Robotic Microswimmers Powered by Ultrasound for Biomedical Applications

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Primary CNF Tools Used: Heidelberg mask writer-DWL2000, ABM contact aligner, scanning electron microscope (SEM)

Abstract:

Microrobotics, an interdisciplinary field that combines robotics, micro/nanotechnology, biomedical engineering, and materials science, paves a novel way for biomedical applications, such as targeted drug and/or cell delivery for cancer therapy. However, the technology itself is still at an infant stage before reaching the full potential for various biomedical applications. In this project, we are aiming to develop an untethered microrobotic swimmer that can be propelled and navigated in liquids using an external ultrasound. A challenging aspect of the project is to develop the nano-size flagellum that can be used to propel the robotic swimmers in fluids. As a first step of this project, we engineered a microcantilever that will be used as the micropropeller for the microswimmer. This SU-8 microcantilever was fabricated using a two-layer photolithography along with a sacrificial layer for releasing.

Summary of Research:

Robotic microswimmers, which have the capability to be propelled and navigated wirelessly in biological fluid, can open new doors for addressing very challenging issues in biomedical fields, such as targeted drug delivery. However, the size of microswimmers, which is usually smaller than one millimeter, made it difficult for on-board integration of components, such as batteries and motors. Hence, novel powering and propulsion mechanisms are demanded. Studies on using various untethered external power sources showed that magnetic and ultrasonic waves were the most promising candidates for *in vivo* applications. In contrast to magnetic actuation, ultrasonic wave has the advantages of low cost and long distance control. Here, we designed a simple microcantilever for the studies of cantilever fluid interaction, in particular, the fluid streaming behavior when the cantilever is under resonance. This study will lay a foundation for the micro-propeller design in future work.

To fabricate the microcantilever structure, we have developed a modified two-layer SU-8 process along with a sacrificial layer (PVA) release method. First, a two-layer SU-8 structure was fabricated on a PVA coated 4-inch silicon wafer by using the standardized alignment photolithography (Figure 1A). Here, the pattern of the bottom layer consists of the cantilevers and that of the top layer supporting structures for the cantilever. (See Figure 1A).

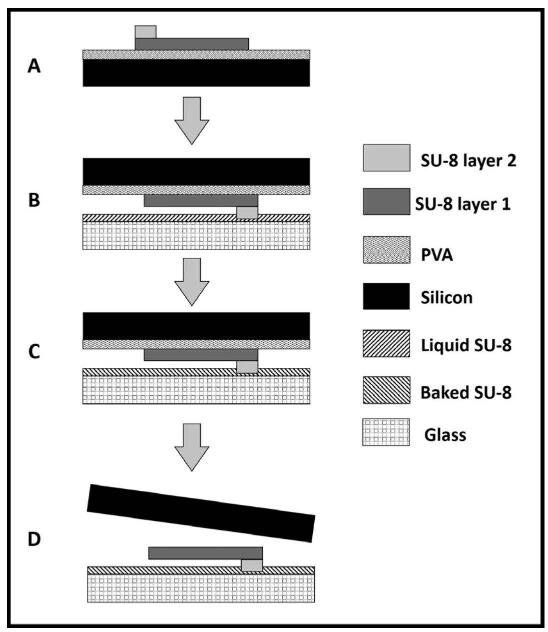

Figure 1: Fabrication process of the SU-8 microcantilever. (A) A two-layer SU-8 structure is fabricated on the PVA coated Si wafer by using alignment photolithography of two SU-8 layers. (B) PVA coated Si wafer with two-layer SU-8 structures is flipped and put on glass slide with a thin layer of liquid SU-8. (C) The sandwiched device is baked to solidify the liquid SU-8 layer on the glass slide. (D) The sandwiched device is immersed into water for 30 min to dissolve the PVA layer and release the Si wafer.

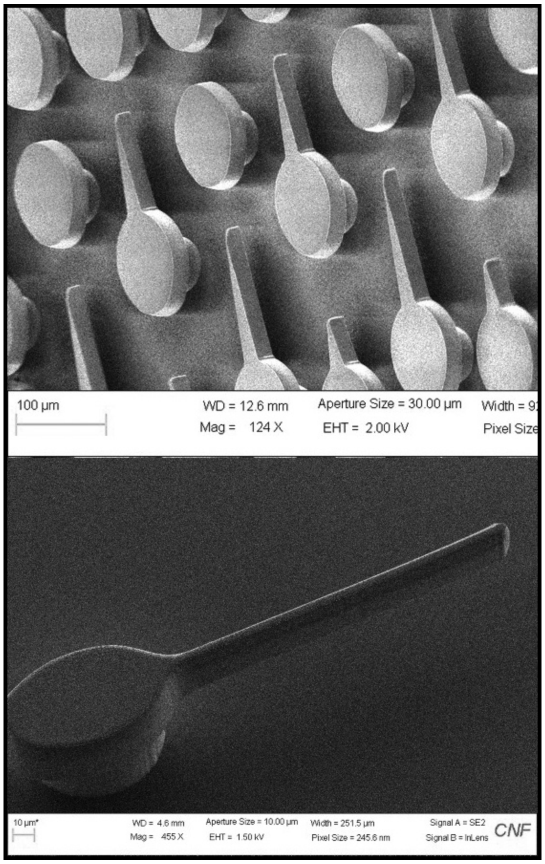

Figure 2: SEMs of SU-8 microcantilevers on glass slides.

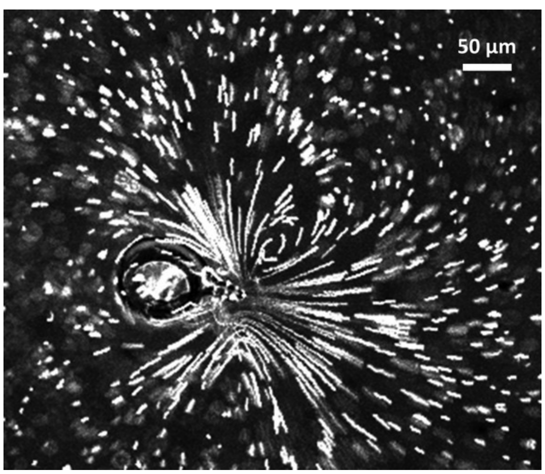

Figure 3: Acoustic streaming of a microcantilever in water revealed by fluorescent microsized beads when the cantilever is excited by the 1.35 MHz ultrasound.

Second, the silicon wafer with the two-layer SU-8 structures was flipped and put on a glass slide, which has been coated with a liquid SU-8 layer (Figure 1B). Then, the sandwiched structure was placed on the hot plate and baked under 95°C for 15 min to solidify the liquid SU-8 layer (Figure 1C). In this way, the second SU-8 layer from the silicon wafer was glued on the glass slide. After cooling down with the hot plate, the sandwiched structure was immersed into water for 30 min to dissolve the PVA layer, and the two-layer SU-8 structure was transferred from the silicon wafer to the glass slide (Figure 1D). In this way, the first and second layer of SU-8 on the silicon wafer has been flipped on the glass slide, which formed a cantilever structure.

The quality of the fabricated microcantilevers can be very good, even for structures with high aspect ratios (Figure 2).

The fabricated microcantilevers were immersed into the water, and an ultrasonic transducer was used to transmit ultrasound waves in the water to excite the microcantilevers. We have tuned the frequency of the ultrasound waves to detect the resonance frequency of the microcantilever based on the magnitude and pattern of the streaming flow around the microcantilever. A dual vortex like flow pattern was visualized by putting 0.83 µm fluorescent polystyrene microbeads when the microcantilever was excited under its first resonance (Figure 3).

Conclusions and Future Steps:

In this work, we fabricated SU-8 microcantilevers by integrating a two-layer SU-8 photolithography method with a PVA sacrificial releasing method. The microcantilever was used as the simplest model for understanding the fluid-structure interaction under ultrasonic excitation. We had successfully excited the fabricated microcantilever remotely by using ultrasound and observed the streaming flow for the first vibration mode of the microcantilever. Future study will be quantitatively characterizing the propulsion force generated by streaming flows under different excitation conditions.