Wafer Scale Piezoelectric Transformers

CNF Project Number: 1121-03
Principal Investigator(s): Prof. Amit Lal
User(s): Meera Vikas Garud

Affiliation(s): Electrical and Computer Engineering, Cornell University
Primary Source(s) of Research Funding: ARPA-E
Contact: amit.lal@cornell.edu, mvg44@cornell.edu
Website(s): https://sonicmems.ece.cornell.edu/
Primary CNF Tools Used: Westbond 7400A Ultrasonic Wire Bonder

Abstract:

Our project aims at developing a wafer scale-wafer mountable piezoelectric transformer for a wafer scale, compact ion accelerator. Miniaturizing conventional magnetic transformers is often a difficult task. However, piezoelectric transformer designs offer a promising alternative by utilizing the vibrational mode shapes of piezoelectric plates to achieve voltage gain. Various modes of vibration, such as shear-transverse, radial, and others, have been explored using different plate geometries. In our research, we aim to tackle the challenge by combining multiple approaches. We design a piezoelectric transformer that utilizes mechanical resonance of the structure, employs multilayer stacking, and incorporates a series electrical connection on the secondary side of the transformer. The device's design is specifically optimized for easy manufacturing and chip-scale assembly onto a PCB board, enhancing its practicality and potential for widespread adoption.

Summary of Research:

We use high Q fused quartz as a substrate and PZT pieces as the piezoelectric material. Figure 1 and Figure 2 illustrate the schematic and photograph of the device stack. The transformer consists of a 200 μm thick PZT layer, a 500 μm thick fused quartz layer, and three PZT pieces connected in series on the secondary side. To manufacture this transformer, we employ the LPKF laser cutter to obtain PZT pieces of the required area, and we use patterned copper tape as the metal contact on both sides of the transformer. We achieve the series connection at the secondary side PZT pieces using wire-bonds. The aluminum wire of the wire bonder is compatible with the sintered nickel metal layer on the PZT pieces. The wire bonds aid in electrical connections without shifting the resonance frequency due to the mass loading effect on the PZT pieces.

Conclusions and Future Steps:

The prototype gives promising results. We achieve a voltage gain of 6 at 8 MHz from a very thin (<1mm) device. To avoid effects of a non-uniform adhesion between PZT pieces and the copper tape on the frequency response, we propose the use of indium plating and flip-chip bonding to have better process control — for which Pico MA FinePlacer FlipChip Bonder would be a useful tool at CNF, and process flow would be modified appropriately. This will also aid in precise alignment of secondary side small PZT pieces with respect to the primary side larger PZT actuator.

References:

[1] Y. Hou et al., "Vertically Stacked Piezoelectric Transformer for High Frequency Power Amplifier," 2023 IEEE Applied Power Electronics Conference and Exposition (APEC), Orlando, FL, USA, 2023, pp. 392-396.

[2] M. Garud, Y. Hou, A. Lal, K. Afridi, "Piezoelectric Transformer using bulk PZT & Fused Quartz for RF Ion Accelerators," in 2023 IEEE International Ultrasonics Symposium (IUS), 2023.

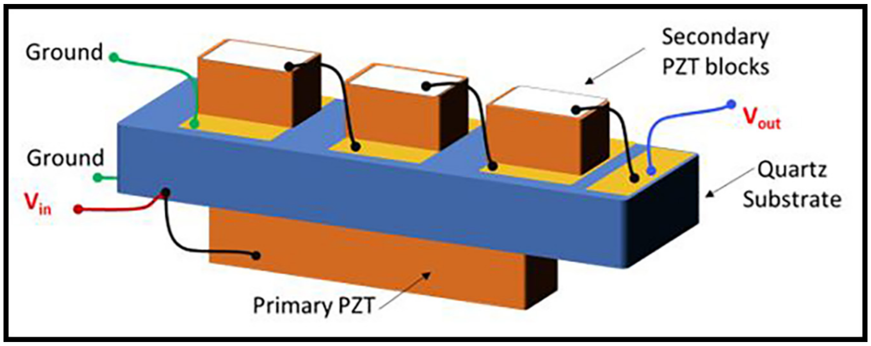

Figure 1: Schematic of the piezoelectric transformer architecture.

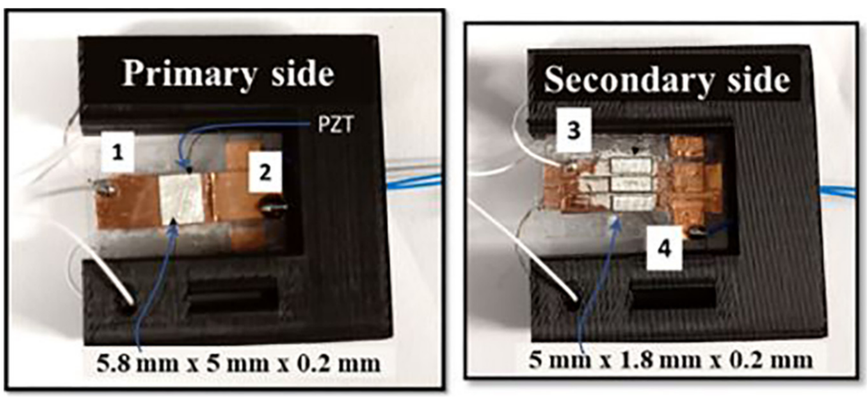

Figure 2: Photograph of a prototype of the transformer mounted on a 3D printed support structure.

PROCESS & CHARACTERIZATION