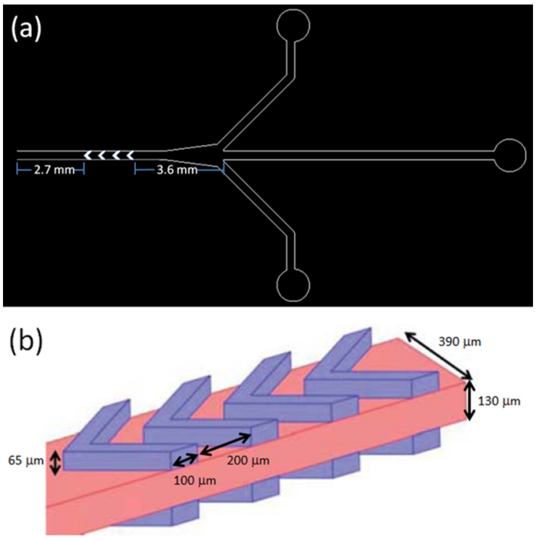

Fig. S1 The design of (a) microfluidic channel and (b) chevron-type grooves.

Gelatin fiber fabrication: 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 core and sheath solutions were loaded into 3 and 20 mL plastic syringes (BD Biosciences) and then introduced to the channel using a double syringe pump (Cole-Parmer, Veron Hillss, IL). 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).

Computational model: The simulations of fiber shapes at various core and sheath flow rates were carried out using the COMSOL Multiphysics (COMSOL, Inc., Burlington, MA) software. Steady-state solutions of incompressible Navier–Stokes flow were coupled with the convection and diffusion module to investigate the profile of the core stream. A single-phase fluid model was applied throughout. The flow field was solved first for each simulation, and the solution obtained was then used to calculate the concentration profile of the fluids in the system, producing an image of the cross-section of the core stream. An adaptive meshing technique was utilized for the simulation of convection and diffusion. The wall boundaries are set to "no-slip" which is the default boundary condition for a stationary solid wall. The outlet boundaries are set to "Pressure, no viscous stress". This boundary condition is physically equivalent to a boundary that is exiting into a large container. It is numerically stable and states total control of the pressure level along the entire boundary.

Characterization: The structural properties of prepared products were characterized by a field emission scanning electron microscopy (FE-SEM) (JSM-6700F at an acceleration voltage of 5 kV). To image the cross-sectional shape, the fibers were cut with a sharp razor. The viscosities of gelatin in DMSO solution at various concentrations were measured using a digital viscometer (DV-E, Brookfield Engineering Laboratories, Inc., Middleboro, MA). The tensile testing of the mechanical properties of gelatin fibers were performed with an Instron Universal Testing machine (Model 5569, Instron Engineering Corp., Canton, MA) at an extension rate of 50 mm/min using a 2 kN load cell. The strain in the sample was measured by keeping the fiber length of 20 mm between the clamps. The Young's modulus was measured at 0.1–0.5% strain using the Bluehill software supplied with the machine.

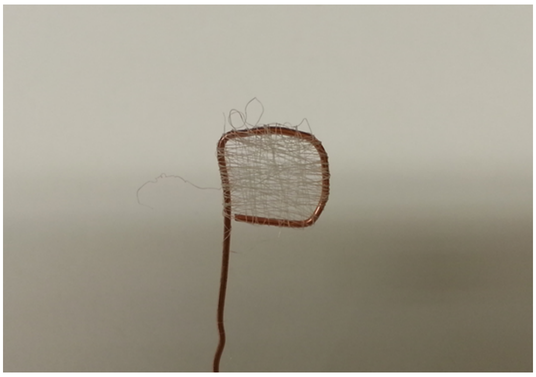

Fig. S2 Photograph of gelatin microfibers fabricated by 11 % gelatin concentrations at the sheath and core flow-rates of 1500 and 10 µL/min, respectively.

References

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2. N. Hashemi, J. S. Erickson, J. P. Golden, K. M. Jackson and F. S. Ligler, *Biosens Bioelectron*, 2011, **26**, 4263-4269.
3. N. Hashemi, J. S. Erickson, J. P. Golden and F. S. Ligler, *Biomicrofluidics*, 2011, **5**.