3D Printed Barbed Microneedle Electrodes

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Introduction

A biophysical sensor is a device that senses signals or chemicals in the body of a human or an animal such as an octopus. To measure the electromyography (EMG) signals in muscles, these sensors need to be flexible and stretchable. The EMG sensors created in the CAM lab incorporate a microneedle, which typically measures 0.1 - 1 mm in length. It inserts into a muscle and acts as an electrode to read the EMG signals. The wires integrated in a sensor can be formed into serpentines to allow for more movement.

Objective & Impact of Professor's Research

These devices could be used to better understand the muscles of flexible animals such as octopuses. Traditionally, it would be very difficult to measure the EMG signals of an octopus' tentacle because the tentacle is so flexible. For a sensor to successfully record these signals, it would have to flex and bend to conform to the movements of the appendage. Our sensor might seem perfect for this purpose, however the current needle design has nothing keeping it inserted, making it ineffective.

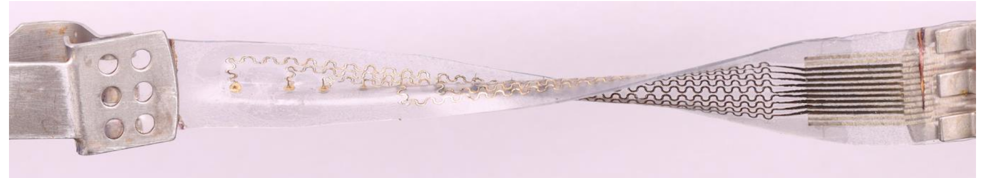

Fig 1. Twisted microserpentine

The objective of my research is to modify this needle design using CAD to increase how well it sticks into a skin-like surface, and then fabricate it using a 3D printer.

Learning Process & Research

To familiarize myself with the CAD software, my mentor tasked me with seeing if I could recreate various dimensioned models. Specifically, they tasked me to recreate their 2D microserpentine model and their 3D microserpentine and microneedle model.

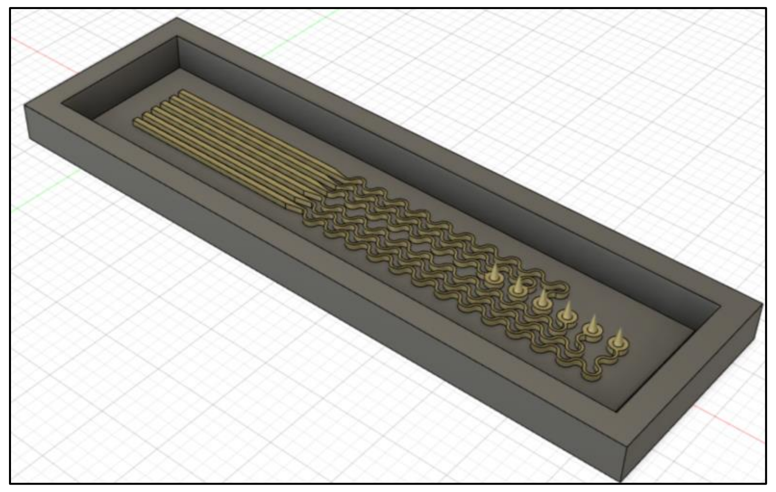

Fig 2 Recreated CAD model of microserpentine design

For our research, we wanted to maximize the extraction force of our microneedles, whilst keeping their insertion force as low as possible. This means it is easy to put in, but difficult to take out. Using Fusion 360, I modeled multiple variations of a barbed needle design, each one slightly changing the parameters of a base design. I also modeled a control, which is simply the regular needle with no barbs. I printed all these designs without the serpentine, to isolate the needle which we needed to test.

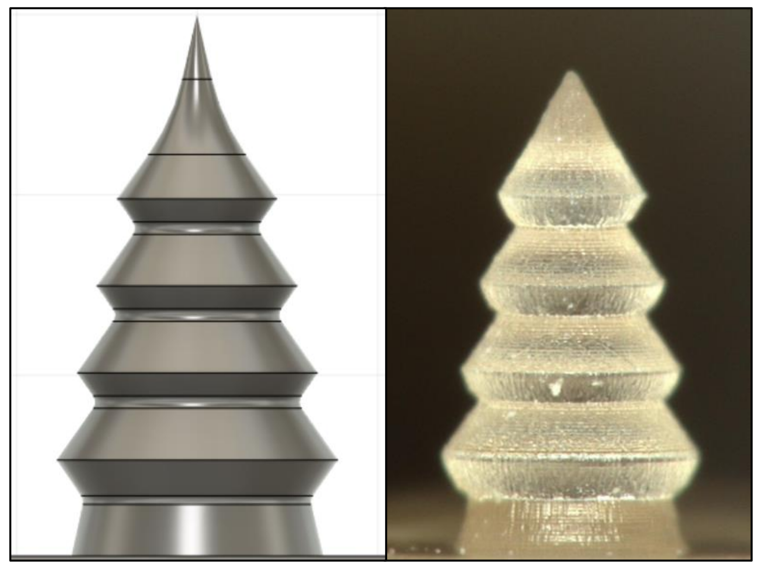

Fig 3. CAD base design versus printed base design

Methods & Results

These designs all were to be clamped into a force sensor to test their insertion and extraction forces. This force sensor was fixed to a linear translation stage, which allowed the needle to move in and out of a sample of polydimethylsiloxane (PDMS).

Fig 4. Microscopic picture of barbed microneedle in force sensor fixture

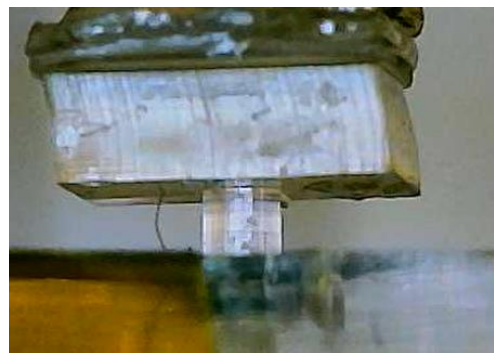

Fig 5. Microscopic picture of barbed microneedle inserted in PDMS

Compiling all my data, I found that the needle with the most desirable data was my control needle! My experiment resulted in this way because the PDMS' surface tension prevented it from getting stuck in the barbs, and the barbs increased the front angle of the needle, making them not able to penetrate the PDMS.

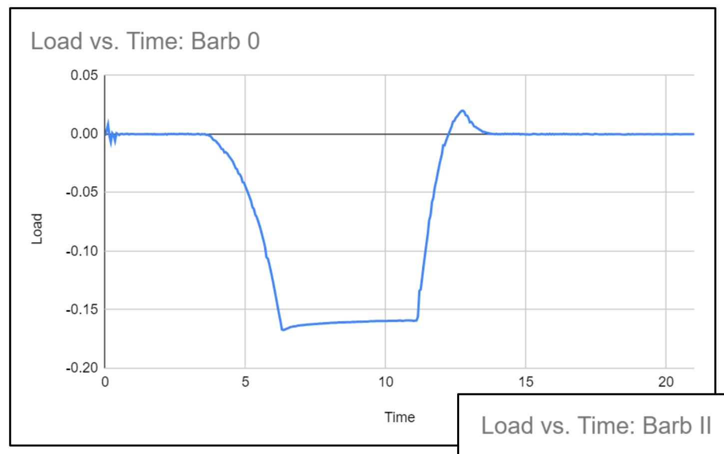

Fig 6. Insertion & Extraction data for control needle

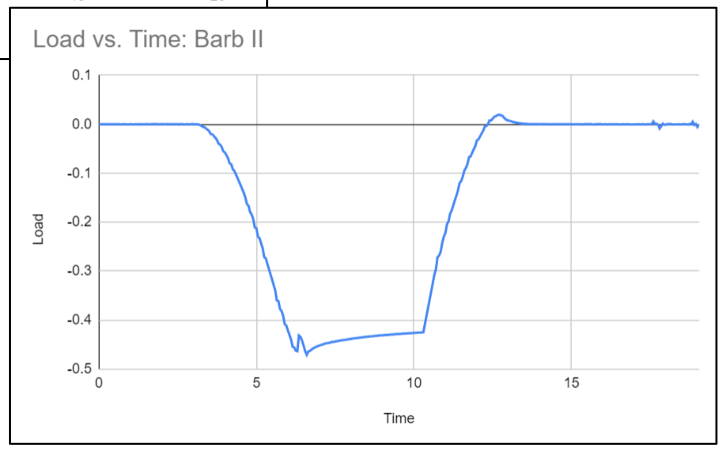

Fig 7. Insertion & Extraction data for barbed needle

Our final model incorporated the flexible microserpentine and a modified needle which kept the high front angle of the control needle, whilst also incorporating a singular barb.

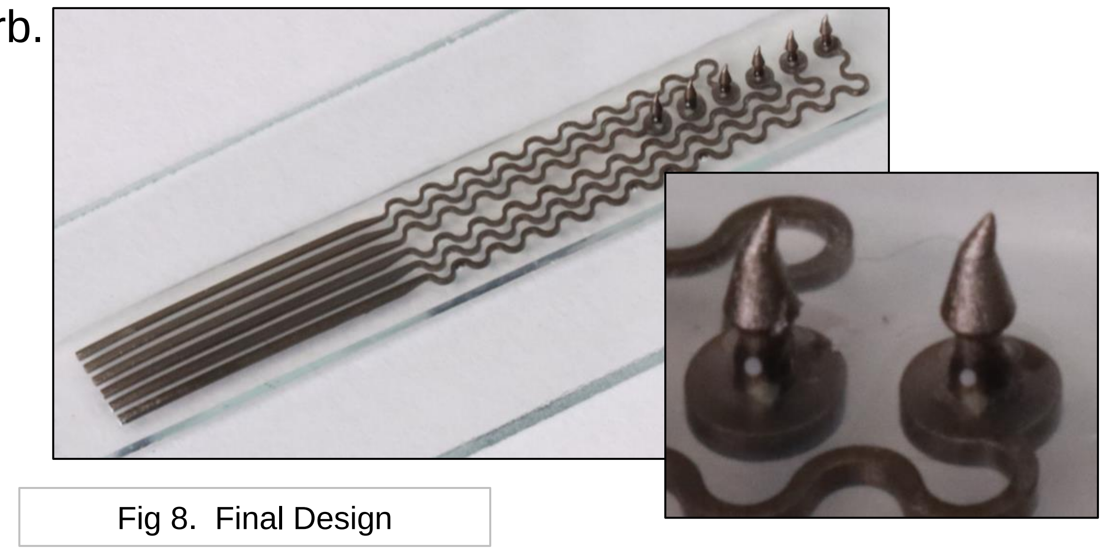

Fig 8. Final Design

Advice for Future SHINE Students

Future SHINE students should be inquisitive! Don't be afraid to ask questions. Your mentor and peers could always show you a new perspective and flip the problem at hand on its head. Try to learn as much as possible by talking not only to your friends in SHINE, but also the other people in your lab.
And most importantly, HAVE FUN! This summer is a whole new learning opportunity for you, so take advantage of this change of scenery. This program is admittedly long, so have some fun and let time fly.

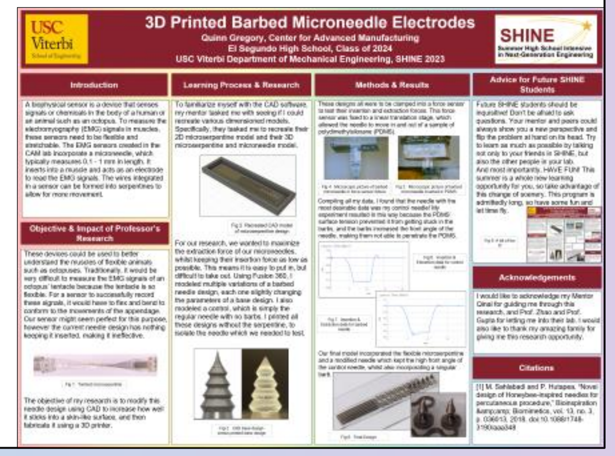

Fig 9. A bit of fun ☺

Acknowledgements

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Citations

[1] M. Sahlabadi and P. Hutapea, "Novel design of Honeybee-inspired needles for percutaneous procedure," Bioinspiration & Biomimetics, vol. 13, no. 3, p. 036013, 2018. doi:10.1088/1748-3190/aaa348