DALHOUSIE UNIVERSITY
FACULTY OF ENGINEERING

Fabrication of an Ultrasonic Scalpel for Neurosurgery

nova scotia health
Dalhousie Ultrasound Lab
Dr. Jeremy Brown
Mr. Matthew Mallay

Department of Electrical & Computer Engineering

Colton Campbell, Justin Greige, Mahmoud Ibrahim, Brandon Senholt

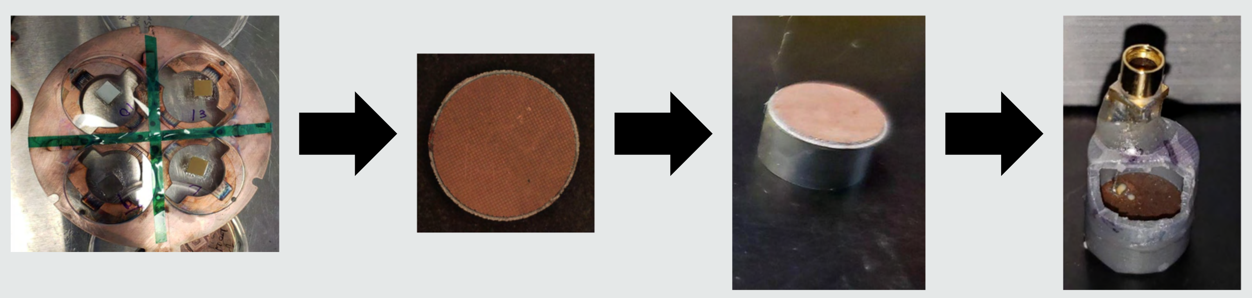
Introduction

Our team was tasked to micro-fabricate and test drive 21 different 8mm diameter transducers built using five different piezoceramics for minimally invasive ablation of brain tumors using histotripsy.

Goal

- To compare the performance of 5 different piezoceramic in terms of sensitivity, cavitation threshold and maximum driving voltage.
- Ceramics must be able to withstand high amounts of pressure to be able to generate cavitation bubbles without breaking down due to delamination or voltage saturation.

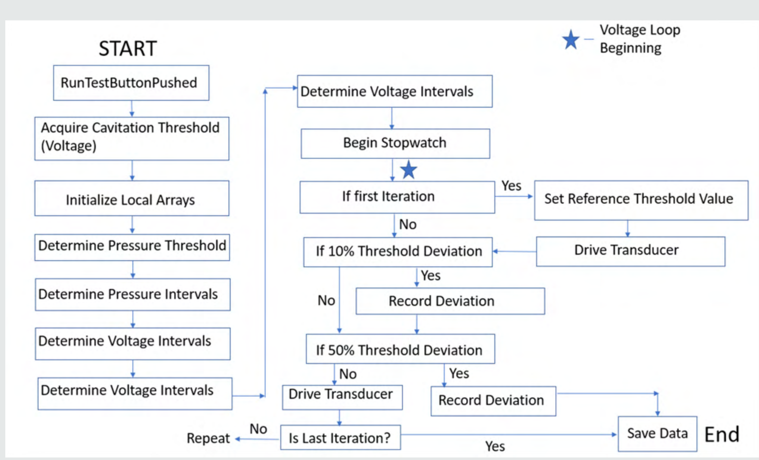
Fabrication Process



- Ceramics are diced on 45% Volume fraction and lapped to desired thickness (290-340 μm).
- Ultrasonic ceramics are coated with 2 μm copper electrode layer to drive voltage across them.
- Ceramics are cleaned then bonded to aluminum lens and wire bonded in 3D printed cases.

Testing Process

- Drive transducers at continually higher voltage pulses and monitor transducer health via cavitation threshold.

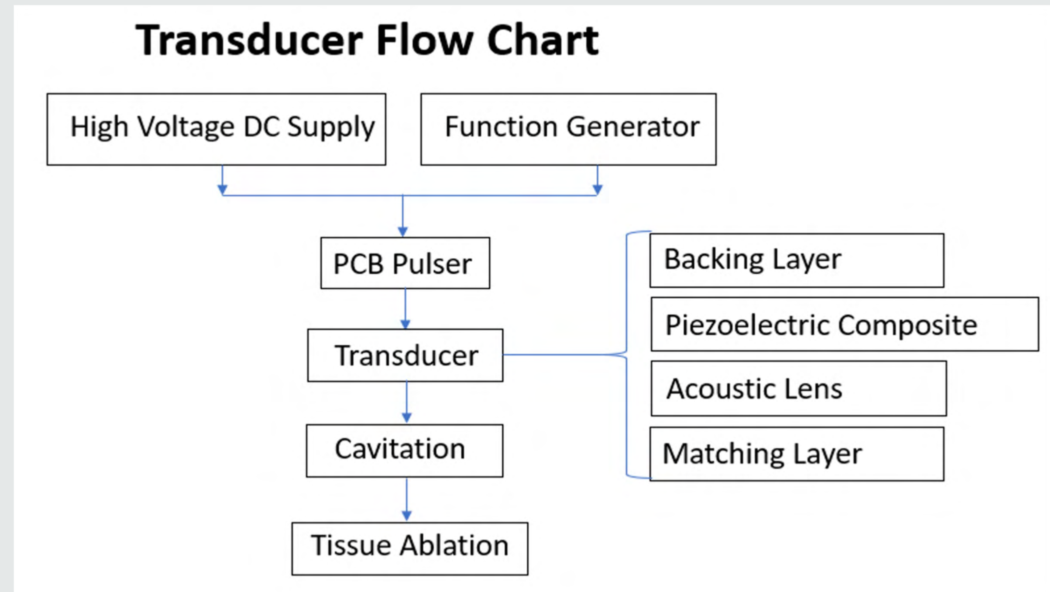


Details of Design

- Constructed using composites made from various piezoceramics.
- Device casings 3d printed.
- Must generate cavitation 8mm from the lens.
- Capable of maintaining cavitation while driven above desired voltage for extended periods of time.

System architecture

- A custom PCB pulser uses inputs from a high voltage DC supply and function generator to drive ultrasonic transducers.
- These transducers convert electric pulses into tissue ablating acoustic waves.

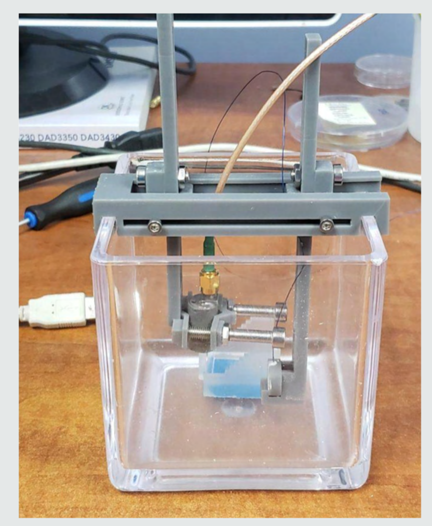


Materials Properties

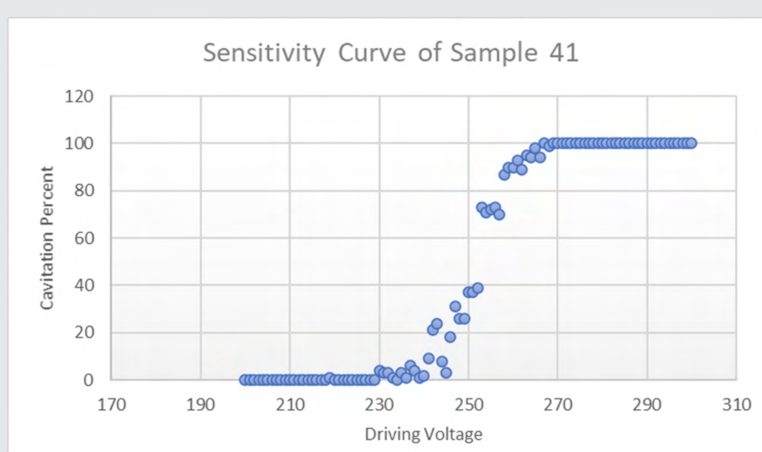
Material	Optimal Thickness (um)	Acoustic Impedance (MRayls)	Coupling Coefficient	Sensitivity	Cavitation Threshold (V)
PMN38	340	16.1	0.608	0.210	230
PZ39	315	23.3	0.559	0.230	170
PZ54	305	15.3	0.575	0.215	194
PZT5H	290	15.0	0.675	0.240	160
PZT5A	310	15.6	0.608	0.188	171

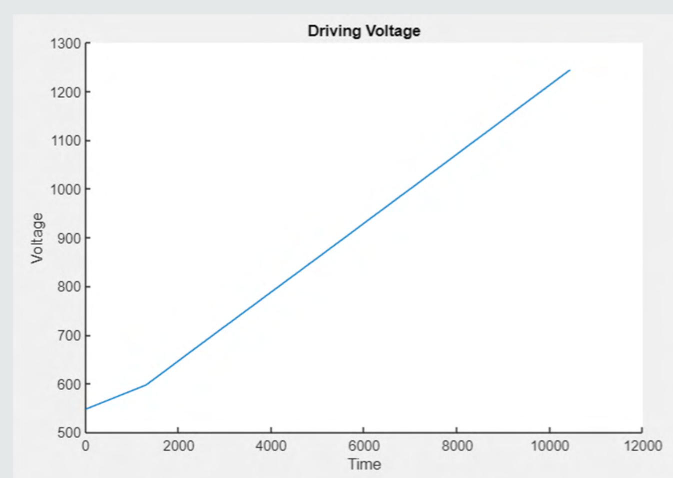
Testing Rig

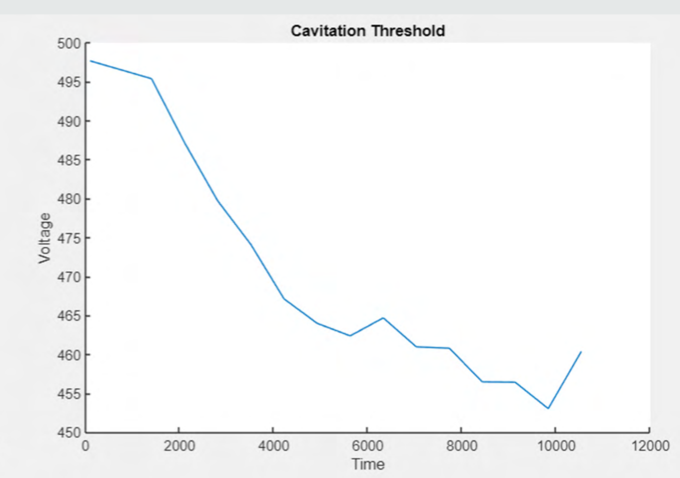
- Model designed in Fusion.
- Horizontal and vertical sliders to adjust positions of the transducer and hydrophone.
- Adjustable to fit various transducer and container sizes.



Driving Graphs



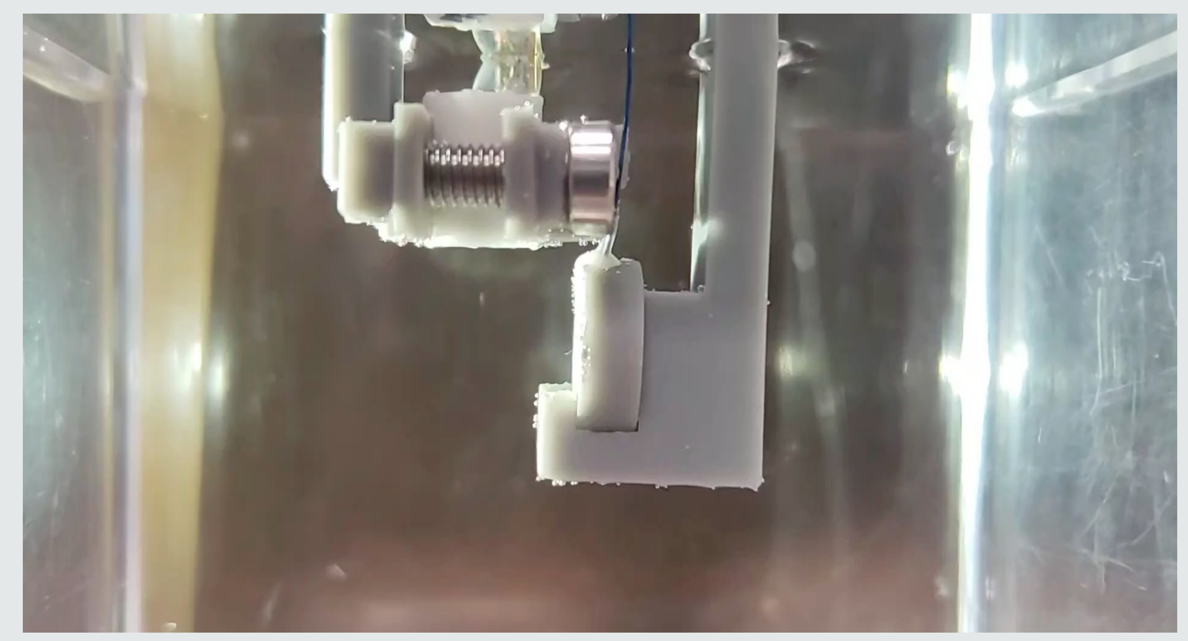




- The following graphs represent the Cavitation Threshold test (S curves) gathered for the PMN38 (sample 41) and the following driving test.
- No degradation in the performance of any transducers from the initial driving test except for the PZ39s.
- Driving the transducers at a higher voltage has currently led to the PMN38s failing despite having one of the best lower voltage performances.

Conclusion & Recommendations

- 21 different transducers were successfully fabricated.
- Almost all have survived for 3 hours while driven beyond the rated voltage.
- The material properties of the transducers have been characterized.
- Currently testing to fully the determine failure point of the transducers.
- Interim conclusion is that PZT5H is the best material.
- Material data sheets should have been read more thoroughly.
- Additional spare transducers should have been built for testing the driving code.
- More time should have been spent validating testing parameters.
- Many external factors affected the consistency of test results.



Demo of Cavitation
(represented by the bubble forming)

References

1. Nova Scotia Health Authority. (n.d.). Nova Scotia Health Authority Logos. Retrieved March 24, 2021, from http://www.nshealth.ca/files/nova-scotia-health-authority-logos
2. Landry, T. G. (2021). CavitationAudioRecordingApp (Version 1.0) https://www.mathworks.com/products/matlab/app-designer.html