ABSTRACT

 Elastomer-based microsystems hold great promise for a diverse range of applications such as rapid prototyping of lab-on-a-chip device, soft-MEMS, and soft-robotics. For better performance in such applications, unconventional elastomeric structures in terms of size, shape, and patterning trajectory, have been intensely sought after in microtechnology but their realization has been a continuous challenge. Here, as my dissertation work, I present new microfabrication schemes which enable the realizations of unconventional PDMS structures, and their applications, which will enrich the field of soft-microsystems.

First, I present a new fabrication scheme for the realization of cylindrical microfluidic (MF) channels with 3D trajectories based on shaping, bonding, and assembly of sucrose fibers. Due to the high water-solubility of the sucrose templates, the scheme is a simple and environment-friendly. Also, it is cleanroom-free and cost-effective. Despite its simplicity, it enables the realization of essential 3D MF channel architectures such as highly curved MF channels, internal loops, and proper end-to-side junctions. It can, also, realize tapered junctions and stenosis which can benefit vaso-mimetic lab-on-a-chip applications.

Secondly, as a practical application of the sucrose-based MF channel, I report the implementation of the *bokeh*-effect-based microfluidic microscopy scheme for point-of-care health monitoring in highly resource-limited environment. For this work, I integrated a single polymer microlens over the sucrose-templated MF channel and retrieved magnified intra-channel images with a commercial, off-the-shelf camera. The *bokeh* microscope exhibited 10∼40 in magnification and 67∼252 μm of field-of-view extent, confirming their utility for point-of-care monitoring of micro-scale objects in MF channels

Third, I present a new technique that enables facile fabrications of high aspect-ratio PDMS micropillars exceeding 2400 μm in height and 100 in aspect-ratio. The key enabling factor is the adoption of the direct drawing technique incorporated with the *in situ* heating for simultaneous hardening and solidification of PDMS. The technique also allows self-aligned installation of highly reflective microspheres at the tips of the micropillars. Using the transparent PDMS micropillar as a flexible waveguide and the microsphere as a self-aligned reflector, I transformed the microsphere-tipped PDMS micropillars into all optically interrogated air-flow sensors and successfully demonstrated its air-flow sensing capability.

Lastly, I present a microscale soft-robotic tentacle with spiral bending capability based on pneumatically driven bending motion of a hollow PDMS microtube. For this work, I establish a new, direct peeling-based technique for building long and thin, highly deformable microtubes and a semi-analytical model for their shape-engineering. Based on them, the artificial microrobotic tentacle exhibits the *multi-turn* spiraling motion with the final radius of 185 μm and squeezing force of ~ 0.78 mN. Thanks to the softness of PDMS and the spiraling motion, the micro-tentacle can function as a soft-robotic grabber of fragile micro-objects. The spiraling tentacle-based grabbing modality, the elastomeric microtube fabrication technique, and the concept of microtube shape-engineering will constitute very valuable additions to future microscale soft-robotics.