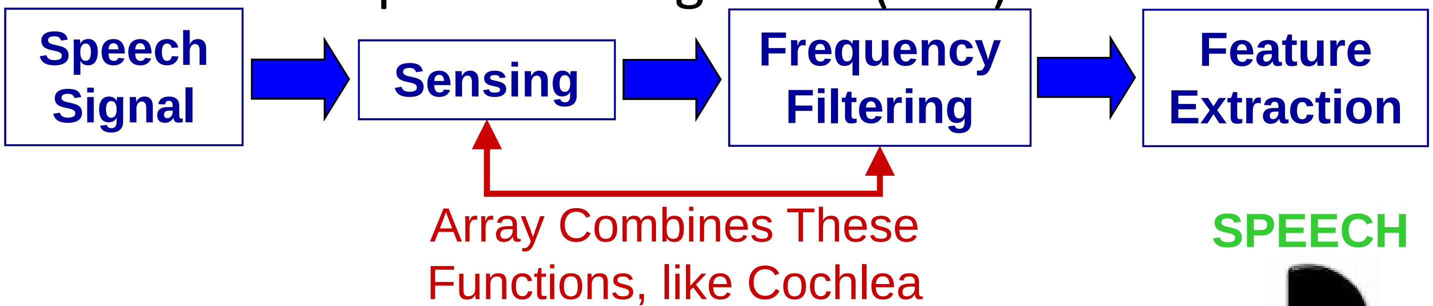
Organization: *University of Southern California*
Lead investigator: *Eun Sok Kim*

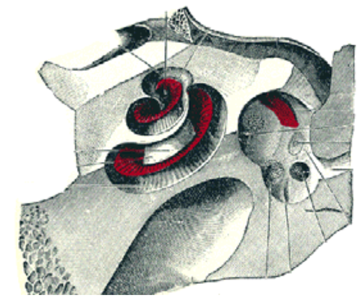
- Research areas of interest
  - *acoustic microelectromechanical systems (MEMS)*
    - *microphone, microphone array*
    - *Q-enhanced resonant microphone*
    - *Microspeaker*

- Type of research group we seek to join:
  - *Speech recognition group that is interested in*
    - *hardware-enhanced speech recognition*
    - *acoustic filter banks*
    - *active noise cancellation*

Introduction, Motivation

- Automatic Speech Recognition (ASR):

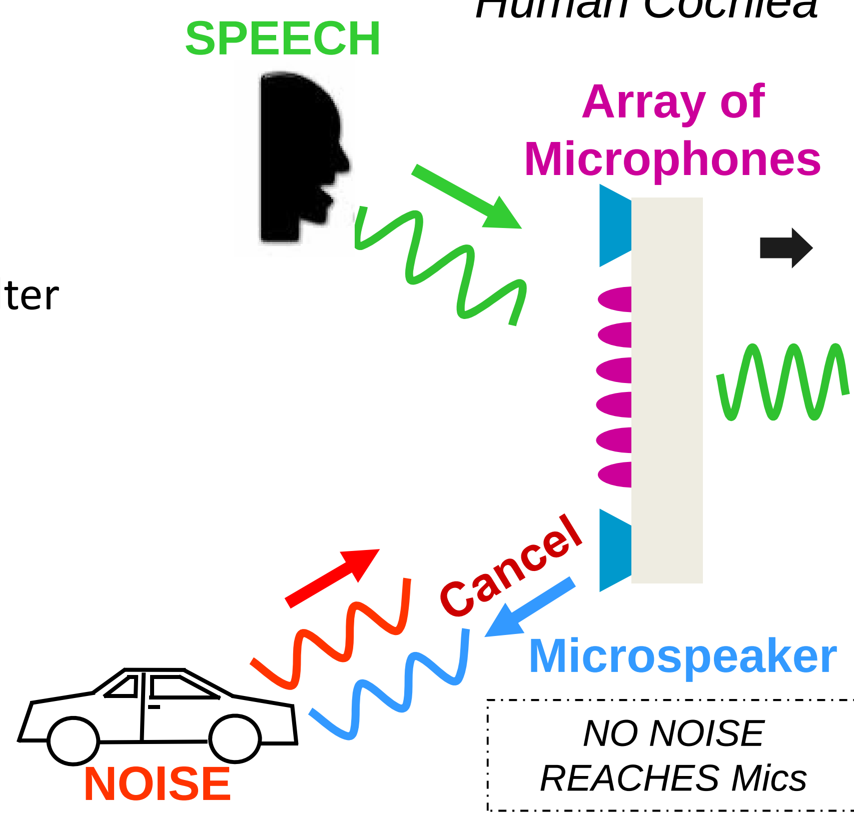




Human Cochlea

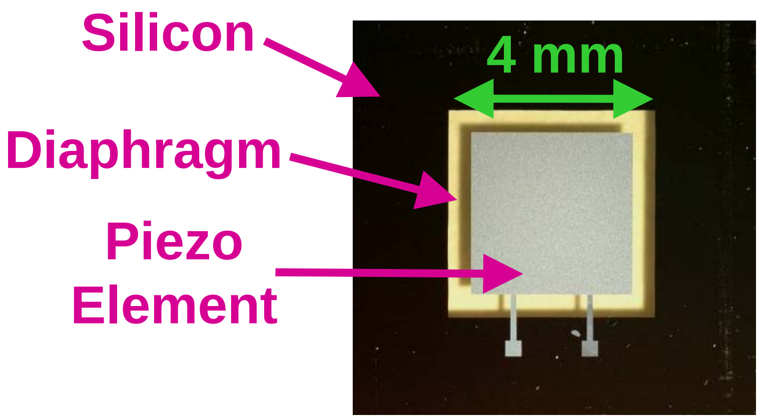
- Microphone Array
  - Novel Sensor Increases Functionality
    - “Physical Filtering” ➔ Eliminate digital filter
    - Directional Noise-Source Identification
- Active Noise Cancellation
  - Eliminate noise ***before*** sensor
    - ➔Further reduction in signal processing
  - Requires On-chip sound source

➔ **Microspeaker for Noise Cancellation**



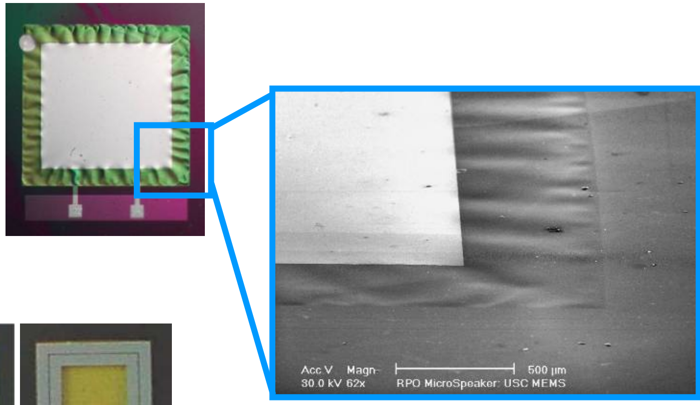
Operational Principle and Design

- Piezoelectric Unimorph
  - Voltage ⇔ Strain
  - Support Layer converts lateral strain into vertical displacement
  - Diaphragm converts displacement into sound

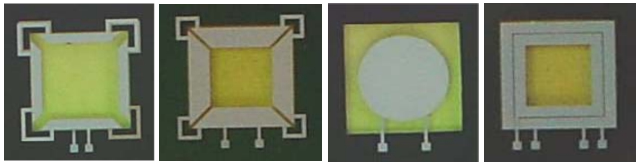


- Design Considerations
  - Diaphragm Residual Stress

Compressive Stress → **Compliant Diaphragm** → **High acoustic Output**

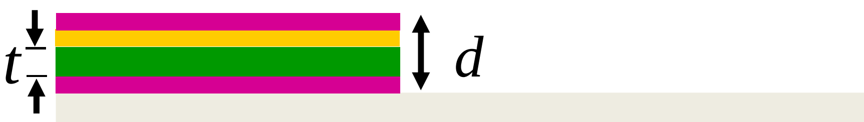


  - Size
    - Trade-off: Strength vs Output
  - Electrode pattern
    - Strain Distribution

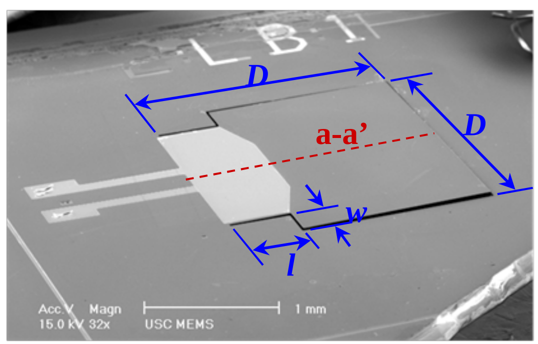


Microphone Built on Piezocantilever

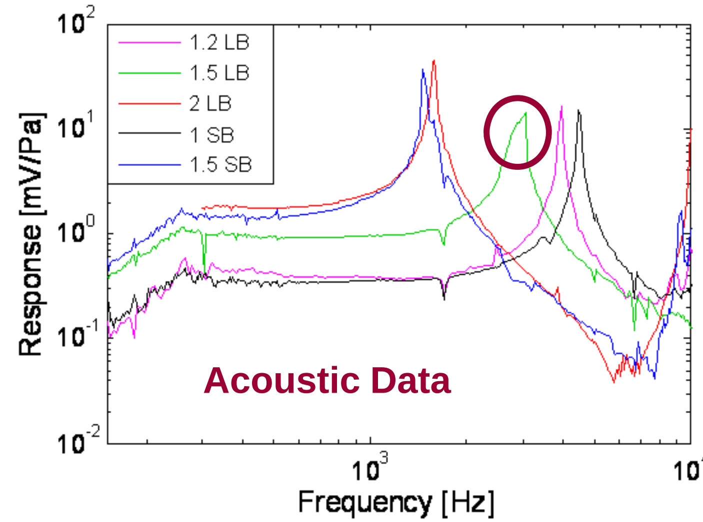
- Rayleigh Method accounting for thickness of piezo group
  - Normalize layer thicknesses based on stiffness ➔ **Effective thickness** = d_{ef}

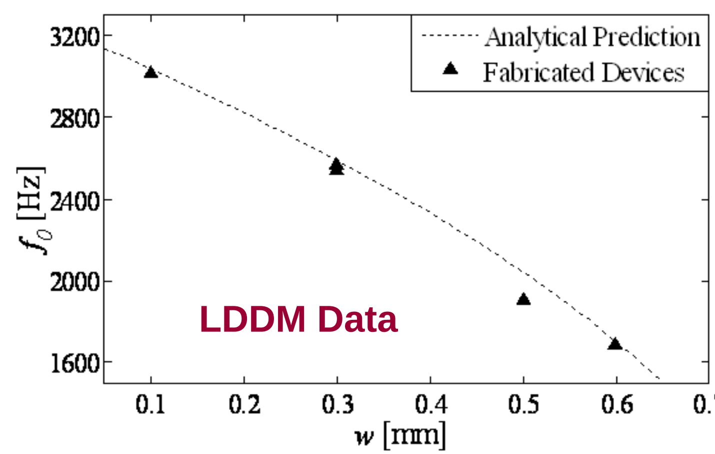


$$d_{ef} = \sum_i \frac{E_i}{c_{11}^{(Si)}} t_i$$



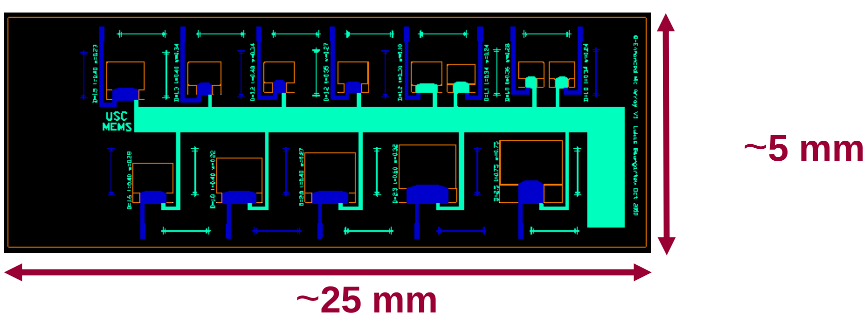
- Many devices tested with LDDM only
  - Much faster
  - Still can get Q and f_0
- Some anamalous devices not included
  - e.g., Device "1.5 LB" above
    - Photoresist strands damp resonance

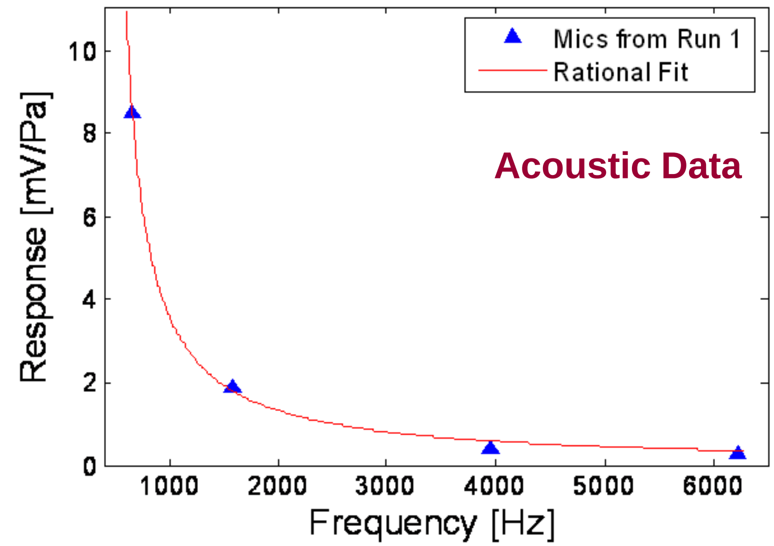


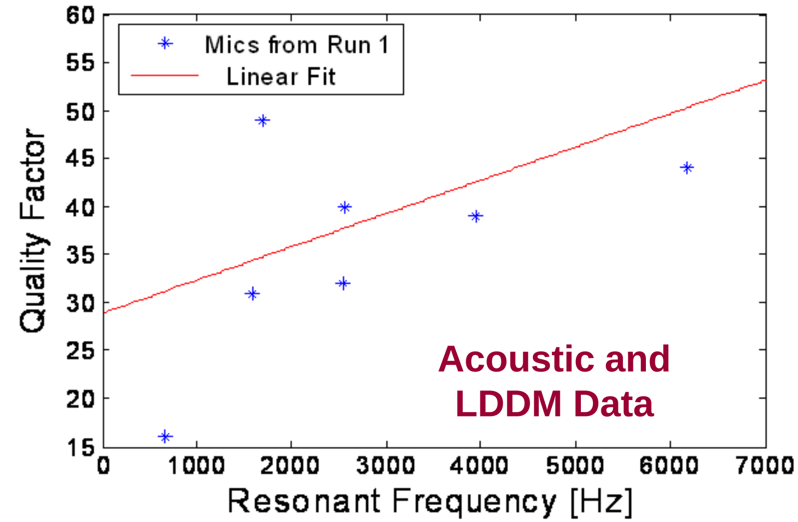


Design of Resonant Microphone Array

- Goal is to span 875 Hz to 6 kHz
  - Somewhat arbitrary but also consider
    - Total Array Size
    - Yield Rate: D < 2.5 mm
    - Number of mics, testing, bonding, etc.
- Extrapolate frequency response from previous runs
- Array is 13 mics
  - Resonant freq. linearly spaced
  - Dimensions of each mic calculated using MATLAB code of Rayleigh Method

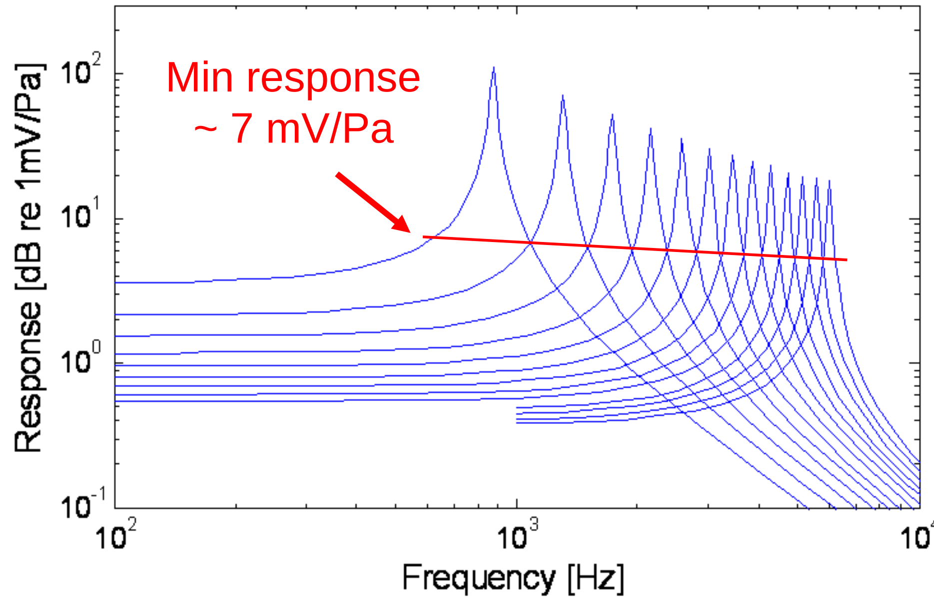


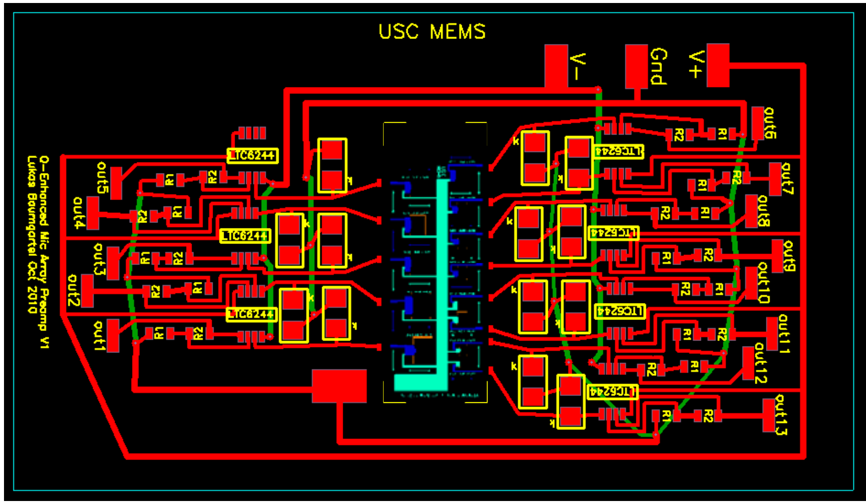




Predicted Response and PreAmp

- Array Response
  - Peaks should be more closely spaced
    - Trade-off's from before
    - Fit seven arrays on a half-wafer
    - If frequencies match, will prove concept
- PreAmp PCB:
  - Linear Technologies LTC6244 op amps
    - $R_{in} = 1\ T\Omega$
    - $C_{in} \sim 3\ pF$
    - 2 amps/chip
  - Mics have common ground
    - ➔ Half as many wire-bonds





Unique Qualifications and Capabilities

- We can develop
  - a bank of acoustically filtered MEMS microphones that are based on a high quality-factor resonance of a diaphragm
  - MEMS microspeakers to be integrated with MEMS microphones for active noise cancellation for improving SNR.

Contact Information

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