

MEMS Microphones at Draper

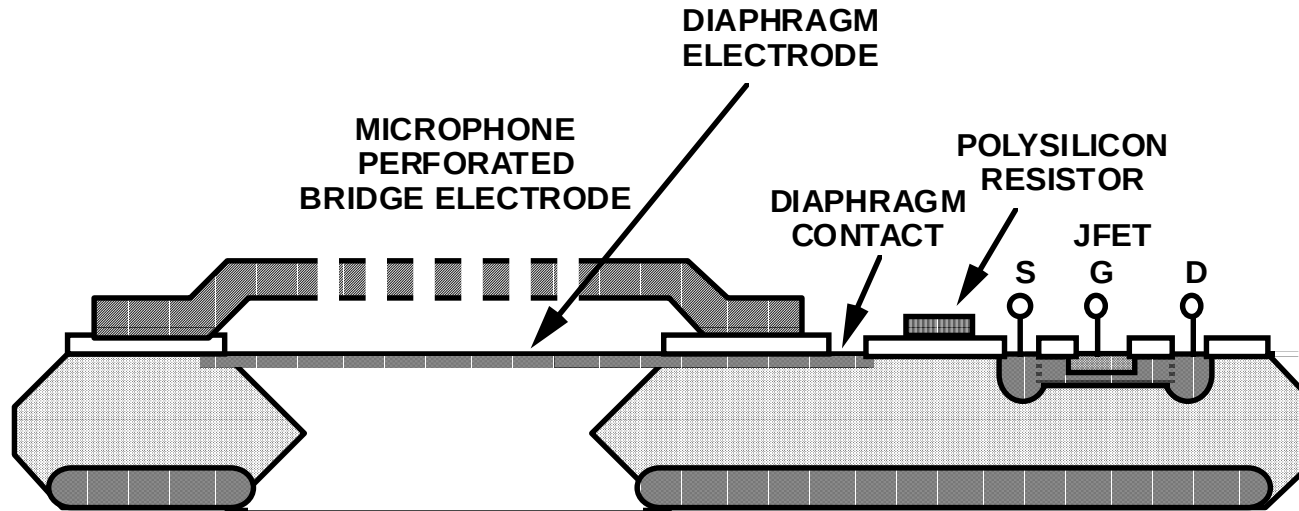
MEMS Air Acoustics Research The Charles Stark Draper Laboratory

J. Bernstein

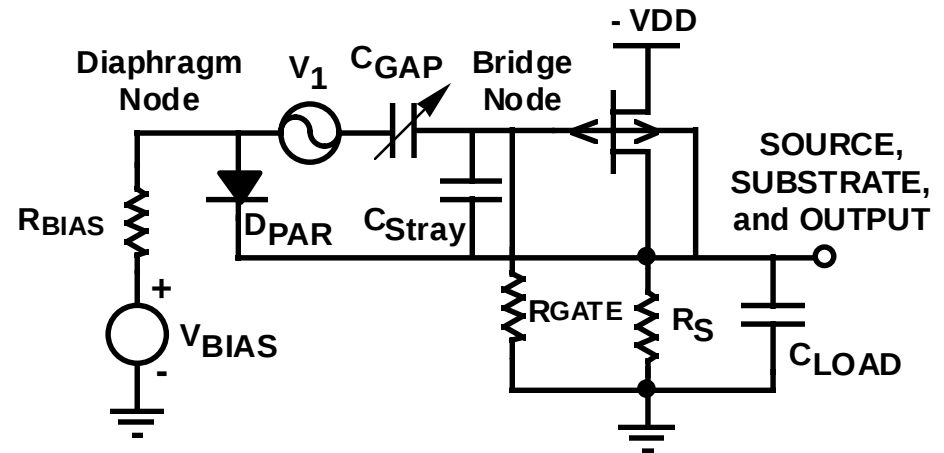
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Condenser Microphone Cross-Section & Circuit Diagram

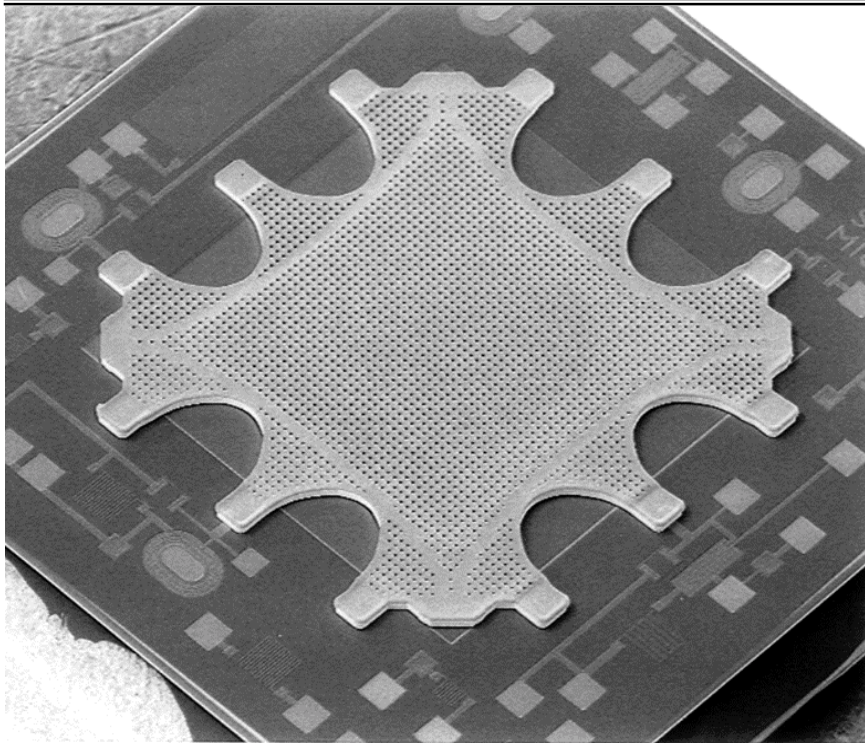


Cross-section of mike with on-chip JFET amplifier



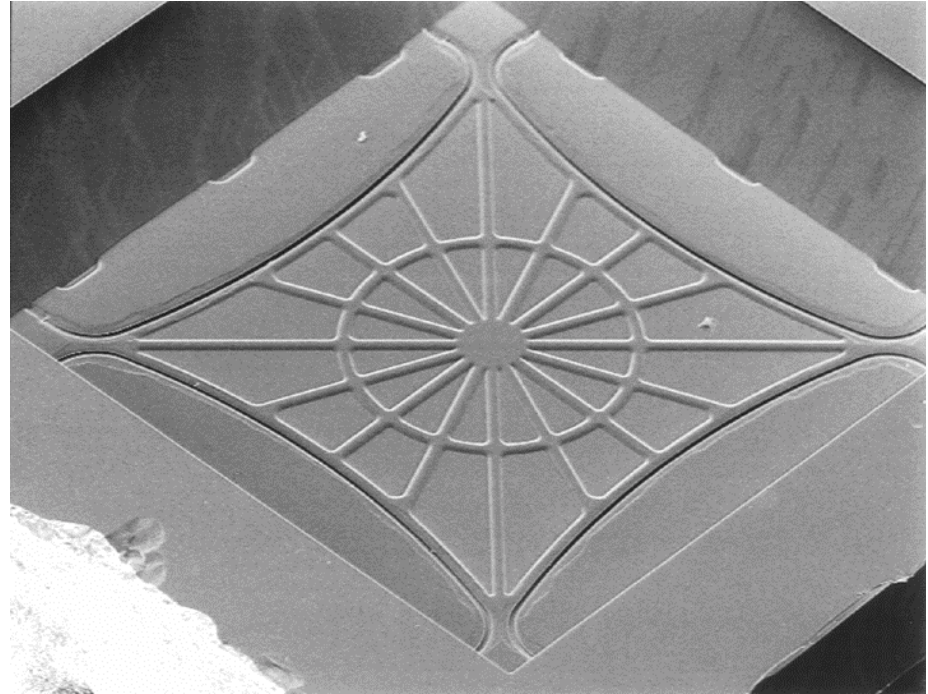
Circuit diagram with parasitics

Micromachined Microphone



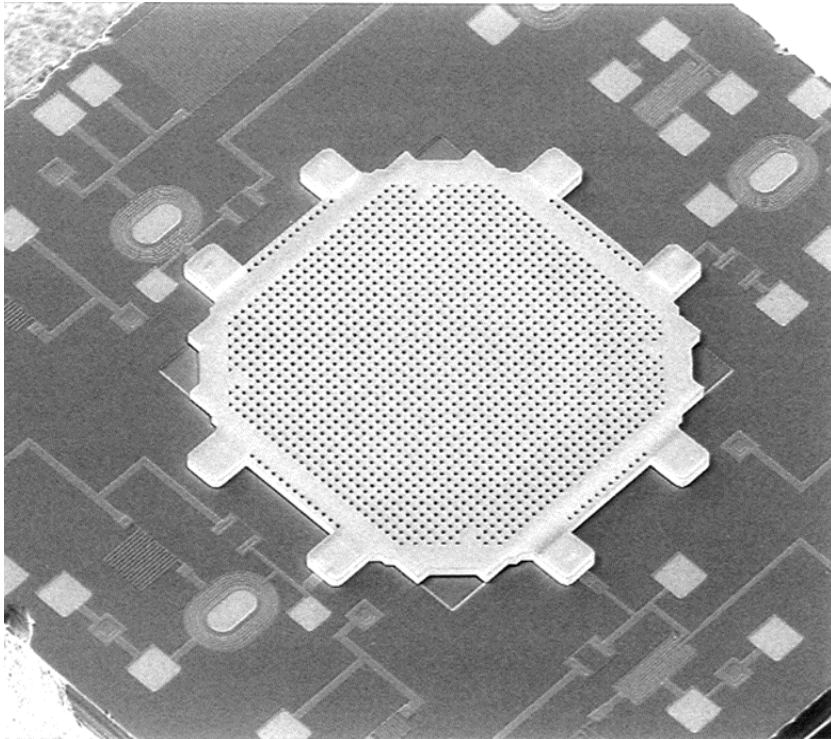
Front view:
Perforated bridge electrode
JFET buffer circuits

Back view:
Reinforced silicon diaphragm
Anisotropically etched through hole



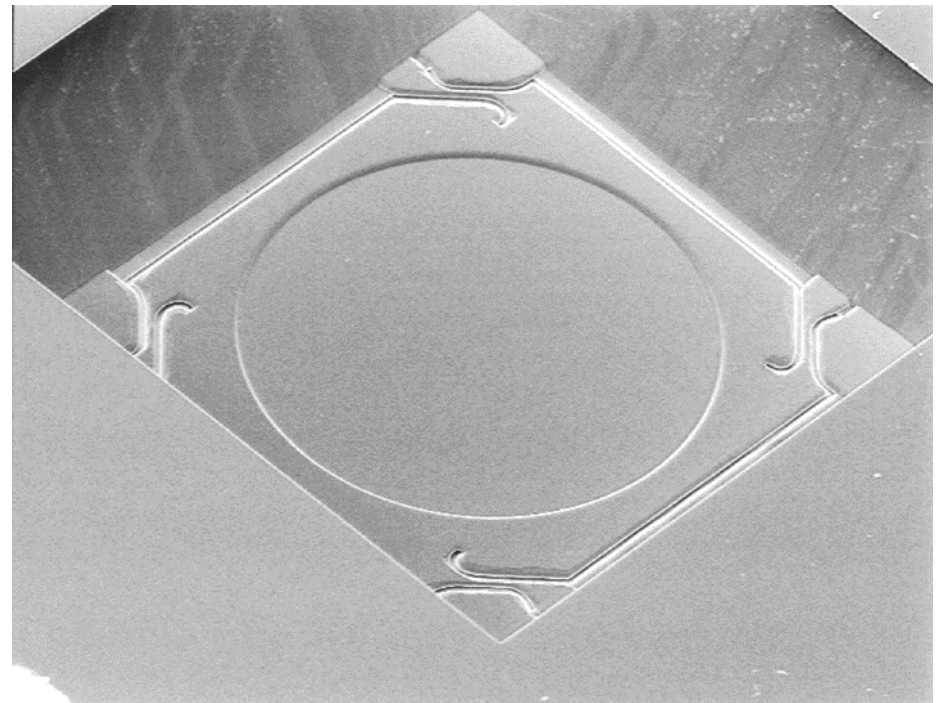
Micromachined Microphone With On-Chip Buffer Amplifier

Condenser Microphone 1mm Diaphragm



**Top View:
Bridge Electrode and Electronics**

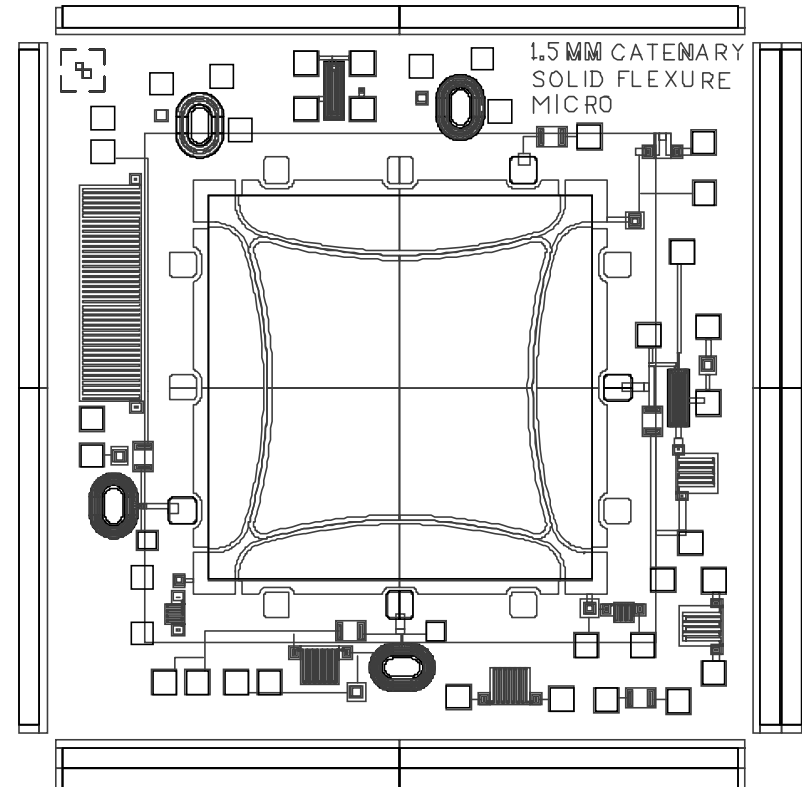
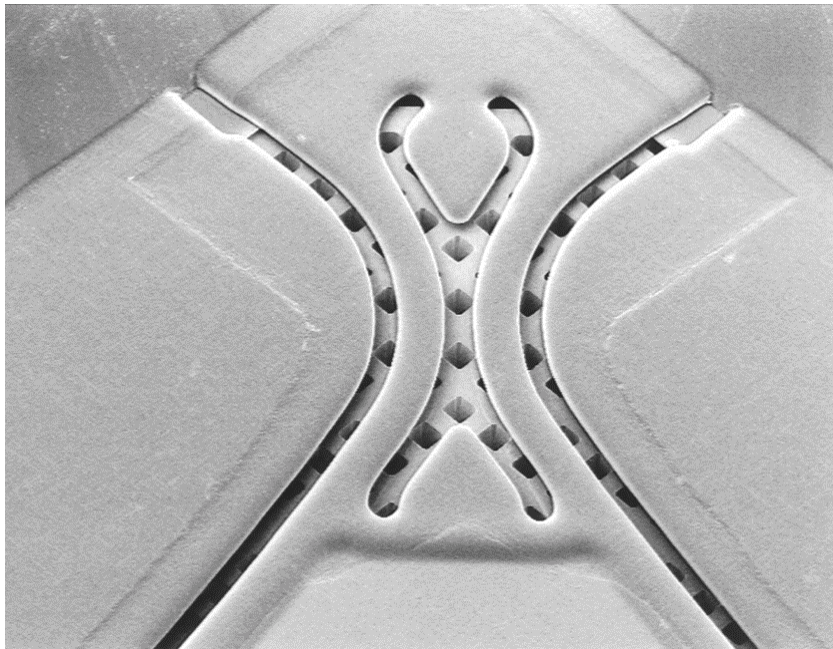
**Bottom View of Diaphragm,
Etch Pit and Springs**
Center of diaphragm is 1 micron thick,
Edges & springs are 6 microns thick



Micromachined Microphone with 1mm Diaphragm

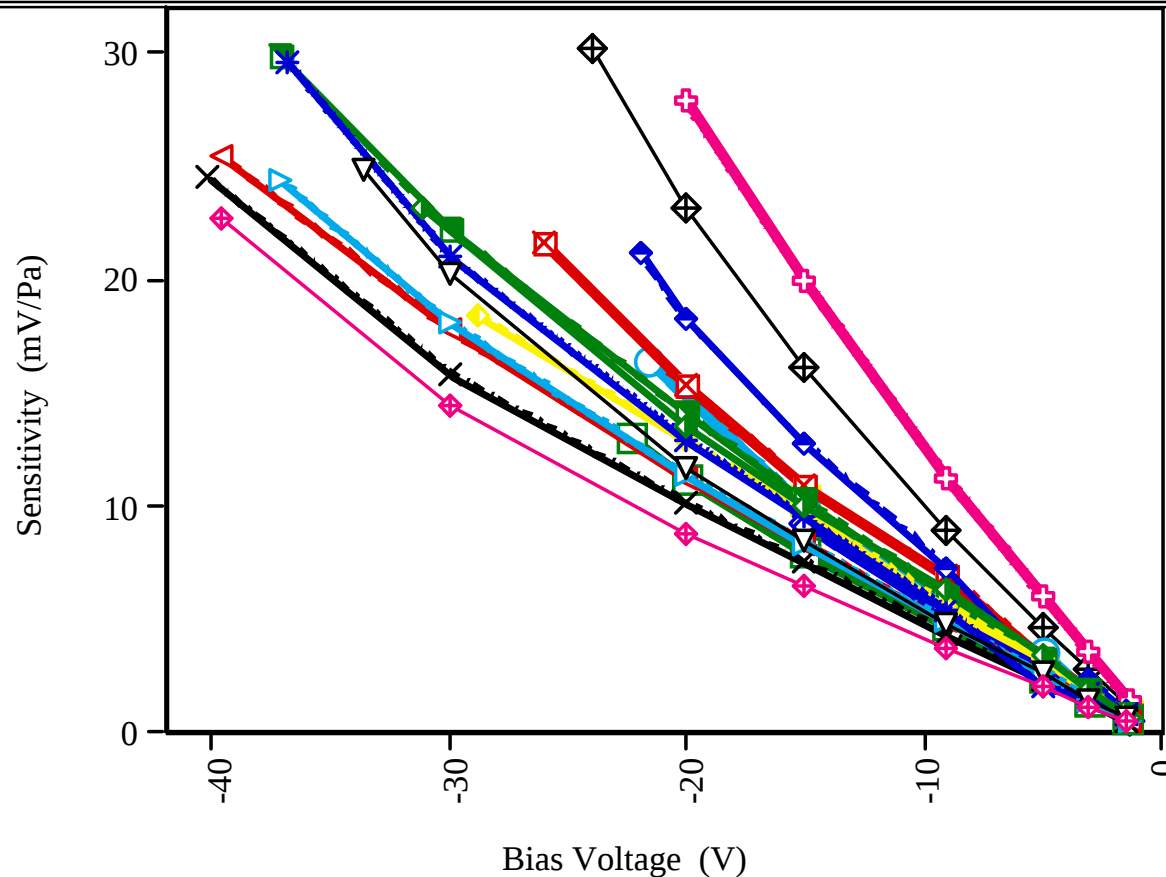
Condenser Microphone Catenary Designs

- To reduce mass of diaphragm, a 1 micron Si layer was used, with a thin border of 6 micron silicon for strength.
- Catenary shape gives good compliance & flatness
- LIGA-like 20 micron thick gold plated electrode



Mask layout drawing

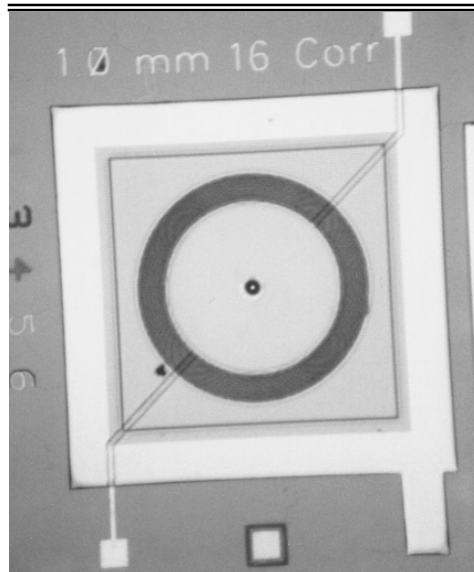
Condenser Microphone Sensitivity vs. Bias Voltage



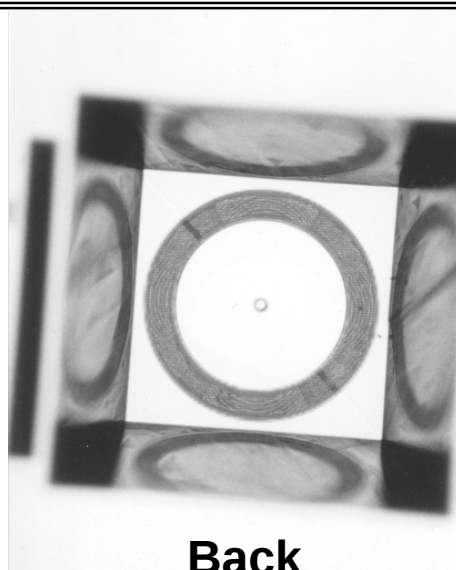
Sensitivity vs. bias voltage for various microphone designs

- Sensitivity & bandwidth of these miniature MEMS microphones are better than commercially available hearing aid microphones
- Bandwidth of 20-30 kHz depending on design

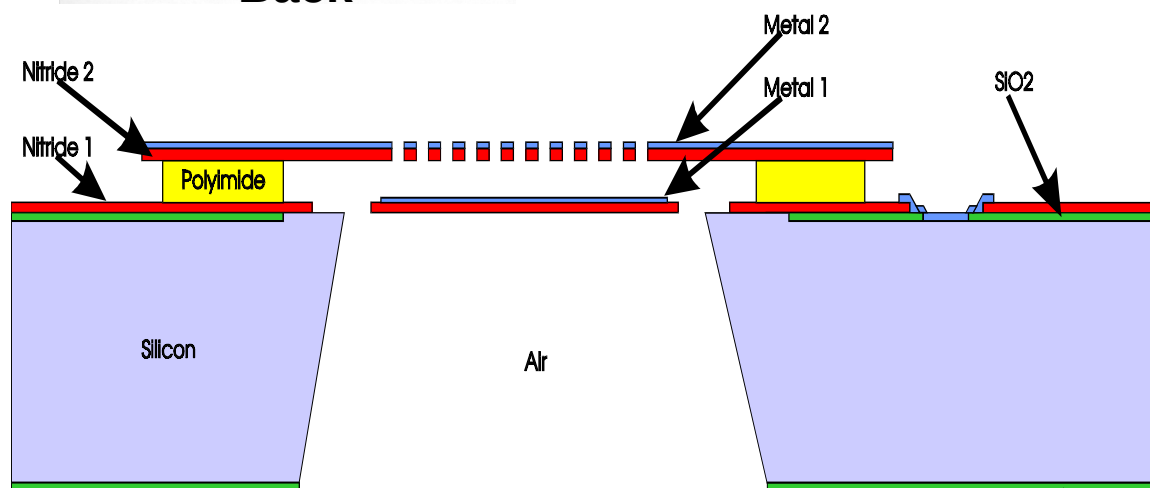
Nitride Membrane Microphones



**Round diaphragms
with corrugations
(front)**



- Silicon nitride membrane microphones were developed for increased bandwidth
- Novel fabrication process
- Polyimide sacrificial layer
- Stress-control of Si_3N_4 critical
- Work by B. Cunningham



Nitride diaphragm microphone cross-section

Conclusions

- **Draper has developed high sensitivity MEMS condenser microphones**
 - **On-chip JFET amplifiers to reduce stray capacitance**
 - **Single crystal silicon diaphragms**
 - **Electroplated perforated bridge electrodes**
 - **Si₃N₄ membrane fabrication process also developed**
- **Custom designs for ultrasound or infrasound possible**
- **Arrays can be built as easily as one sensor**
- **Technology licensed to:**
 - NCT, National Semiconductor and Siemens (Munich)**

References

- J.J. Bernstein and J. T. Borenstein, "A Micromachined Silicon Condenser Microphone With On-Chip Amplifier", Digest of the 1996 Solid State Sensor and Actuator Workshop, pp. 239-243, Hilton Head, S.C., June 2-6, 1996.
- B. Cunningham and J. Bernstein, "Wide Bandwidth Silicon Nitride Membrane Microphones", SPIE Micromachining and Microfabrication Process Technology III, Austin TX, September 29-30 1997.