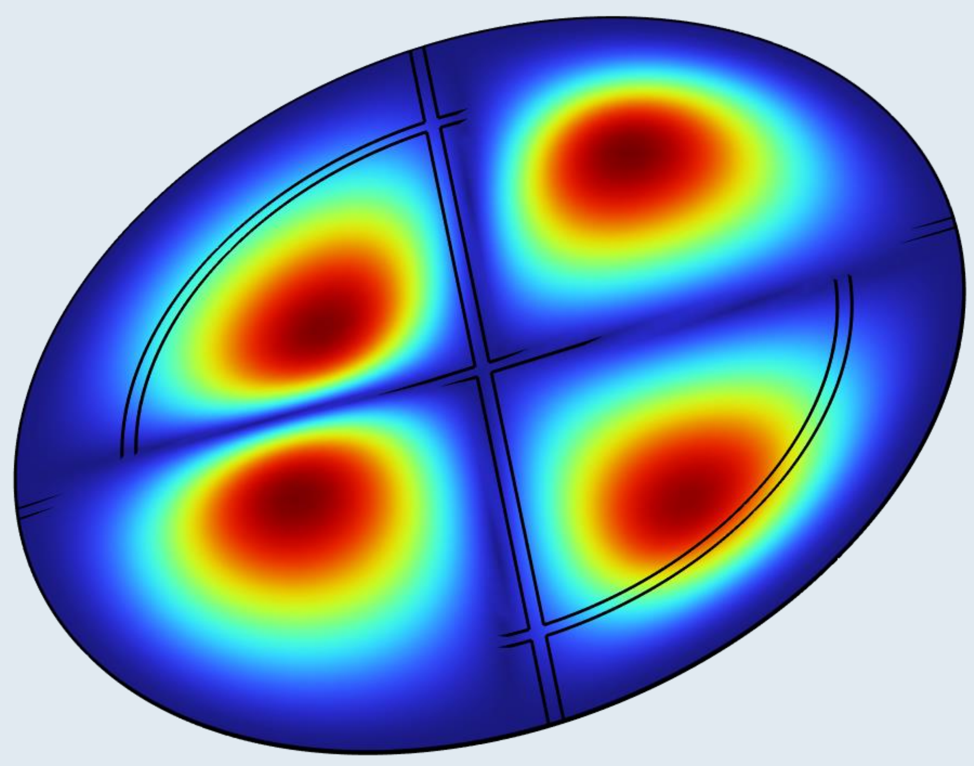

Single Membrane MEMS-based Acoustic Emission Sensor For Multi-frequency Detection

Utilizing multiple electrodes on a single membrane PMUT device for the detection of acoustic emissions in concrete structures

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Abstract

Acoustic emission (AE) detectors play a significant role in the nondestructive testing of structures like pipelines, pressure tanks, and bridges. Commercially available AE detectors are bulky and expensive. Microfabrication technology provides a cost-competitive solution for reducing the overall footprint of AE detectors. Moreover, it is pertinent for AE sensing technology to be capable of detecting a wide range of frequencies for identifying AE sources and associating defects correctly. Current research (Ref 1.,2.) is focused on applying several MEMS-based devices for multi-frequency detection.

In our work, we have shown the utility of an 8-electrode configuration on a single membrane PMUT device for multi-frequency detection. This is made possible by using a peculiar arrangement of electrodes that takes advantage of several transverse modes of vibration of a circular membrane.

Methodology

The 3D model of the PMUT device consists of a three-material stack – Silicon as the device layer, Aluminum nitride as the piezoelectric layer, and Aluminum as the metal layer (Figure 1. Left). A broad spectrum body load is applied to the entire structure, simulating an acoustic emission event, and the terminal voltages are acquired from the aluminum electrodes separately.

The voltage acquired from appropriate electrodes – depending on the resonance modes, is summed to get the final output. For example, the voltage output from electrodes 1 through 4 (Figure 1. Right) is added for the transverse mode (0,1).

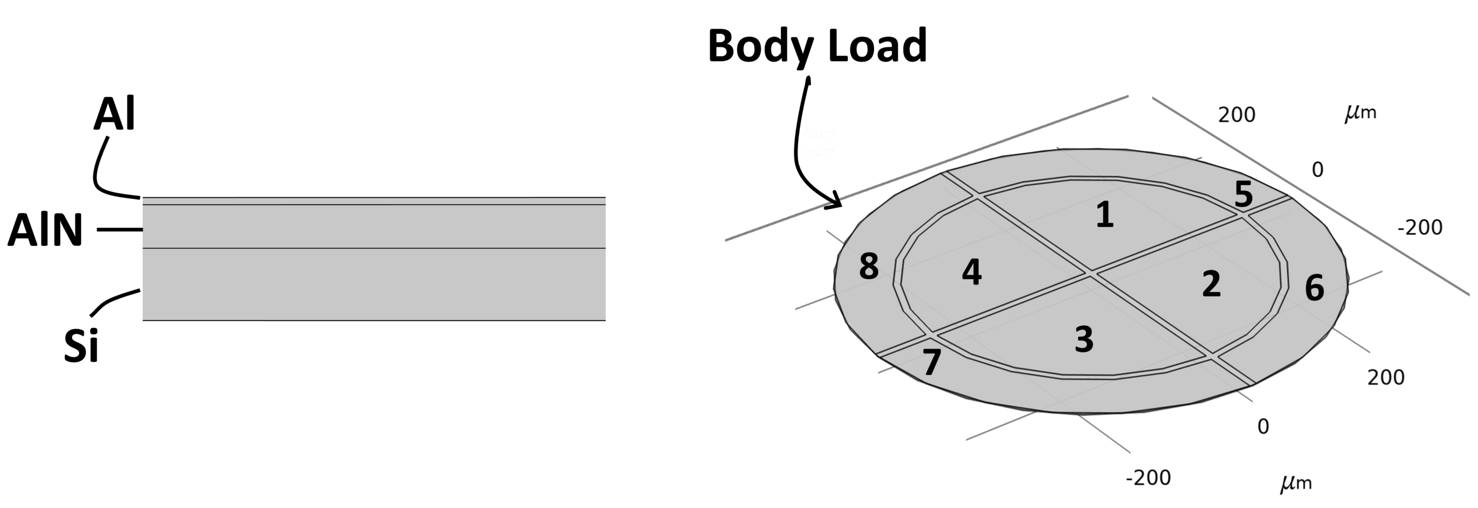

FIGURE 1. Left: Material stack used for the MEMS-based AE detector. Right: 8-electrode configuration on a single membrane with the body load applied to the entire device.

Results

The single membrane PMUT device with its 8-electrode configuration is able to detect multiple frequencies, as shown in Figure 2. The device is designed for the detection of three transverse modes (0,1), (1,1) and (2,1). As seen in the insets of the plots in Figure 2. (b), (c) and (d). However, due to the asymmetry introduced by the electrodes, the (1,1) and (2,1) resonance modes are seen to be split on the voltage vs. frequency spectrum.

The simulated device is shown to have a detection capability for frequencies of 61 kHz, 132 kHz, and 223 kHz. This frequency spectrum is particularly useful in the non-destructive testing of concrete by AE detection.

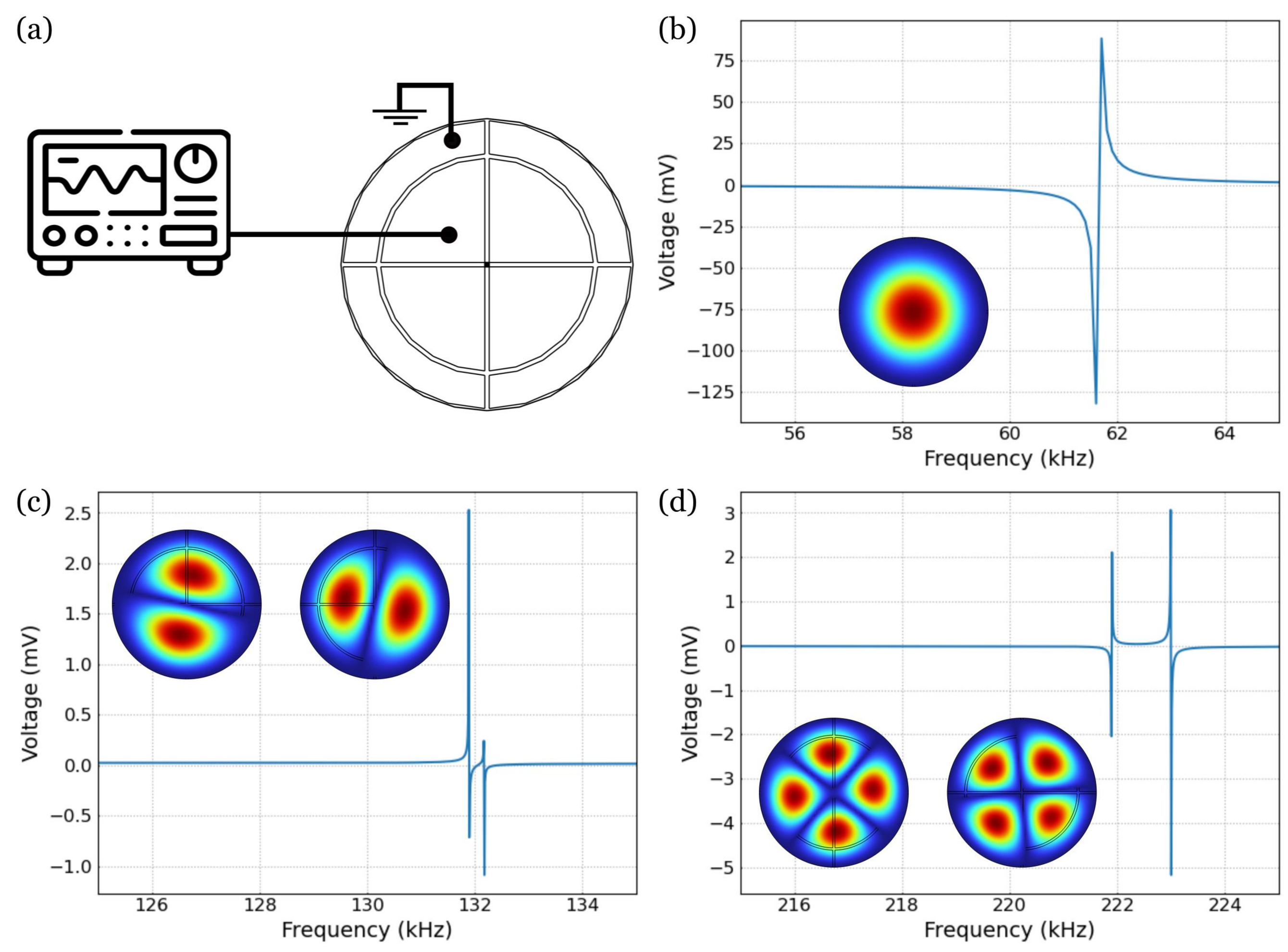

FIGURE 2. (a) Representative electrical connections for voltage measurement. (b), (c), (d) Voltage output for transverse modes

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