MULTIFUNCTIONAL 3D PRINTED $BaTiO_3$ PLATONIC SOLIDS PACKAGING FOR IMPLANTABLE MICRODEVICES

Sayemul Islam[1], Sumnoon Ahmed[1], Alanis I. Santiago[1], Michael Domic[1], Jungkwun Kim[2], Seung H. Song[3], and Albert Kim[1]*

[1]Dept. of Electrical and Computer Engineering, Temple University, Philadelphia, PA, USA, [2]Kansas State University, Manhattan, KS, USA, [3]Sookmyung Women's University, Seoul, Korea

I. Introduction

- Implantable microdevices allow continuous monitoring and autonomous diagnosis of many chronic diseases by enabling sensing, actuation, stimulation, or drug delivery.
- Ultrasonic powering is an emerging technique with overarching advantages of long-distance operation and superior power transfer efficiency at an mm-scale receiver over traditional methods such as a battery or inductive power sources.
- However, cuboids or disc receiver is less than ideal.
  - Propagating waves are often deflected within the path (due to inhomogeneous acoustic media)
  - The miniature implants can shift and rotate
- A **multifunctional packaging technique** for implantable microdevices is presented.
- The packaging is based on **3D printed** bulk **piezoelectric barium titanate ($BaTiO_3$ / BTO)** ceramic with **unique geometrical shapes** (i.e., regular convex polyhedrons; Platonic solid).

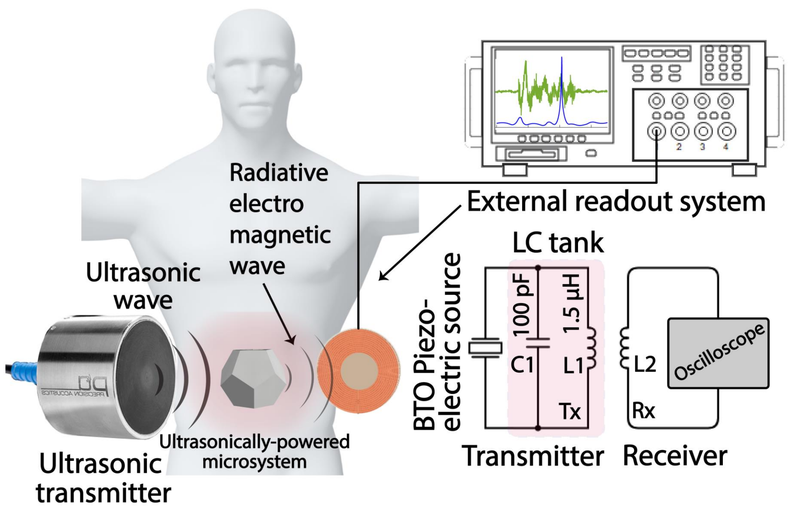

Figure 1: *Implantable 3D printed and packaged microdevice sending information through RF radiation by using ultrasonic interrogation.*

II. Materials and Method

Fabrication process:

- PVDF:DMF = 1:8.8, mixed at 80°C in the water bath for 15 minutes.
- PVDF+DMF:BTO = 1:3.345, mixed for 5 minutes.
- 3D printed platonic solids using a 3D printer and mixture.
- Dried at 120°C for 2 hours.
- Debinded at 650°C for 1 hour and sintered at 1190°C for 3 hours.
- Electrodes deposited using silver epoxy.
- Poled with a high electric field (> 1kV/mm) for 1 hour.
- Integrated an LC oscillator and placed it inside the custom hollow shape and sealed using biomedical resin.

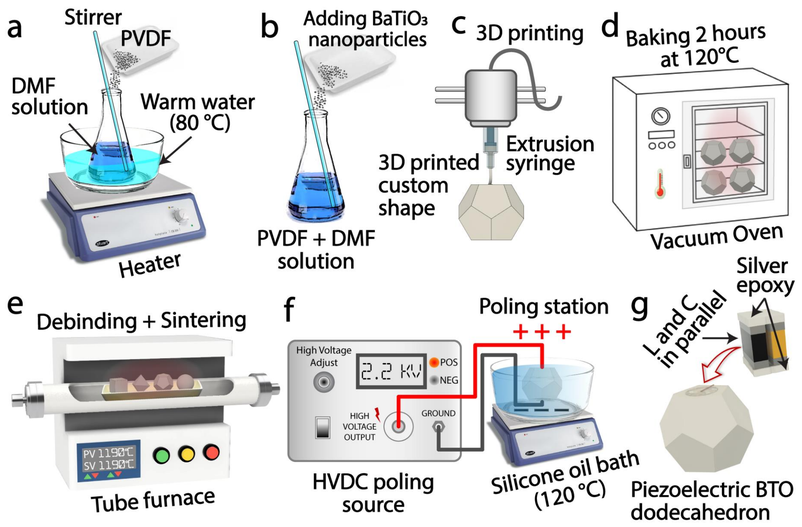

Figure 2: *The fabrication process of implantable microdevices.*

- SEM images before and after sintering the transducer show the construction of bulk piezoelectric material (Fig. 3).

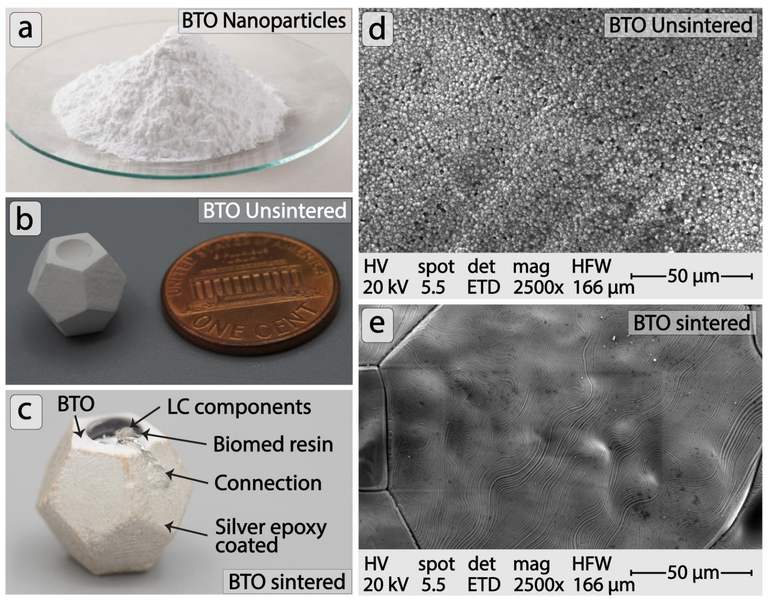

Figure 3: *(a) $BaTiO_3$ NPs, (b) sintered $BaTiO_3$, (c) electronics integrated and packaged into the microdevice, (d) SEM pictures of pre-sintered, and (e) sintered $BaTiO_3$ sample.*

III. Experiment Setup

- A water tank with DI water is used to mimic the biological environment.
- Acoustic absorbers are used to minimize acoustic reflections and noises.
- Source: A 60 mm FUS (Focused Ultrasound) transducer to transmit ultrasonic energy.
- Implant unit: 3D printed piezoelectric BTO with LC transmitter (Tx).
- External Rx: An oscilloscope with an antenna coil.

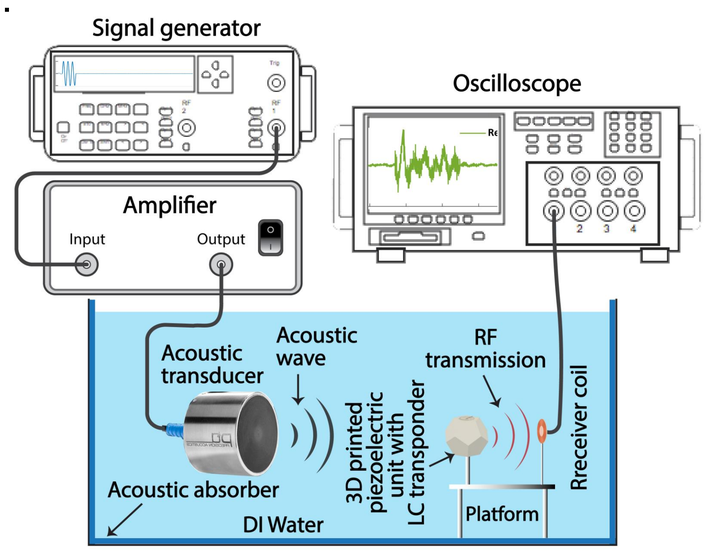

Figure 4: *Experiment setup showing the interrogation technique.*

IV. Results and Discussion

- BTO receives ultrasonic energy from FUS.
- Converts to an electrical signal.
- Oscillates the LC transponder at a certain resonance frequency.

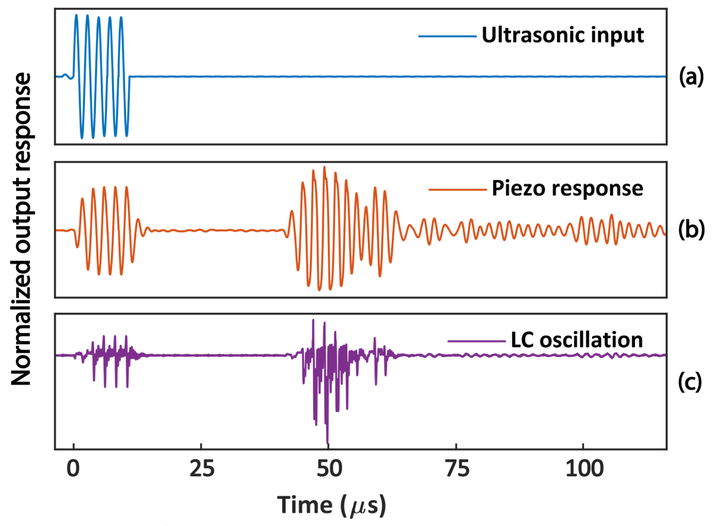

Figure 5: *(a) Ultrasonic excitation, (b) piezoelectric response from BTO sample, and (c) oscillation in the LC circuit due to the excitation.*

- LC transponder radiates at a frequency corresponding to inductor (L) and capacitor (C) values (sensing element can be either L or C).

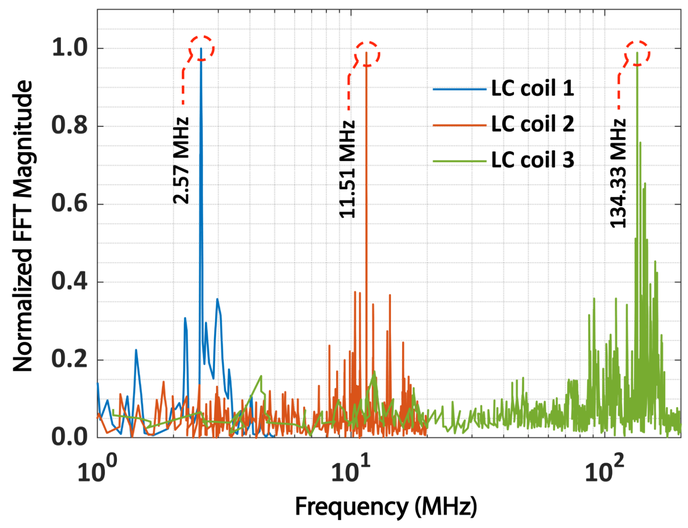

Figure 6: *Received RF peaks identified for three different LC combinations.*

Table 1: *LC tank parameters and corresponding peaks.*

Parameter	LC type - 1	LC type - 2	LC type - 3
Dimension	L = 1.1 mm W = 1.0 mm	L = 1.1 mm W = 1.0 mm	L = 1.1 mm W = 1.0 mm
Inductance	100 µH	1.5 µH	15 nH
Capacitance	100 pF	100 pF	100 pF
Calculated resonance	1.59 MHz	12.99 MHz	129.95 MHz
Experimental values received	2.57 MHz	11.51 MHz	134.33 MHz

V. Conclusion

- A multifunctional 3D printed $BaTiO_3$ dodecahedron piezoelectric transducer is demonstrated to be used as packaging for implantable microdevices.
- As a proof of concept, LC transponders were packaged inside of the transducer.

VI. Acknowledgment

- College of Engineering, Temple University
- National Science Foundation (NSF) CAREER Award
- Transducer Research Foundation (TRF)