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Aluminum Nitride Piezoelectric Microphones as Zero-Power Passive Acoustic Filters

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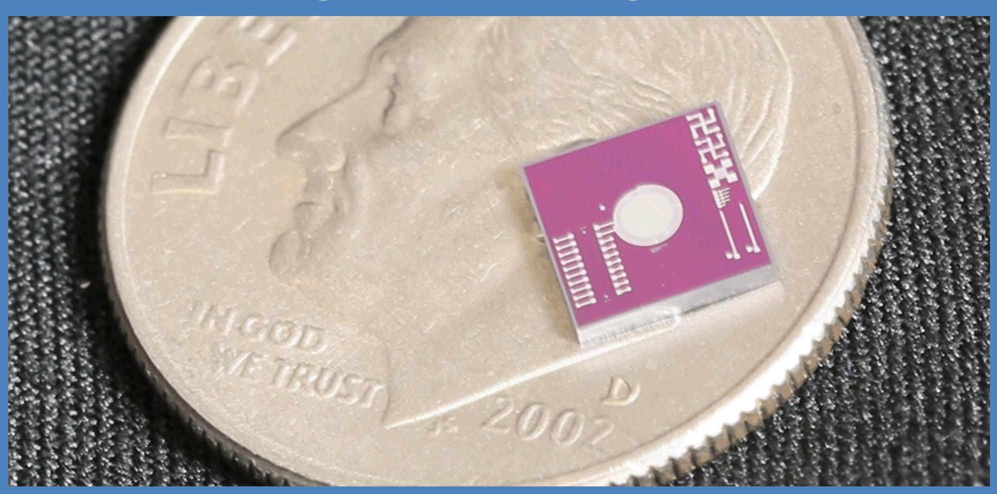
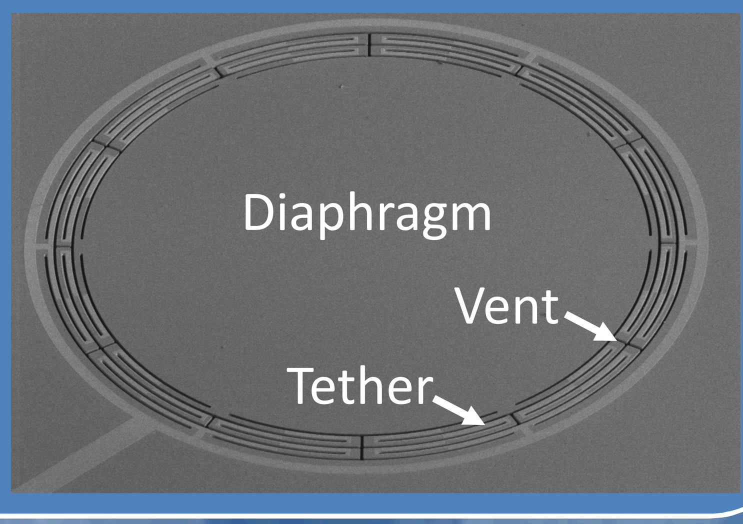
ABSTRACT

With the advent of the internet-of-things, sensors that are constantly alert yet consuming near-zero power are desired. Piezoelectric micro-electro-mechanical systems (MEMS) convert mechanical or acoustic energy into electrical signals while consuming zero power. This work describes piezoelectric MEMS microphones based on aluminum nitride (AlN). The microphones operate as passive acoustic filters by placing their resonant response within bandwidths of interest. Devices are demonstrated with operational frequencies from 430 Hz to greater than 10 kHz with quality factors as large as 3,000 and open-circuit voltages exceeding 600 mV/Pa.

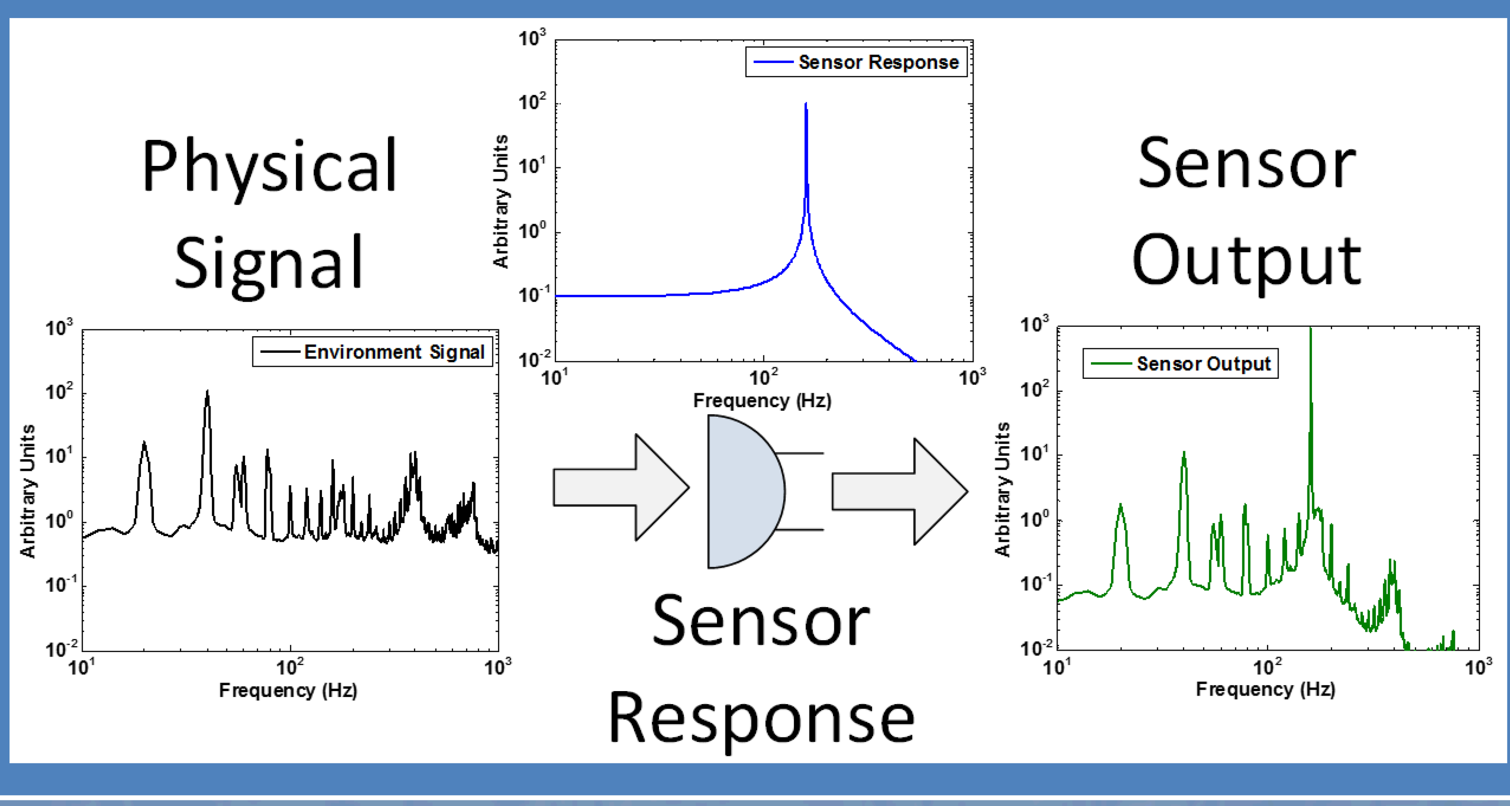




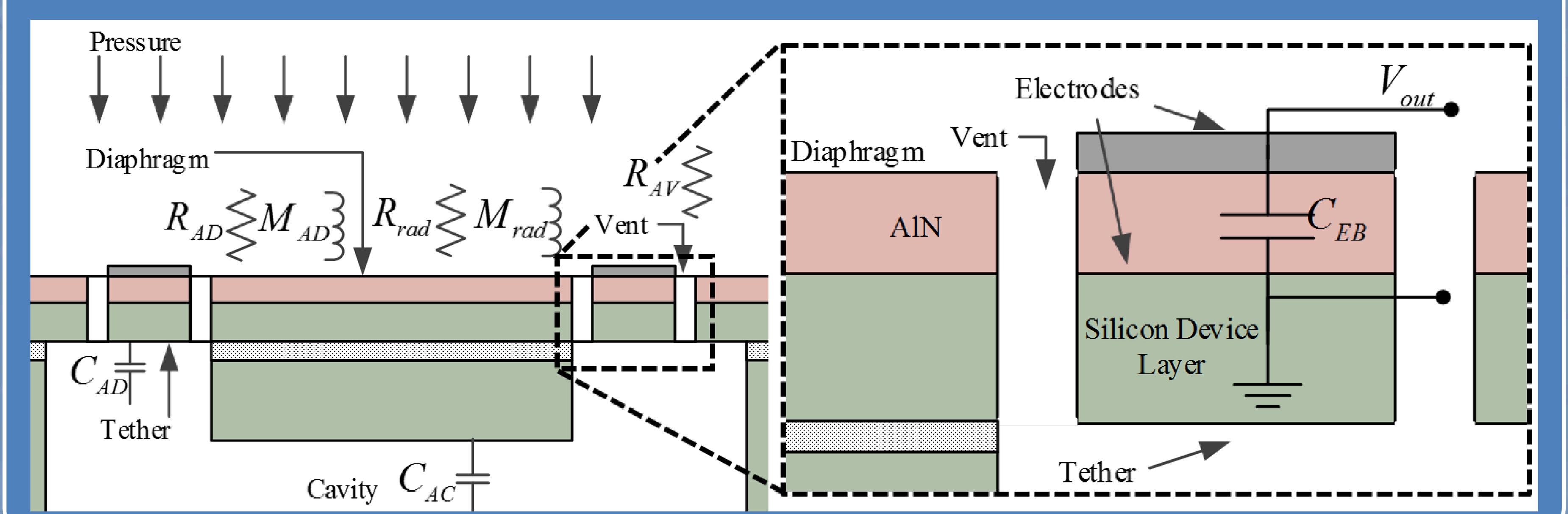
DESIGN

The microphone consists of a diaphragm suspended by tethers of single crystal silicon (Si), AlN, and an aluminum top electrode. The trench etch that forms the tethers creates a vent that equilibrates static pressure between the front and back of the diaphragm.

In general, a desirable microphone would maintain a flat-band response over a broad frequency range. Resonant microphones are designed such that their resonance peak occurs within normal microphone bandwidths at a selected frequency. This allows passive filtering of noise and amplification of the desired signal.



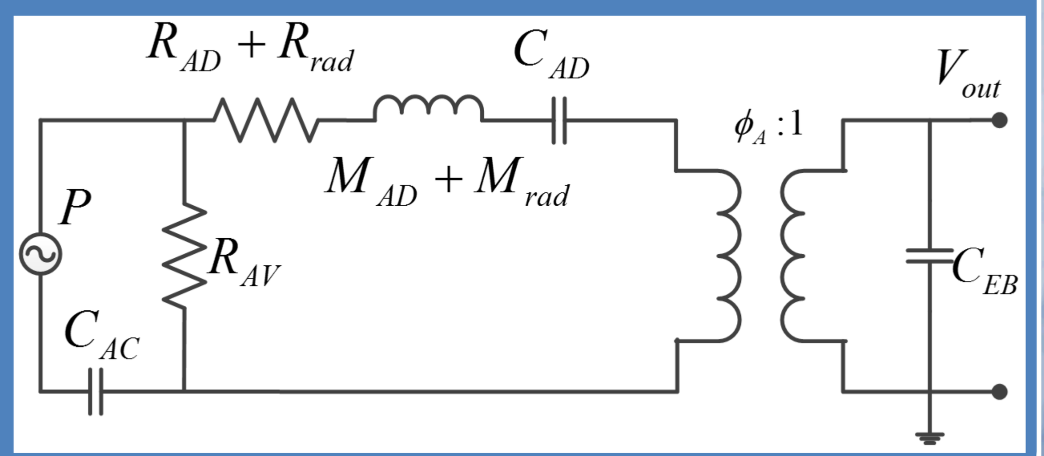
MODELING



Devices are modelled by lumped elements in the acoustic and electrical domains. In the acoustic domain, the tethers are represented by a spring with compliance C_{AD}, the diaphragm mass is given by M_{AD}, and mechanical losses by, R_{AD}.

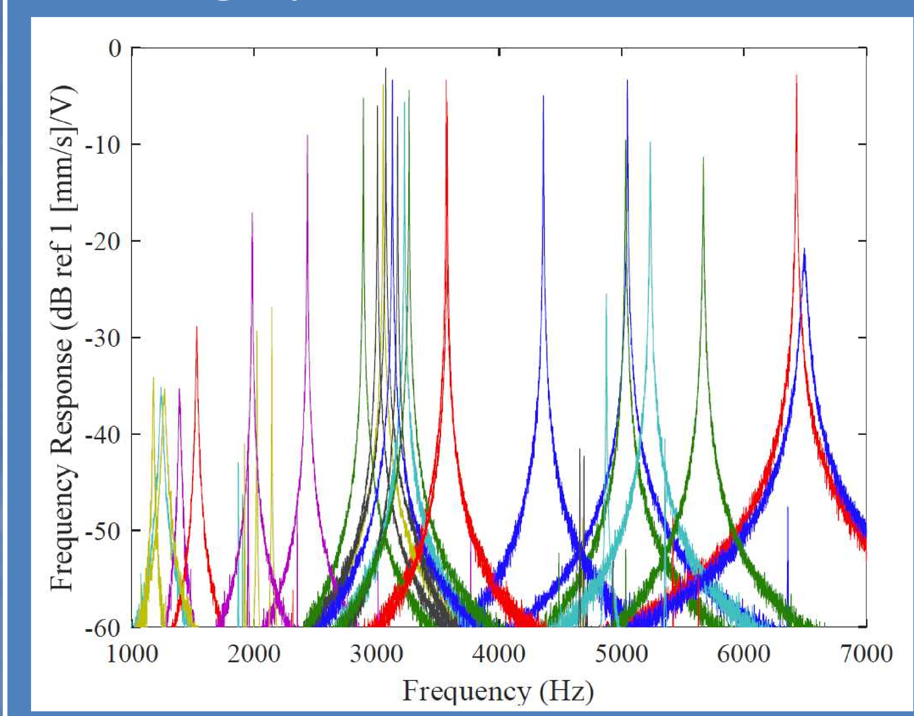
Impedance and motion of the fluid surrounding the diaphragm are represented R_{rad} and M_{rad}. The gaps around the tethers produce the vent resistance R_{AV} and the back cavity is represented by a spring with compliance C_{AC}.

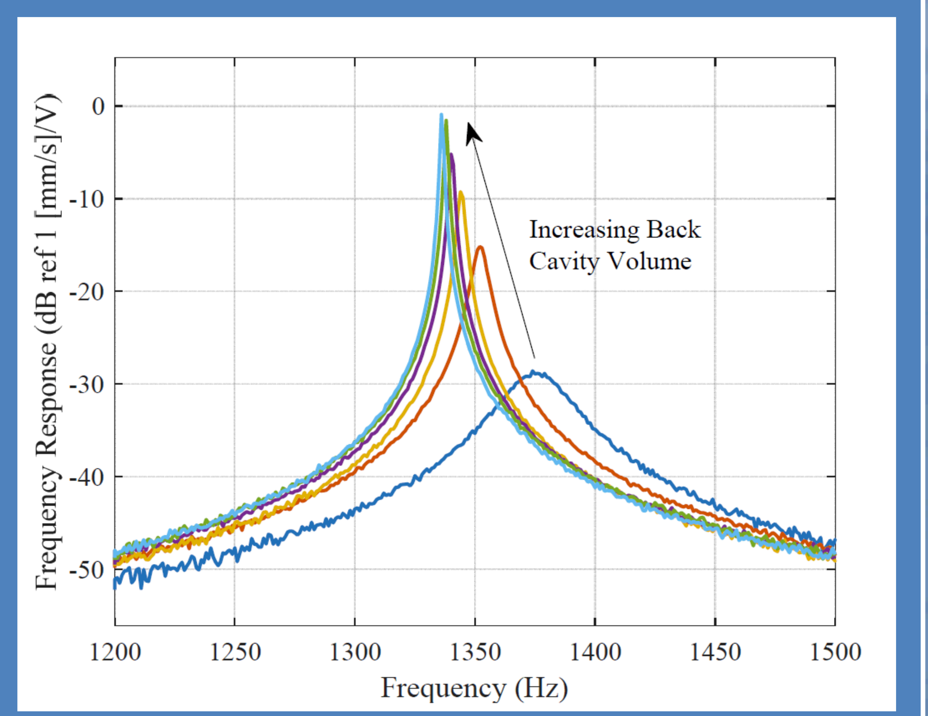
The acoustic domain is coupled into the electrical domain by a transformer with transduction factor $\emptyset_A$. As observed in the equivalent circuit, the vent resistance and back cavity compliance create a high-pass filter which determine the device cut-on frequency.



CHARACTERIZATION

Devices were first tested on a laser vibrometer. Microphones were obtained with resonant frequencies ranging from 430 Hz to over 10 kHz with quality factors up to 3000. The back cavity was adjusted and the high-pass filter behavior was confirmed.





The microphones were then tested in a plane-wave tube where sensitivities of up to 600 mV/Pa were obtained

SUMMARY

In this work, resonant MEMS microphones based on piezoelectric AlN were developed to create passive, acoustic filters. Unlike general microphones, devices were designed to operate around their resonant frequency. Devices were demonstrated with resonant frequencies ranging from 430 Hz to over 10 kHz while maintaining quality factors up to 3000. Open-circuit voltages exceeding 600 mV/Pa were obtained. Future work will combine these zero-power sensors with very-low-power ASIC CMOS chips to create a near-zero power wakeup system.

ACKNOWLEDGEMENTS

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