Progress Towards Electrical Interface Chips for BioMEMS

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Abstract and Introduction:

The conjunction of biology and nanolithography has allowed for the development of many unusual devices—unique hybrids of biological cells and man-made structures. Here, we describe the development of one such device, designed to characterize the contraction force of a skeletal muscle cell. Shimizu, et al. [1] measured the force of a single C2C12 myotube by anchoring it to a silicon cantilever and base, electrically stimulating the cell, observing the cantilever movement using an optical microscope, and calculating the resulting force of contraction. Building upon their work, we fabricated micron-scale cantilevers made of the non-cytotoxic photoresist SU-8 3050. In addition to developing the fabrication process for the SU-8 cantilevers, we characterized them using optical microscopy and profilometry. Currently, we are investigating optical frequency domain reflectometry (OFDR) as a method for more accurately measuring the movement of the cantilevers. Accurate characterization of cantilever movement as the cell contracts will allow for a more precise measurement of the force exerted by an individual skeletal muscle cell.

Fabrication:

We used photolithography to fabricate SU-8 cantilevers onto glass slides. Following several cleaning steps, we spun on OmniCoat™ first for five seconds at a speed of 500 rpm and an acceleration of 100 rpm/s, and then 30 seconds at 3000 rpm and 255 rpm/s. We baked the OmniCoat™ for one minute at 200°C. Next, we spun on SU-8 3050 using the same spin parameters at the OmniCoat. Subsequently, we soft-baked the SU-8 on a hotplate at 95°C for 25 minutes. Using the MJB-4 mask aligner, we exposed the SU-8 through a chrome-coated glass mask for 31-34 seconds. We did a post-exposure bake (PEB) on the hotplate at 95°C for 3-5 minutes. Then, we developed the SU-8 while agitating the developer by hand for ~ 6 minutes. We cured the SU-8 on a hotplate at 200°C for five minutes and consequently developed the OmniCoat for ~ 30 seconds. We descumed for 600 seconds before etching the slides in agitated buffered oxide etchant (BOE). This step released the cantilevers. After each step requiring rinsing, we rinsed the glass slides in a water bath and dried them on a hotplate at 100°C.

Characterization:

Profilometry. Although the data is not shown here, we determined the height of the cantilevers to be 40-50 μm prior to etching using profilometry. Additionally, we measured the etch rate of the BOE to be ~ 0.46 μm/min.

Optical Microscopy. We used optical microscopy to examine the quality of the cantilevers. After development, the cantilevers, shown in the bright field image in Figure 1, Panel A, were straight and totally developed. The dark field image in Panel B reveals that the cantilevers were adhered to the glass slide and the sidewalls were vertical. Conversely, the dark field image in Panel C reveals that the cantilever was no longer adhered to the slide after development. After etching, there was an unknown residue on the cantilever as shown in Panel D, which we were able to remove using a combination of solvents.

Optical Frequency Domain Reflectometry (OFDR). OFDR works on the following principle: a tunable laser couples light into SMF-28 optical fibers set up as a Mach-Zehnder interferometer, where at one end the fiber points at structures on the sample. Due to the Fresnel reflections off these structures, a frequency is detected and then Fourier transformed so that it corresponds to the round trip times of the light from the fiber tip to structures on the sample.

In order to detect a 15 μm wide cantilever, we etched channels into the glass using a commercial glass-etching cream so that the center of the fiber tip points at the cantilever, as shown in Figure 2. Figure 3 shows what we believe to be peaks from the fiber tip and the cantilever. The black curve is the raw data. Using Igor Pro for data analysis, we mirrored the data to the left of the fiber peak and plotted it to the right of the fiber peak. We then subtracted the light-grey "mirrored data" from the black raw data to obtain the dark-grey curve for the cantilever peak only. Data analysis revealed that the cantilever was located ~ 0.885 mm away from the fiber, which is plausible given that the fiber was attached to the glass slide by hand using a stereoscope.

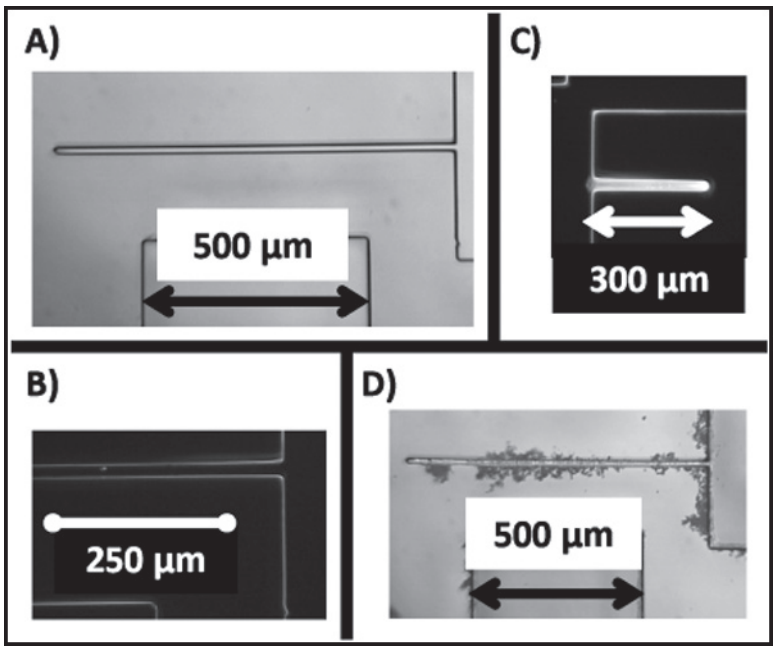

Figure 1: A) Bright field image of a good cantilever after development. B) Dark field image of a good cantilever after development. C) Dark field image of a bad cantilever after development. D) Bright field image of a good cantilever after etching with BOE.

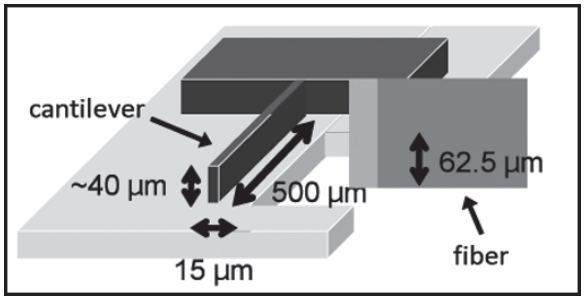

Figure 2: An optical fiber to be used with the OFDR system is glued to the glass slide so that it points at the cantilever.

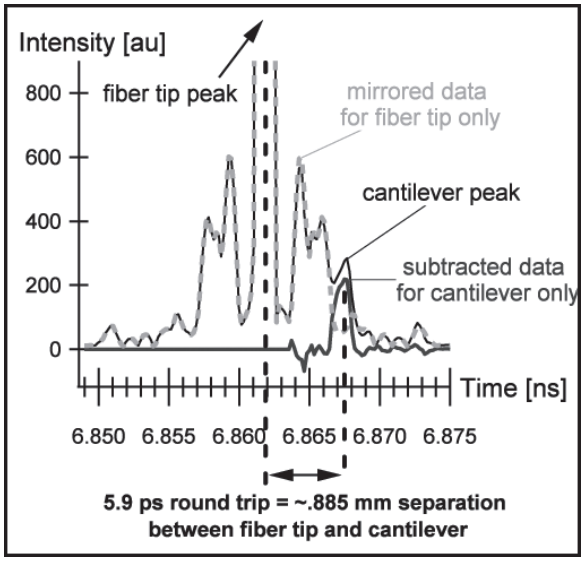

Figure 3: OFDR determined that the stationary 15 µm wide cantilever is located ~ 0.885 mm away from the fiber tip.

Conclusions:

As a result of optical microscopy, we were able to determine which cantilever dimensions allowed for better adhesion to the glass before etching, and the proper exposure and development times. In general, wider cantilevers (~ 15 μm) with lengths of 500 to 900 μm adhered better to the glass. OFDR has been successful so far at detecting a stationary cantilever, although a more precise setup will be required in order to test a moving cantilever. Particular attention should be paid to the noise, which affects OFDR measurements.

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References:

[1] K. Shimizu et al., Biomedical Microdevices, Volume 12, Number 2 (2010), 247-252.