Fabrication of different forms of chitosan-coated alginate fibers on a single microfluidic platform

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I. Introduction

For decades, researchers have used various tools to fabricate tissue-like biological constructs. Fibers make up most of human tissues, such as the extracellular matrix. The most common methods of creating fibers are electrospinning and microfluidic spinning. While some microfluidic systems may involve high voltage, the coaxial flow method used in this study is voltage-free, making the process safe and allowing the loading of cells, drugs, and proteins inside fibers without damage.

Alginate and chitosan are selected as the biopolymers in this study. Alginate is a popular natural hydrogel for fiber fabrication because of its low cost and high biocompatibility. Alginate and chitosan are commonly used together due to their electrostatic association.

Many techniques have been reported for fabricating alginate fibers. The solidification of fibers inside microfluidic channels makes fiber extrusion challenging. In addition, other methods require adjusting the device design to achieve different forms of fibers.

Aqueous two-phase systems (ATPS) have been used in numerous applications. To address the challenges outlined above, microfluidics is combined with ATPS. We introduce a spacer phase between alginate and crosslink agents to prevent immediate contact. Depending on the thickness of the spacer phase, the crosslinking agent must diffuse for a certain distance before reaching the alginate phase. As a result, we can control the rate of solidification. Moreover, ATPS allows us to fabricate different forms of fibers by adjusting only the inlet pressures.

II. Methods

The microfluidic platform is made using the standard soft lithography method. We utilize ATPS based on dextran and poly(ethylene) glycol as the base fluids. The ATPS phase separates into a dextran-rich (DEX) phase and a poly(ethylene) glycol-rich (PEG) phase, and generally, we utilize PEG and DEX as the basis of the fiber and continuous phases, respectively. We also dissolve 1.5% alginate in the innermost PEG phase of the microfluidic device. The innermost PEG phase is cladded by a DEX phase, which is then surrounded by an outer PEG phase that contains 2% barium chloride. Fibers form once the barium chloride from the outer PEG phase diffuses across the intermediate DEX phase and gel the innermost alginate-PEG phase. We modulate the pressure profiles in each inlet and change the ATPS fluids in the inlets to create solid, hollow, and droplet-filled fibers. Fibers are soaked for an hour in a 1% chitosan solution to form a thin chitosan coating around the fibers.

III. Results

We obtained experimental results from different pressure profiles at each inlet to obtain a phase diagram that indicates regimes leading to different types of fibers. Increasing the pressure of the first two inlets transitions the fiber-forming core fluid from backflow, to droplet-filled single threads, and then to continuous single threads. We can co-flow the two innermost fluids in the device by altering the pressure profile of the inlets. We also alter the overall fiber diameter by adjusting the pressure of the innermost inlet. Once cross-linked, continuous single threads, continuous co-flow threads, and droplet-filled threads, become solid, hollow, and droplet-filled fibers.

IV. Conclusion

This technique enables the fabrication of different forms of chitosan-coated fibers by using only one platform. In the future, we anticipate loading drugs into fibers, and applying the fibers to various tissue engineering applications.

References

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