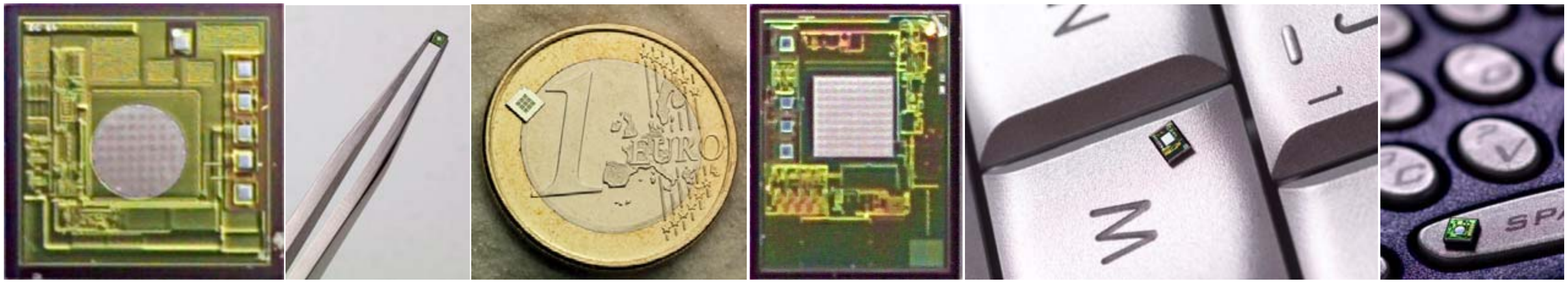


Akustica

Dr. Kaigham (Ken) J. Gabriel

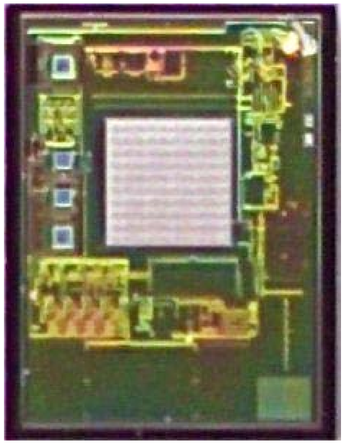
Chairman & CTO

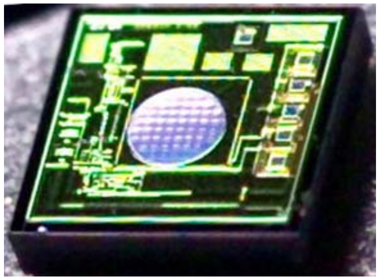
Akustica, Inc. • 2835 East Carson Street • Suite 301 • Pittsburgh, PA 15203 USA • 412-390-1730 • www.akustica.com

What if integrated circuits could hear, speak and sense the world around them?

Akustica Improves Voice Quality

Microphones, speakers and complete acoustic systems on a single MEMS chip …





… enabling cell phones, laptops and other electronic devices to speak, hear, and feel.

Better Microphone Technology …

- Digital and directional microphones

…with Integrated Voice Processing ...

- Algorithms to suppress wind and background noise

… and Multi-Sensor Clusters

- Detect vibration interference and extract noise

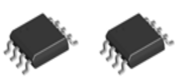
AKUSTICA

Sensory Silicon™

Patented CMOS MEMS technology enables system-on-chip integration of multiple sensors, electronics, and signal processing.

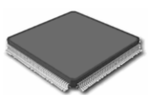
Microphones

\+



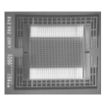
Analog / Mixed Signal Electronics: Amplifiers, A/D Converters

\+

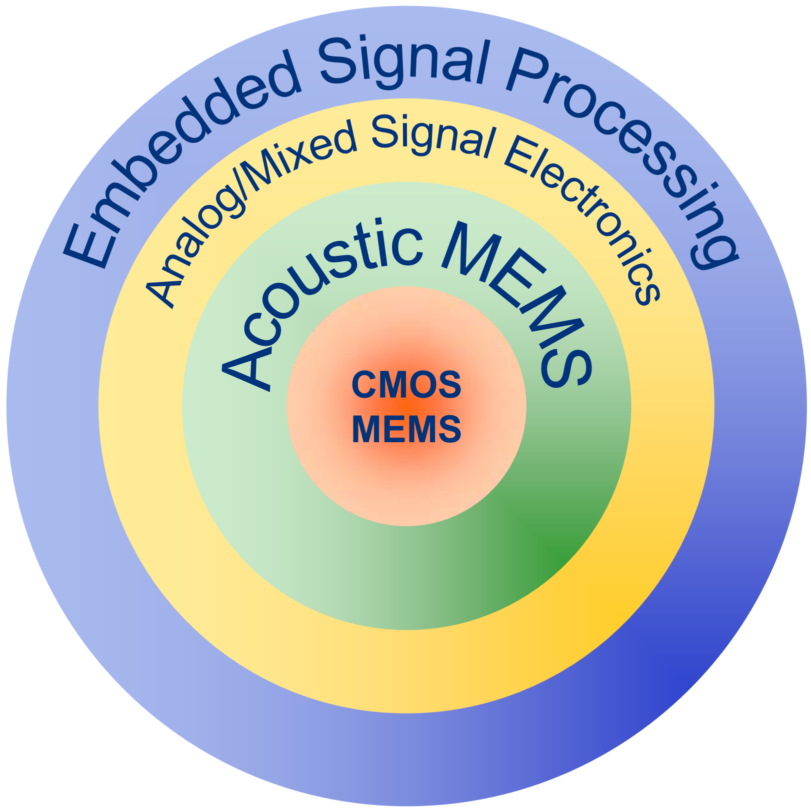


Signal Processing

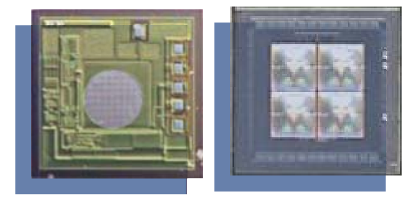
\+



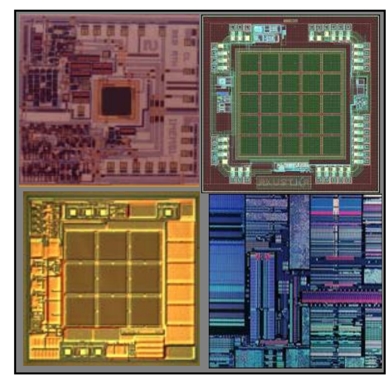
Inertial Sensors



Microphone and Speaker Chips



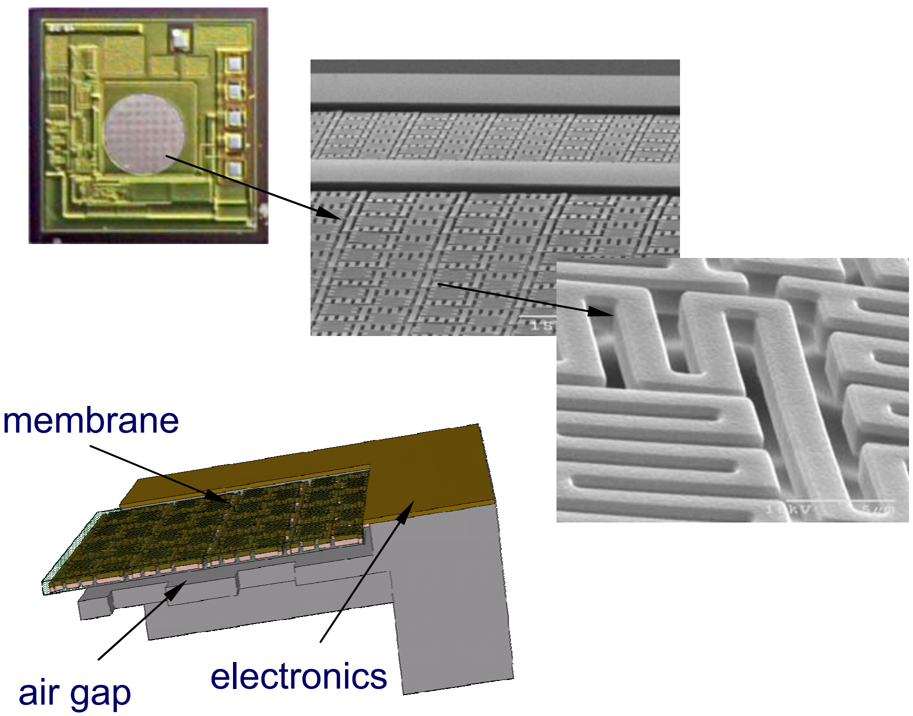
Sensor Clusters



AKUSTICA

CMOS MEMS Technology

MEMS structures made out of ***the CMOS thin-film materials*** using conventional CMOS with ***no changes to CMOS baseline processes***

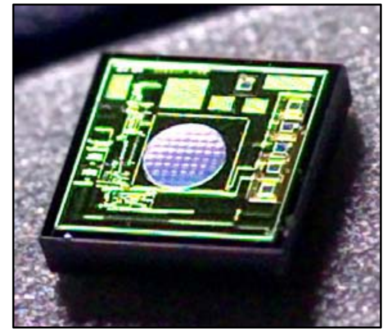


Carnegie Mellon

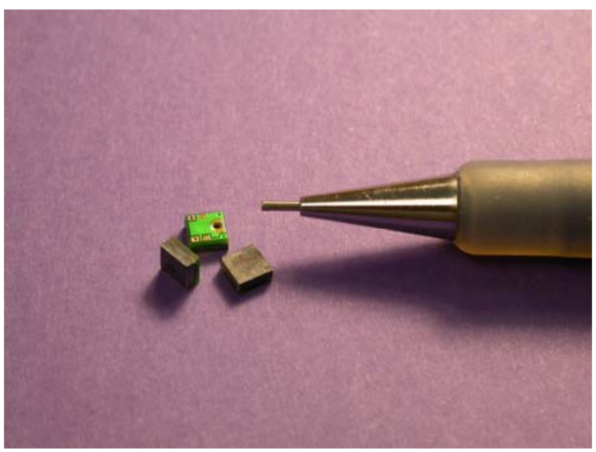
- Base Patents Licensed from Carnegie Mellon University
- Additional IP and know-how developed
- Advantages
  - *leverages quality, capability and capacity of global semiconductor industry*
  - *accelerates speed and frequency of product design*
  - *monolithic construction of circuits with MEMS decreases cost and increases performance & reliability*
  - *enables new functionality and capabilities*

Initial Products

AKU1000 – Analog Output Microphone



- Monolithic silicon microphone
- Surface mount to improve manufacturing yield
- Automated pick & place saves assembly cost
- 2X smaller footprint / thinner profile than ECM
- Production ramp - Now



AKU2000 – Digital Output Microphone

- Integrated 14-bit, 4^{th}-order Σ-Δ modulator
- Monolithic solution for superior transducer performance (10X lower parasitics)
- Immune to RF and EM interference enabling increased audio design flexibility
- Production ramp – Q4

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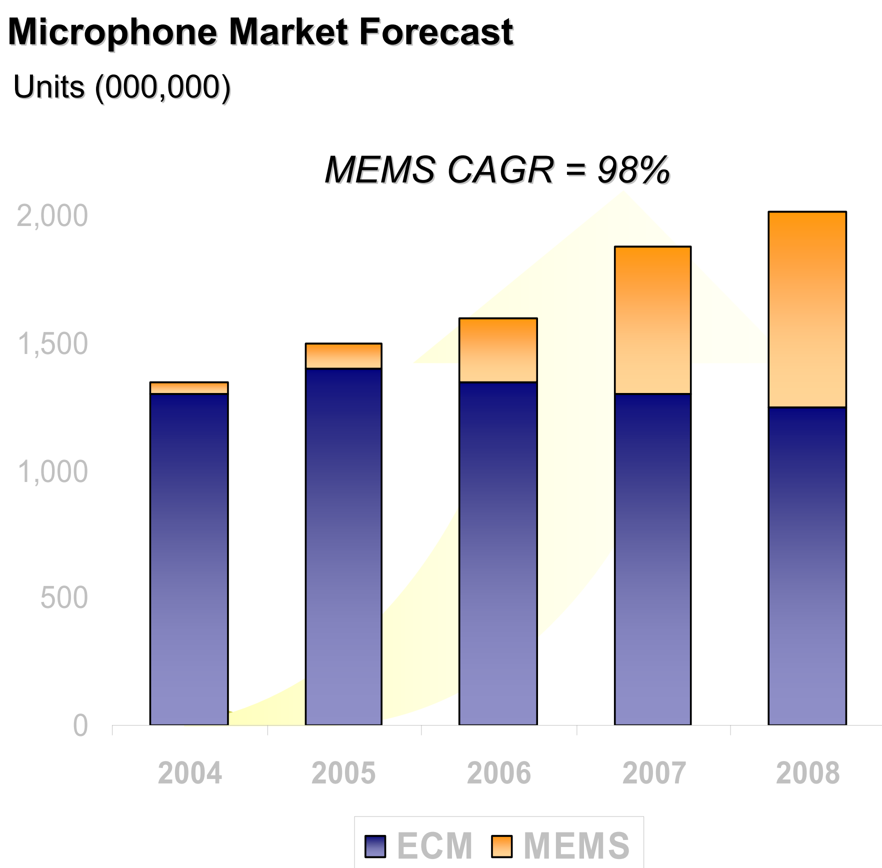
Large and Growing Installed Market



- On an annual basis, global OEMs and ODMs purchase:
  - 1.5 B microphones
  - 3.0 B near-field speakers
- MEMS microphones are rapidly replacing conventional ECMs (~100M units in '05)
  - MEMS microphones rapidly adopted into mobile handsets
  - >500m MEMS microphones forecasted for 2008
  - Attractive pricing and margin opportunities
- Secured high volume analog silicon microphone supply contract

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Target Markets

Communications – Smart Phones

- Enable next-generation handsets: thinner, smaller, lighter phones with better directionality, noise cancellation & fidelity
- Cell phones that sound great in noisy environments
- Moving to digital bus architecture

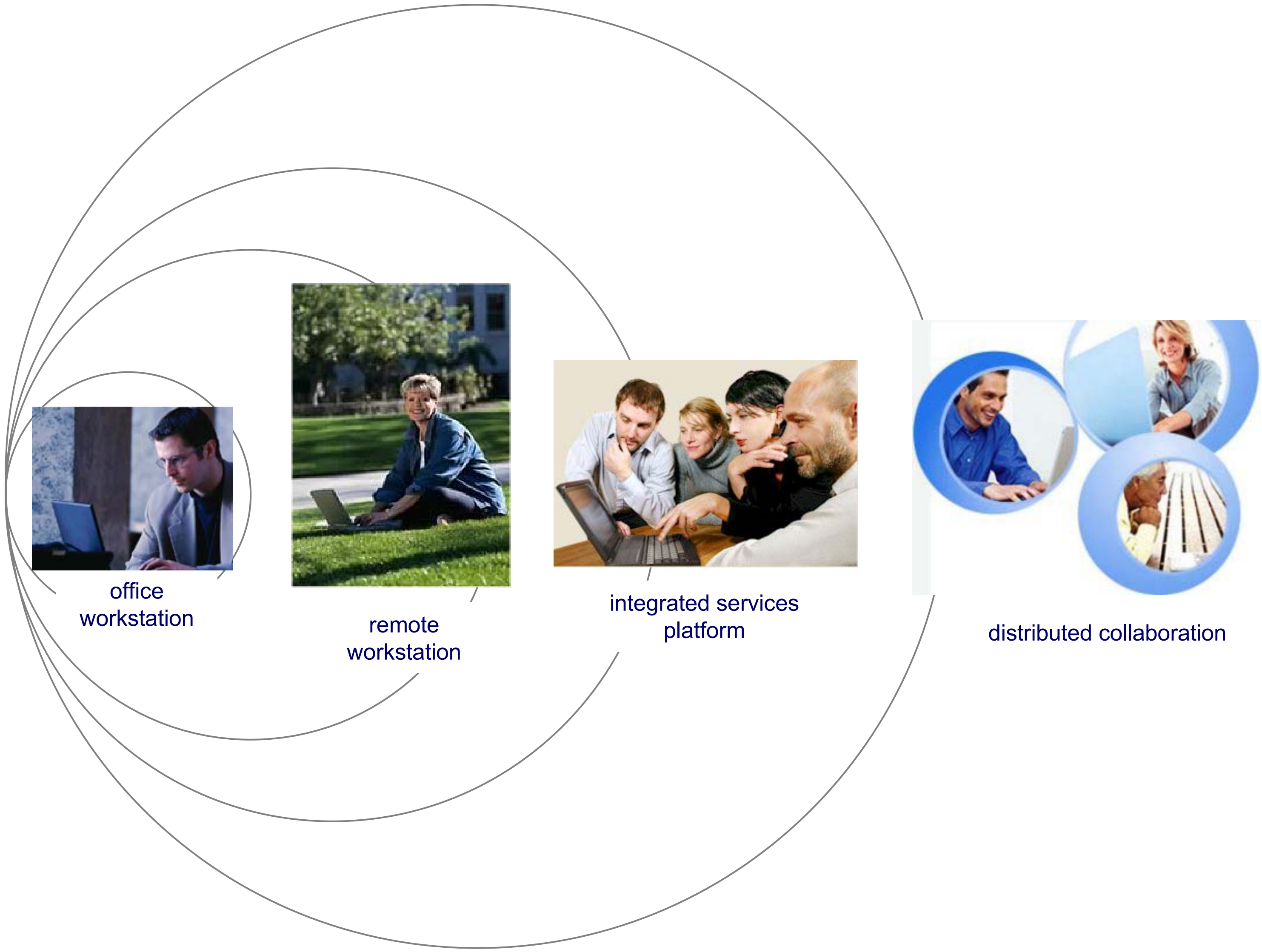
Personal Computing - Notebooks

- Improved voice conferencing in VoIP applications
- Enable full utilization of next generation Intel hardware and Microsoft software
- Require the addition of multiple microphones in displays for multi-media speaker-phone applications

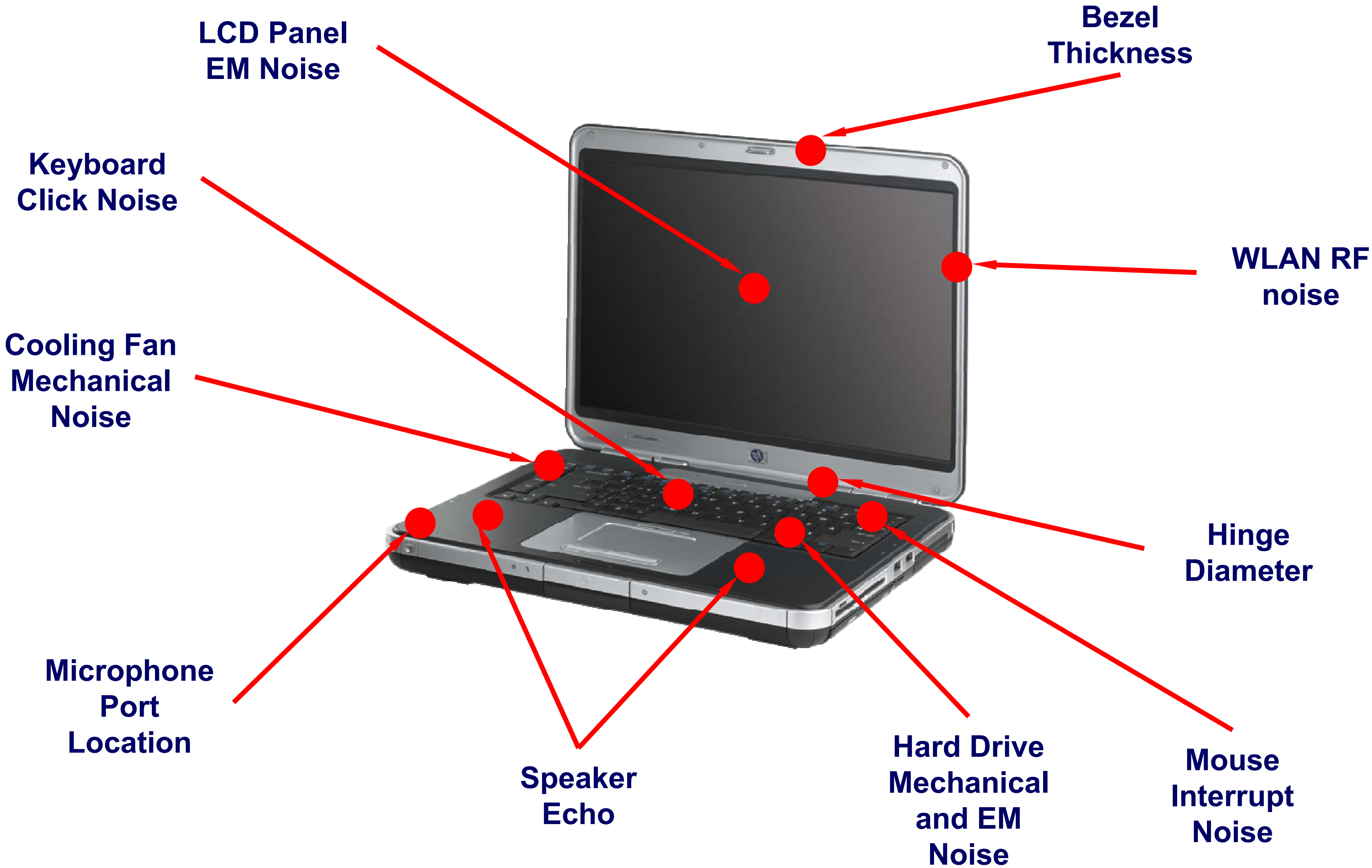
Digital Media – Consumer Electronics

- Raise audio quality to correspond to high quality video
- Component reduction enables smaller devices such as headsets
- Enables rich new uses of sound in cameras, voice recorders, and other consumer devices

Notebooks Usage Case Evolution



Acoustic Issues



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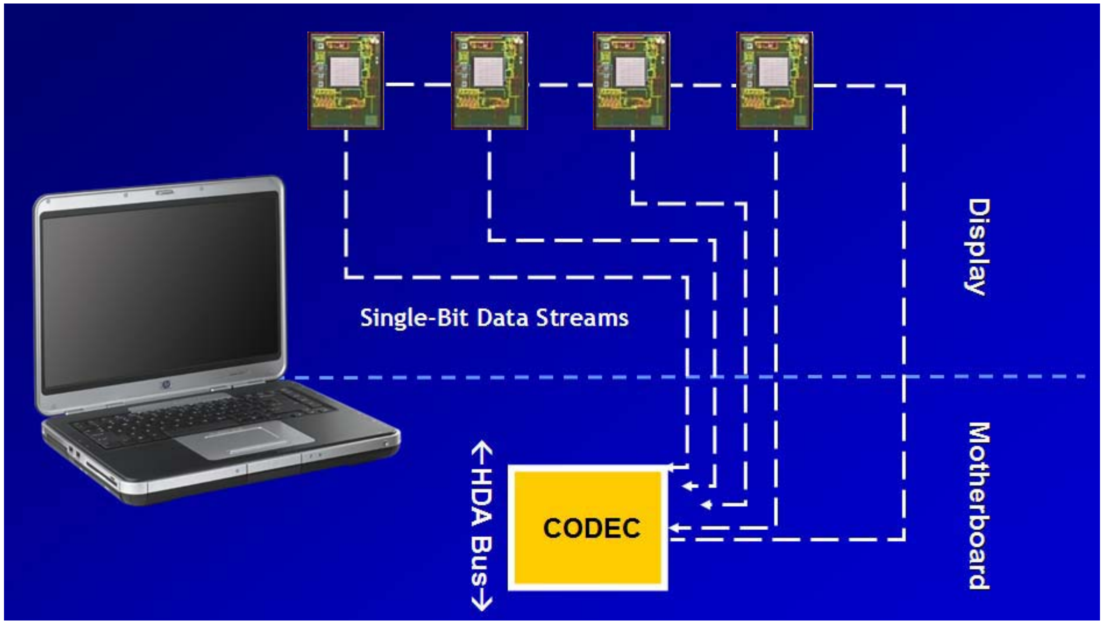
Akustica Overcomes The Challenges

FLEXIBILITY AND MANUFACTURABILITY

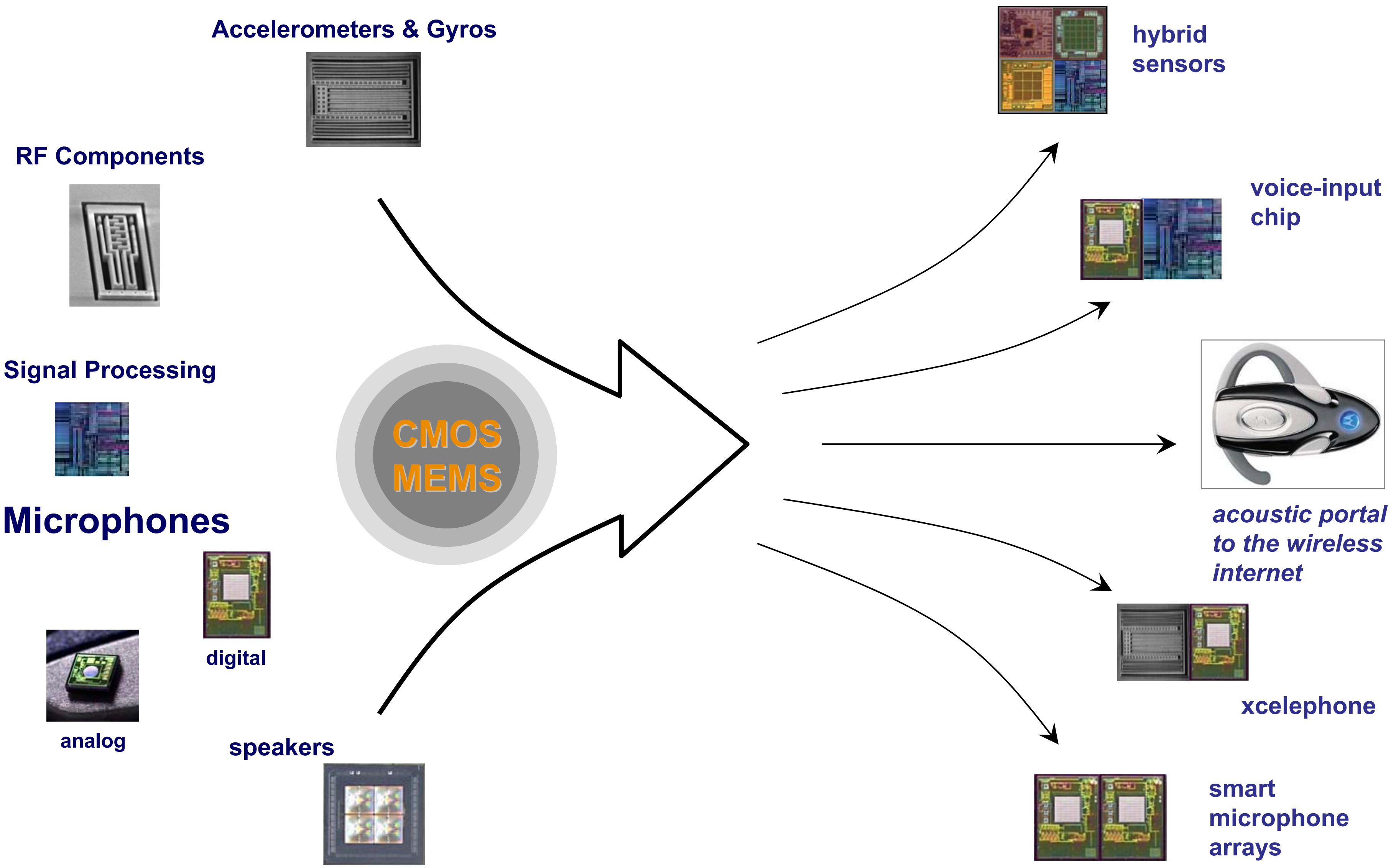
- Digital Microphones enable ideal placement in bezel
  - Noise susceptibility is reduced
  - Allows signal transfer through the hinge
  - Silicon technology enables very thin and small footprint
  - Digital architecture reduces customization and calibration in assembly

- Reduced component count and cost
  - Integrated pre-Amp
  - Simple ribbon cable interconnect

- Requires an HD Audio CODEC that has a direct interface to digital microphones



Product Roadmap and Vision



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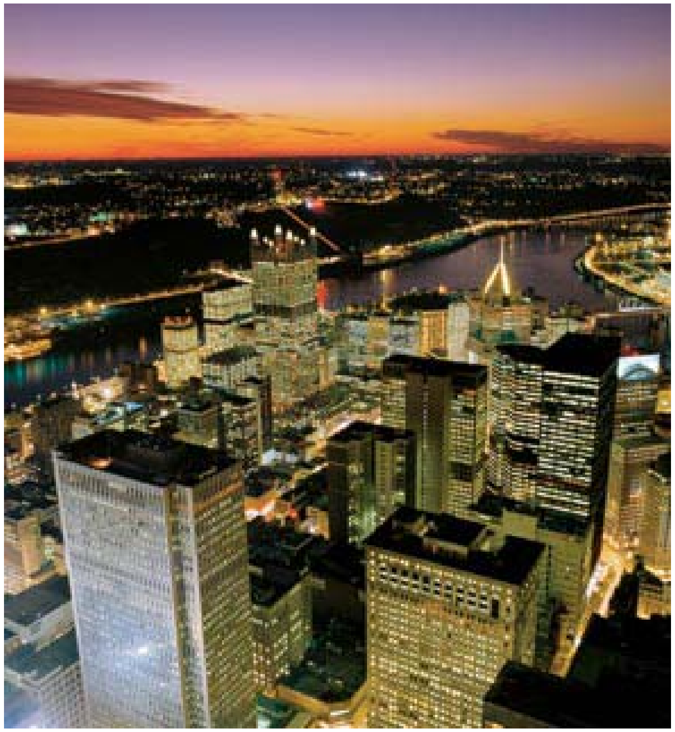
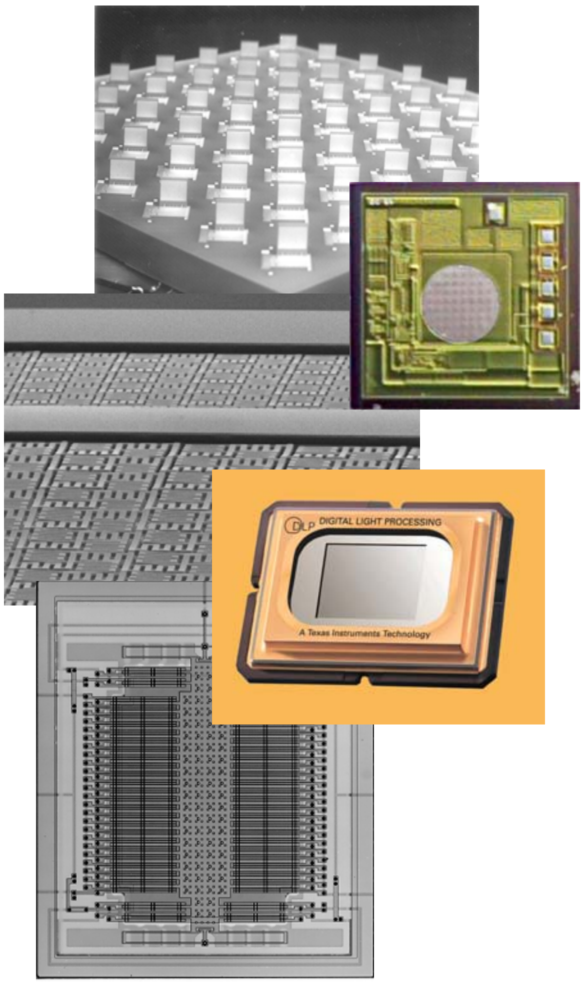
Company Profile



- HQ in Pittsburgh, PA USA
- Formed in 2001 by Ken Gabriel and Jim Rock
- Carnegie Mellon University Patents & Akustica IP
- 42 Employees, 80% Engineers
- Private, Venture-Backed ($30M)
- Commercializing CMOS MEMS for Major Consumer Electronic Applications

CMOS Microelectromechanical Systems (CMOS MEMS)

The Power of Many



Dr. Kaigham (Ken) J. Gabriel

Chairman & CTO
Akustica, Inc.

Information Systems Migration and MEMS

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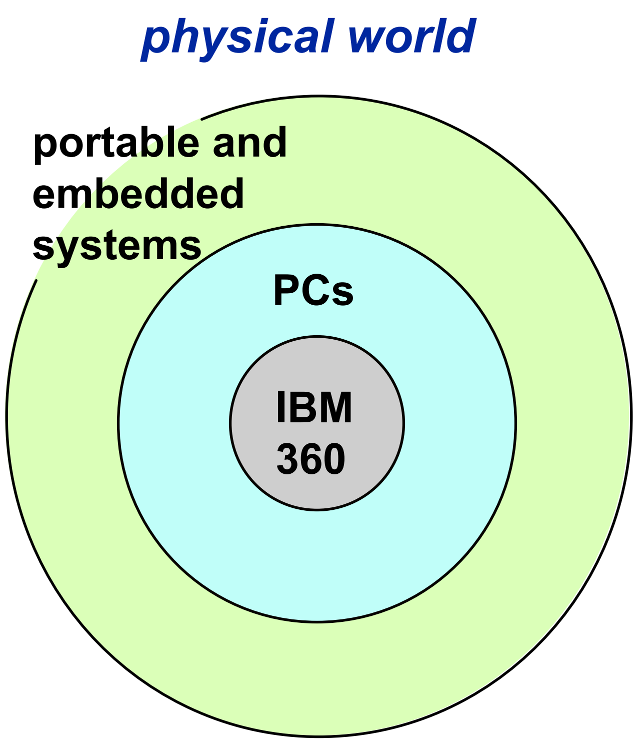


- ***Increasing number of information systems***
  - portable computing
  - cellular phones
  - internal combustion engine controllers
  - household appliances
- ***Embedded in and portions of larger systems***
  - larger systems not solely information systems (telecom, automotive, biomedical, structural)
  - relatively small fraction of cost, size & weight
  - key enabling component
  - need to sense and act as well as compute
- ***Creating demand for greater diversity of interaction with physical world***
  - mechanical
  - electromagnetic
  - chemical and biological
  - optical

MEMS will invest engineered systems with greater ability to sense and act in the physical world

MEMS

• **MEMS merges computation with sensing and actuation to change the way we perceive and control the physical world,**

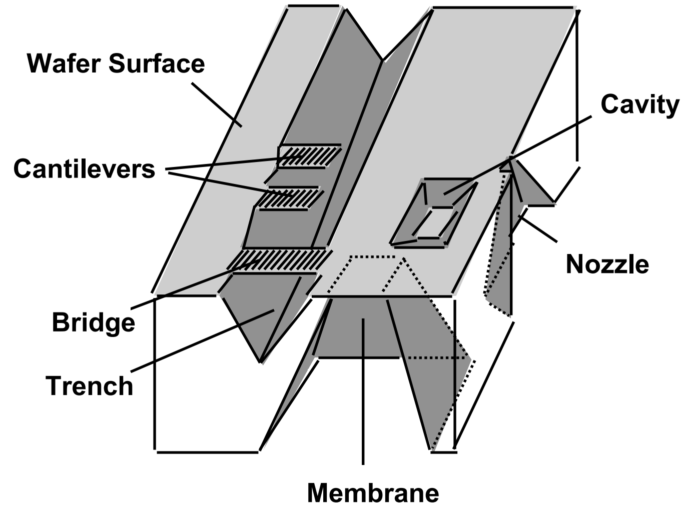
• **is a new way to make both mechanical and electrical components,**

• **and conveys the advantages of *miniaturization*, *multiple components*, and *microelectronics*.**

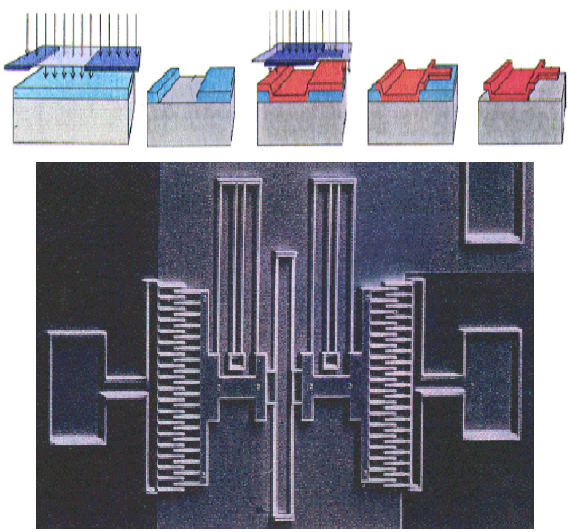
• **MEMS mechanical components have dimensions measured in microns and numbers measured from a few to millions**

• **MEMS makes possible integrated electromechanical systems, and puts these systems on the same cost-performance trajectory of microelectronic systems**

Common MEMS Fabrication Processes

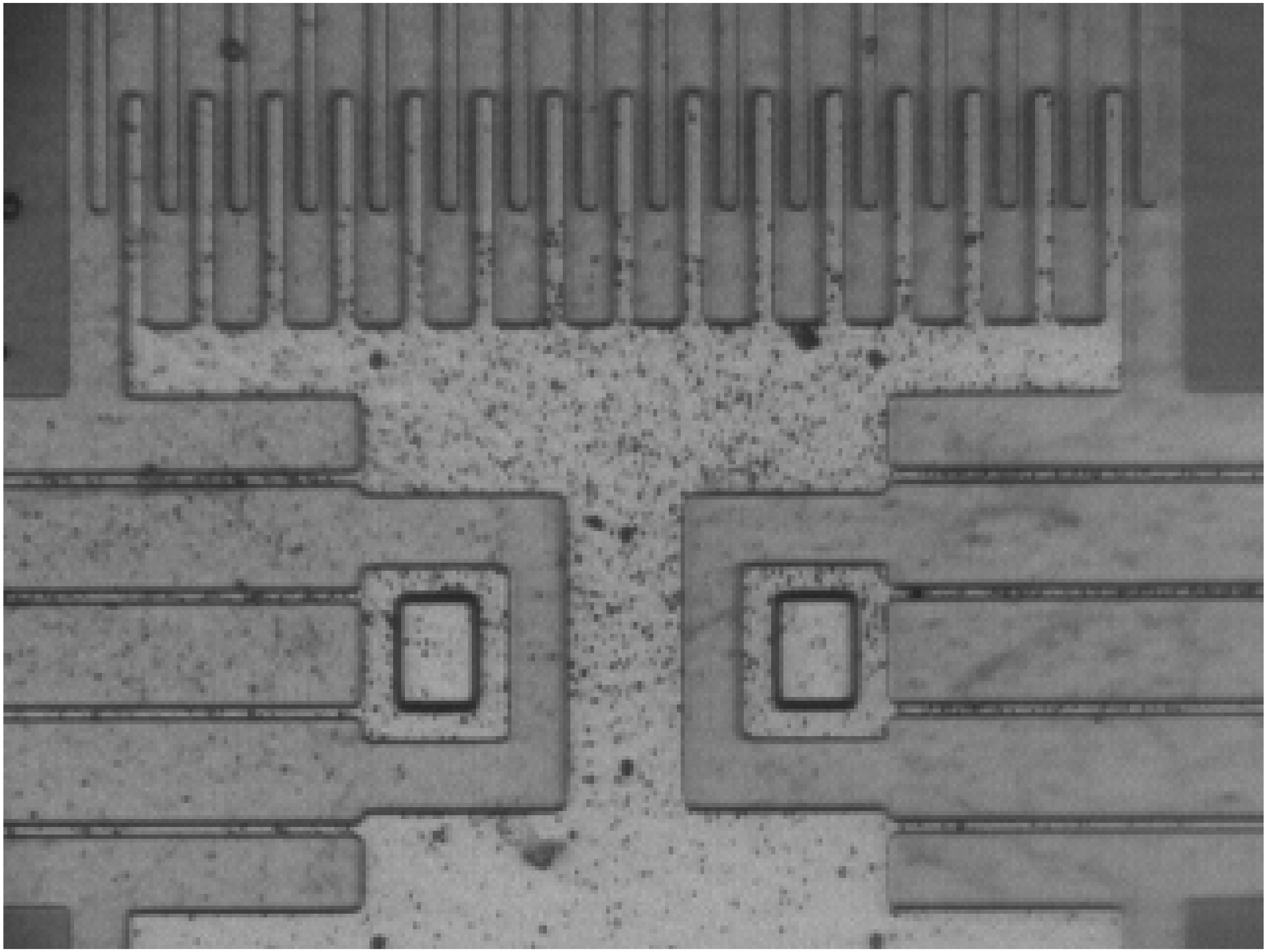


bulk micromachining

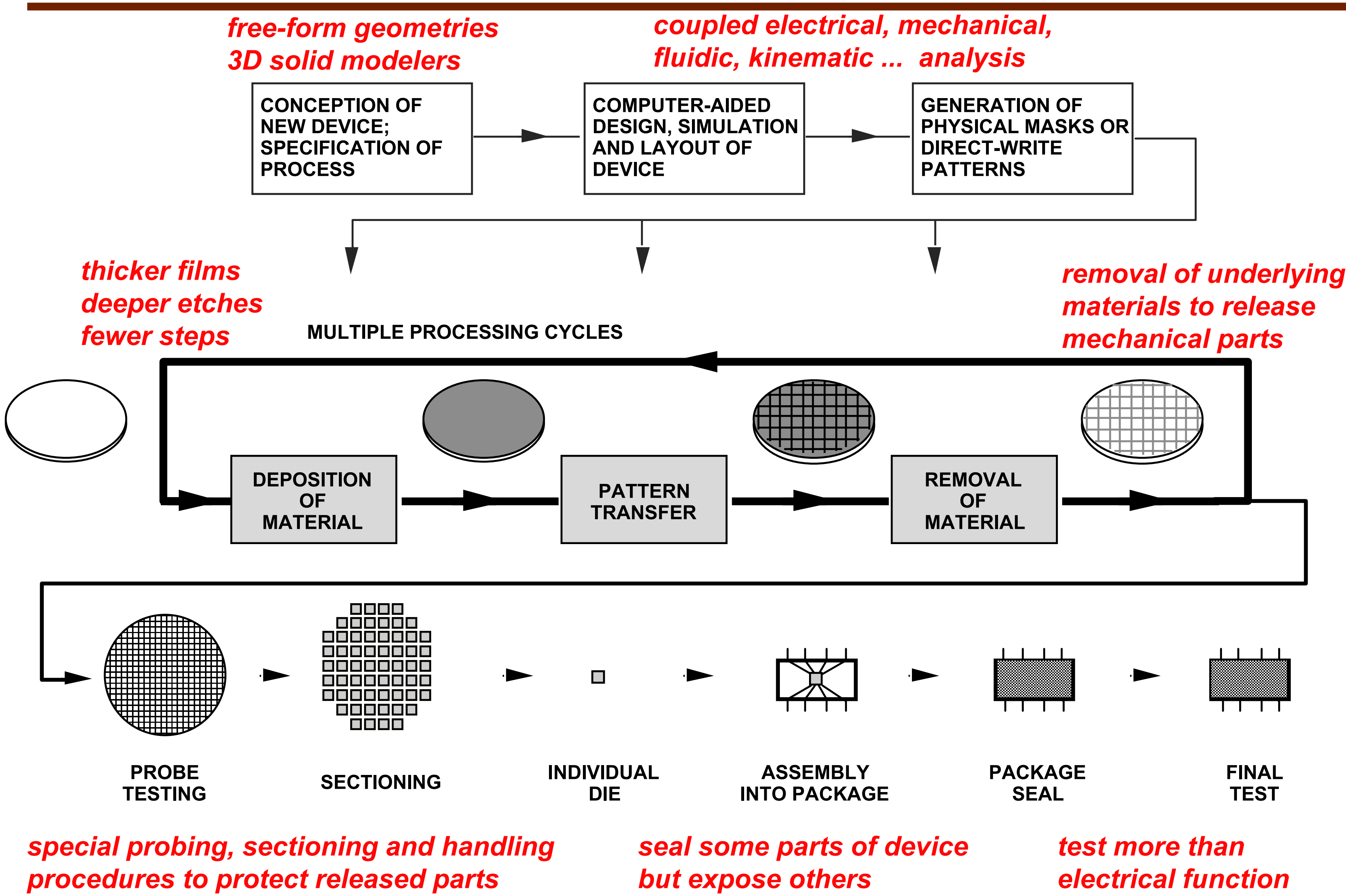


surface micromachining

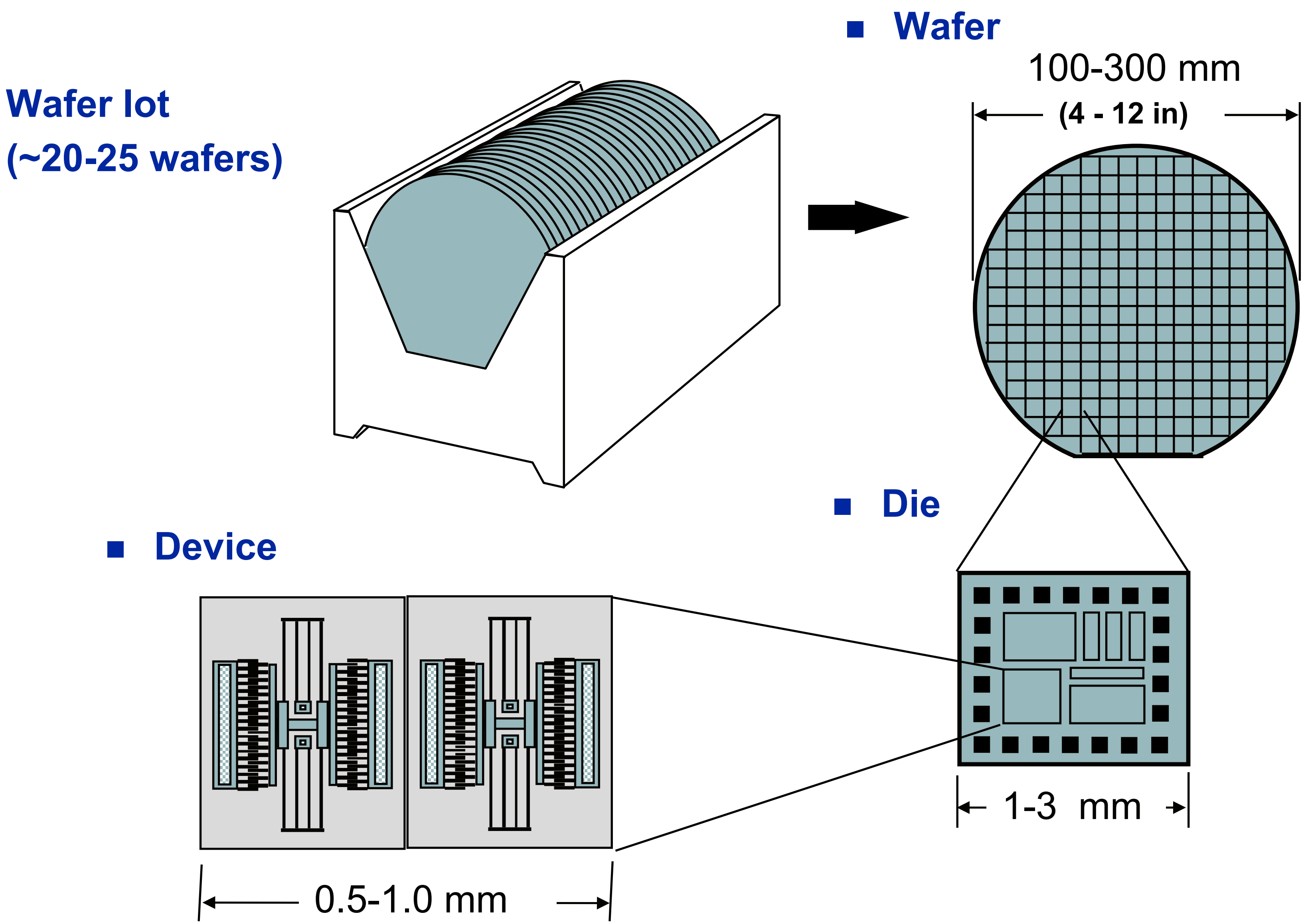
Surface Micromachined Structure



MEMS Builds on Microelectronics Manufacturing

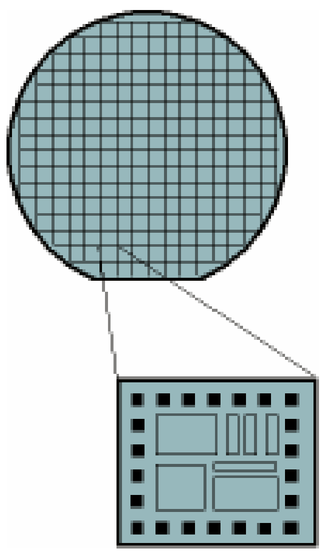


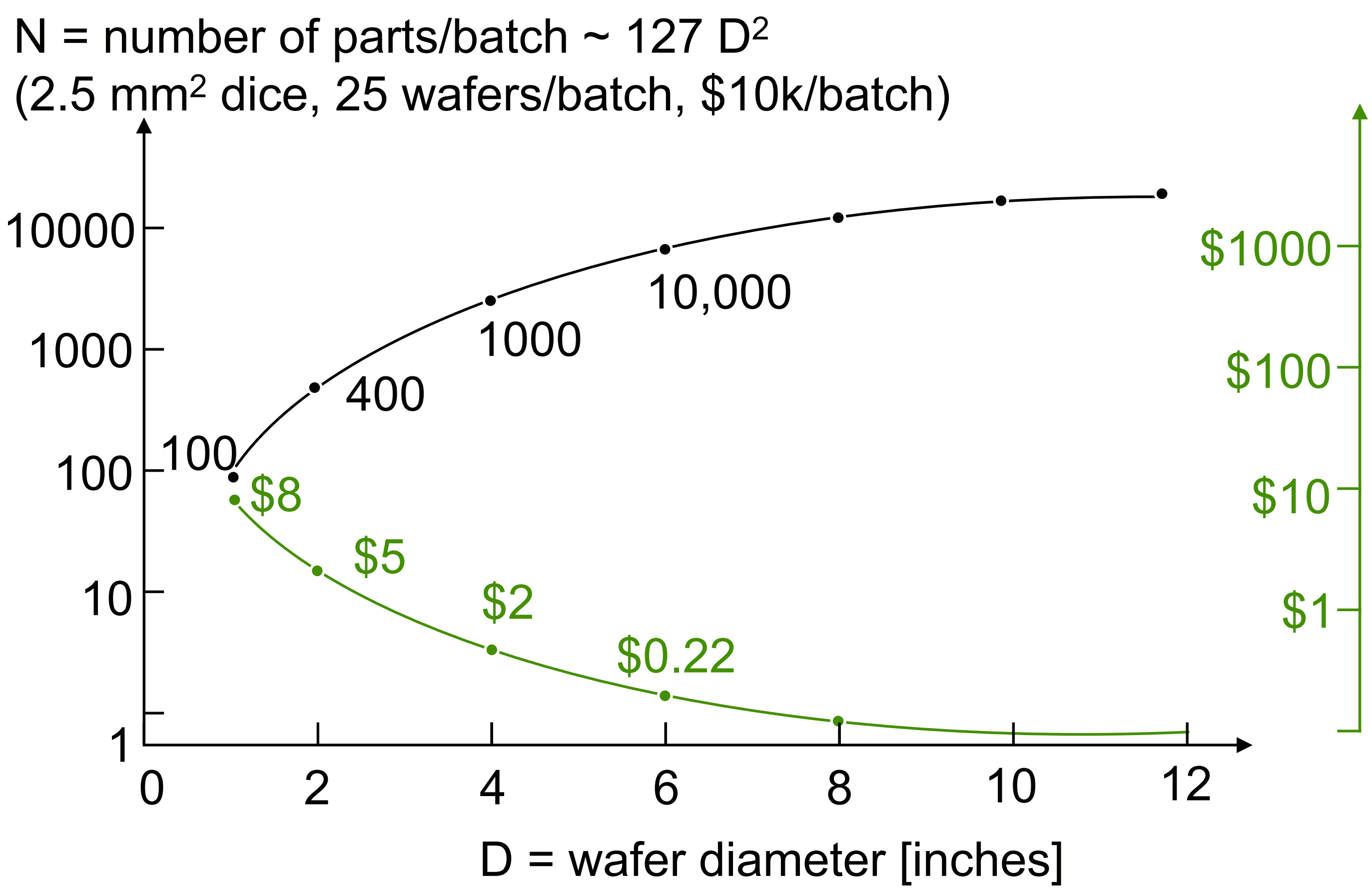
Microelectronics & MEMS Fabrication



Economics of Batch Fabrication

- **High manufacturing cost is spread over many parts-- low cost per individual part**
- **Die size and total process yield (= product individual process step yields) are the two most important determinants of part cost**

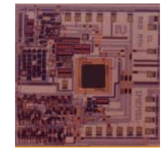




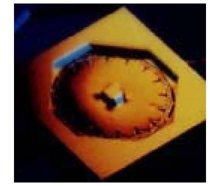
Present and Emerging Applications of MEMS

AKUSTICA

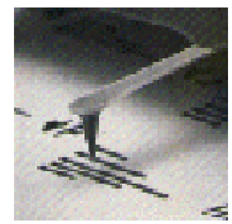
- **inertial measurement units on a chip** for personal guidance, toys, virtual reality, munitions guidance, and security/safety systems



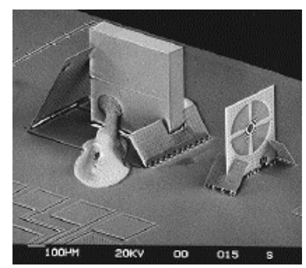
- **distributed unattended sensors** for asset tracking, structural assessment, environmental monitoring, security & border surveillance, and process control



- **integrated fluidic systems** for miniature analytical instruments, chip-based DNA processing & sequencing, propellant and combustion control, chemical factories on chip
- **radio frequency and wireless** for relay & switching matrices, reconfigurable antennas, switched filter banks, electromechanical front-end RF filtering and demodulation

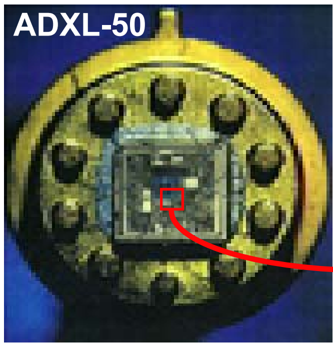


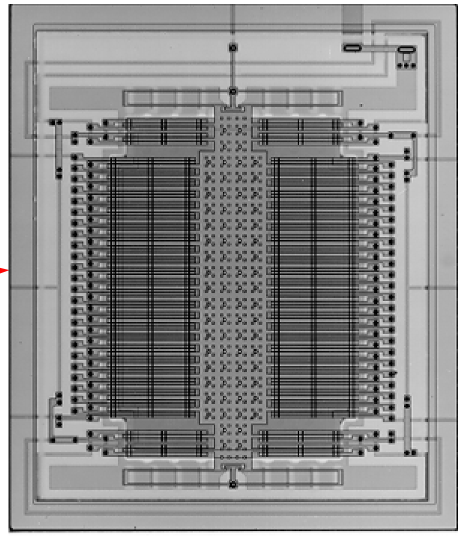
- **embedded sensors and actuators** for condition-based maintenance of machines & vehicles, on-demand amplified structural strength in lower-weight systems/platforms and disaster-resistant buildings
- **mass data storage devices** for storage densities of terabytes per square centimeter



- **integrated micro-optomechanical components** for fiber optic telecommunications switching networks, optical data storage, bar code scanning and displays
- **active, conformable surfaces** for distributed aerodynamic control of aircraft, adaptive optics, and precision parts & material handling

Acceleration Sensor on a Chip for Airbags





capacitive sensing

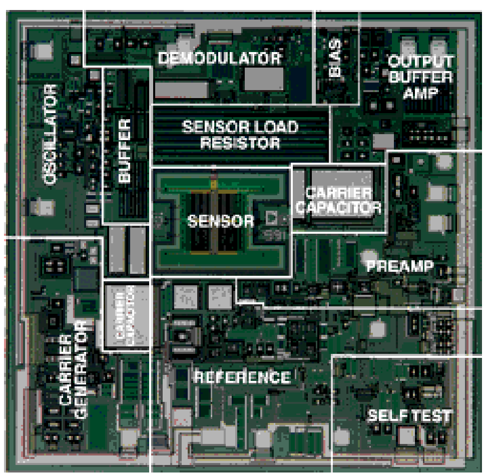
+/- 50 g full scale

DC to 1 kHz

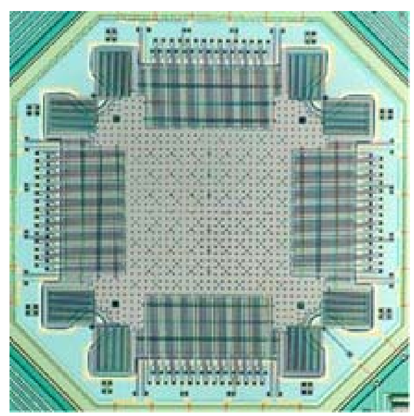
5 volt supply

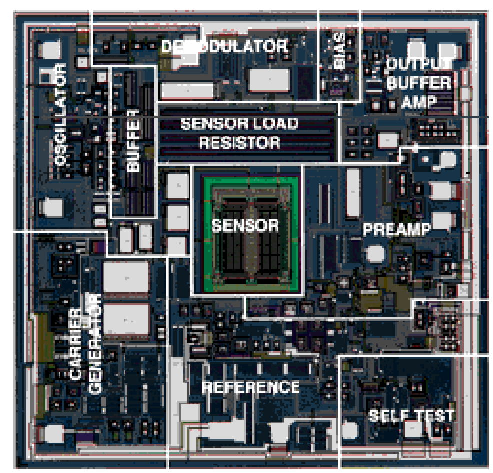
$10 in volume

- single mechanical component with ~ 200 transistors (3 μm design rules)
- monolithic sensing, self-test, calibration and signal conditioning functions
- manufactured in an integrated circuit fabrication line like any other type of semiconductor chip



enables a family of products



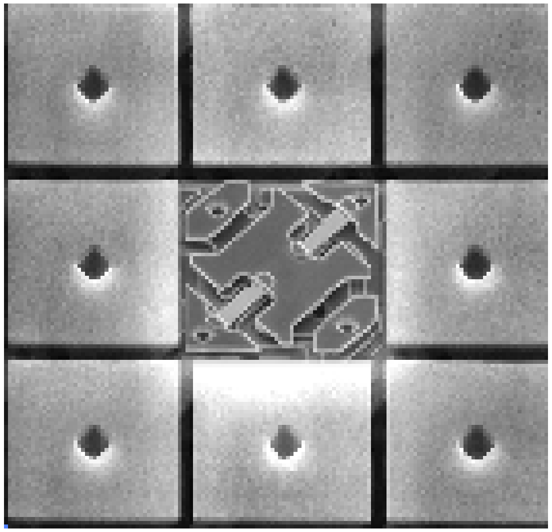


Analog Devices, Inc.

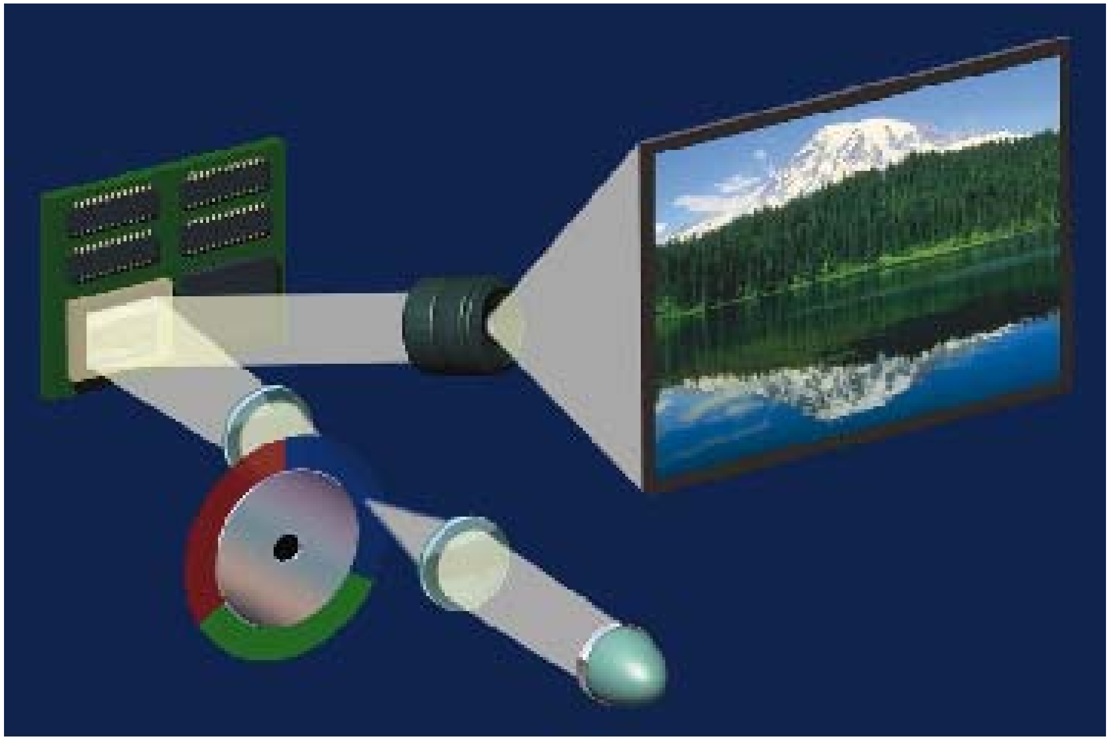
Digital Micromirror Display Technology

848 x 600 pixel resolution SVGA DMD Chip

1024 x 768 XGA chip (Dragonfly Projector)



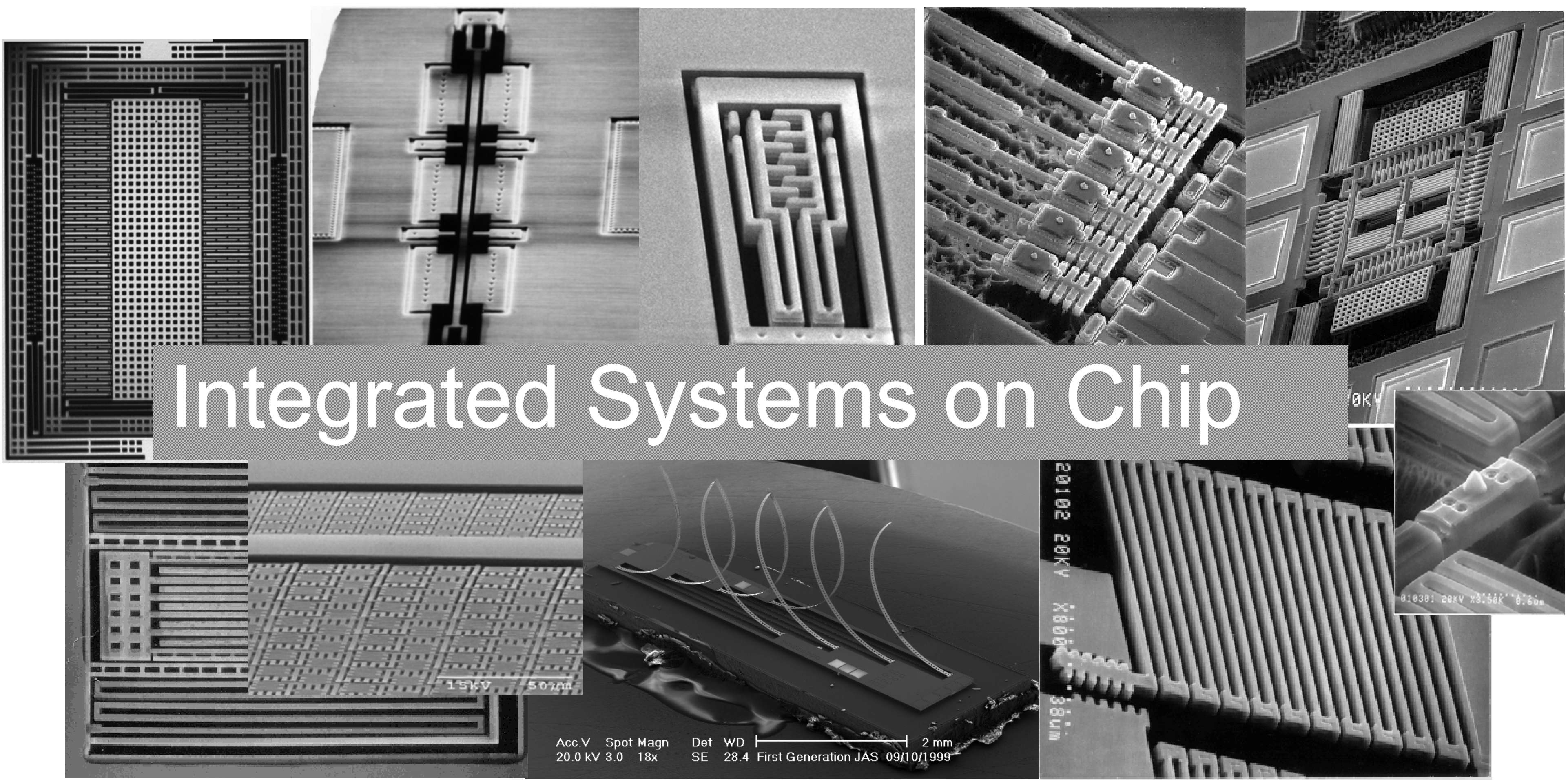
- ~ 520K to 2M mirrors
- 16 μm x 16 μm mirrors
- digital gray scale using pulse width modulation
- MEMS arrays built on top of SRAM



Texas Instruments, Inc.

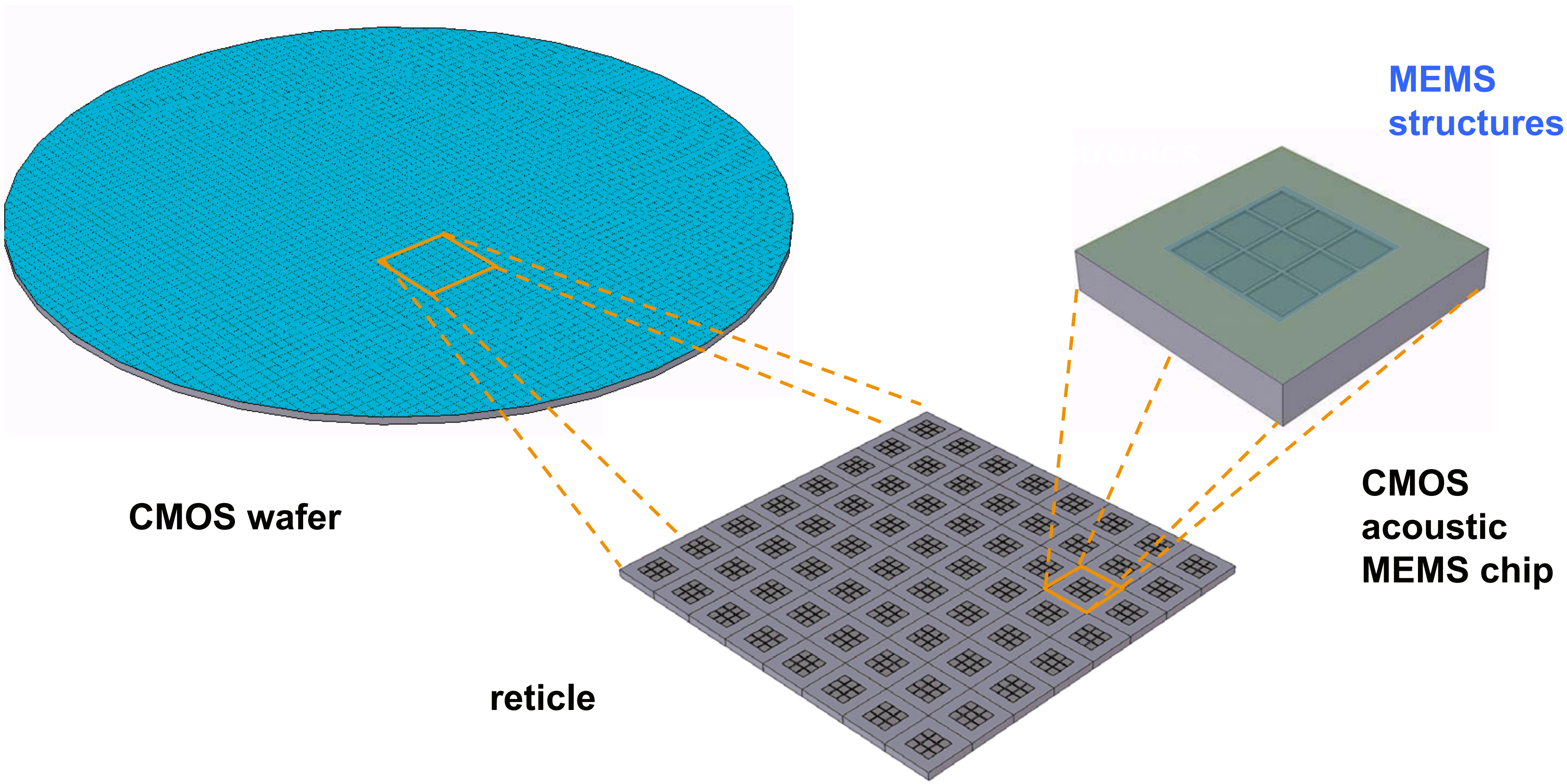
Carnegie Mellon CMOS MEMS

Inertial sensors, RF MEMS, infrared sensors, acoustic speakers, ultrasonic sensors, BioMEMS, biomedical devices… with on-chip detection and conditioning

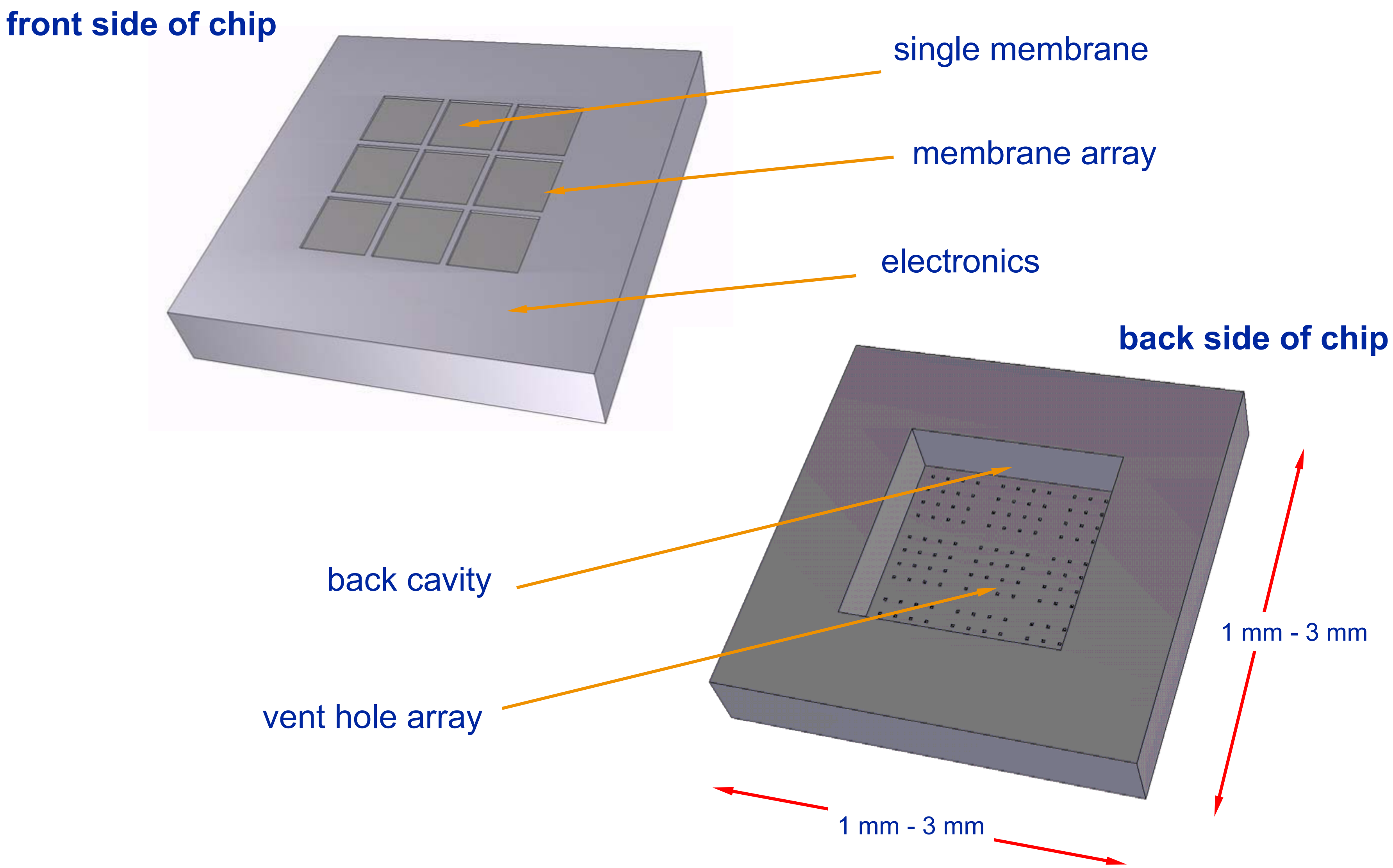


CMOS Acoustic MEMS – Starting Point

- MEMS structures made in conventional CMOS with ***no changes to CMOS baseline process or materials***
- MEMS made ***out of the CMOS thin-film materials***

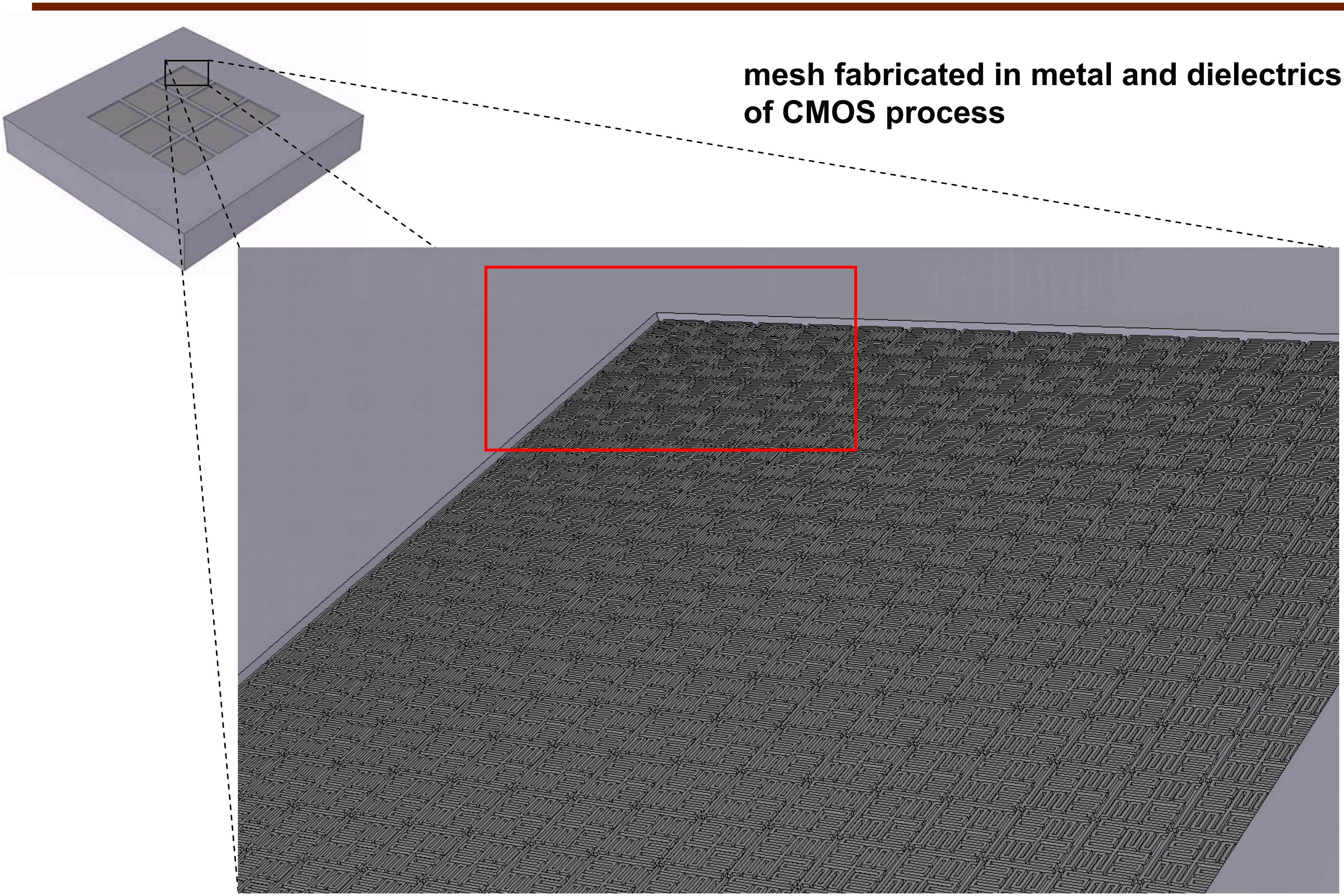


Microphone Chip Example

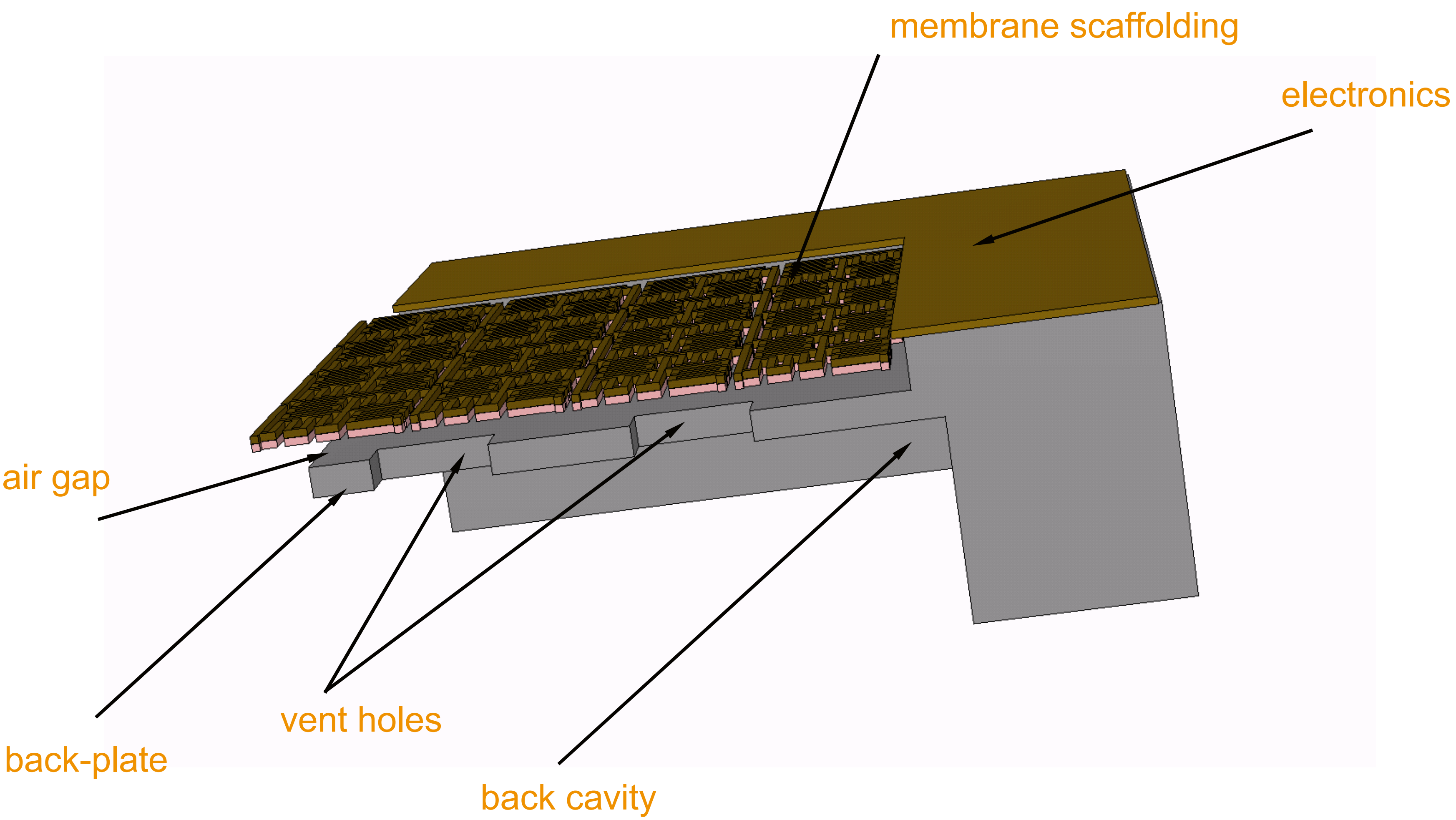


Membrane Mesh Scaffolding

mesh fabricated in metal and dielectrics of CMOS process

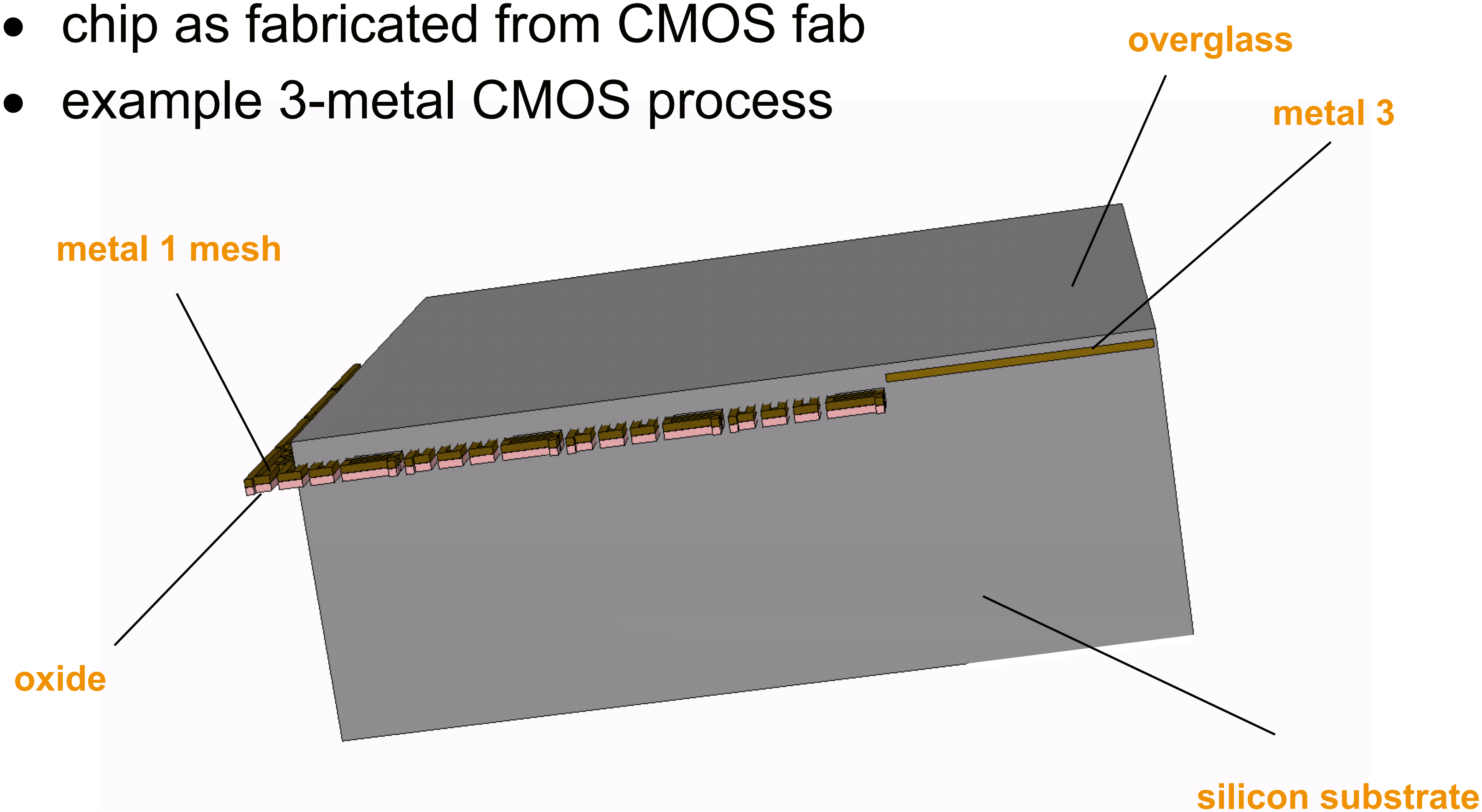


CMOS Acoustic MEMS Chip Detail



Fabrication Sequence for CMOS Acoustic MEMS

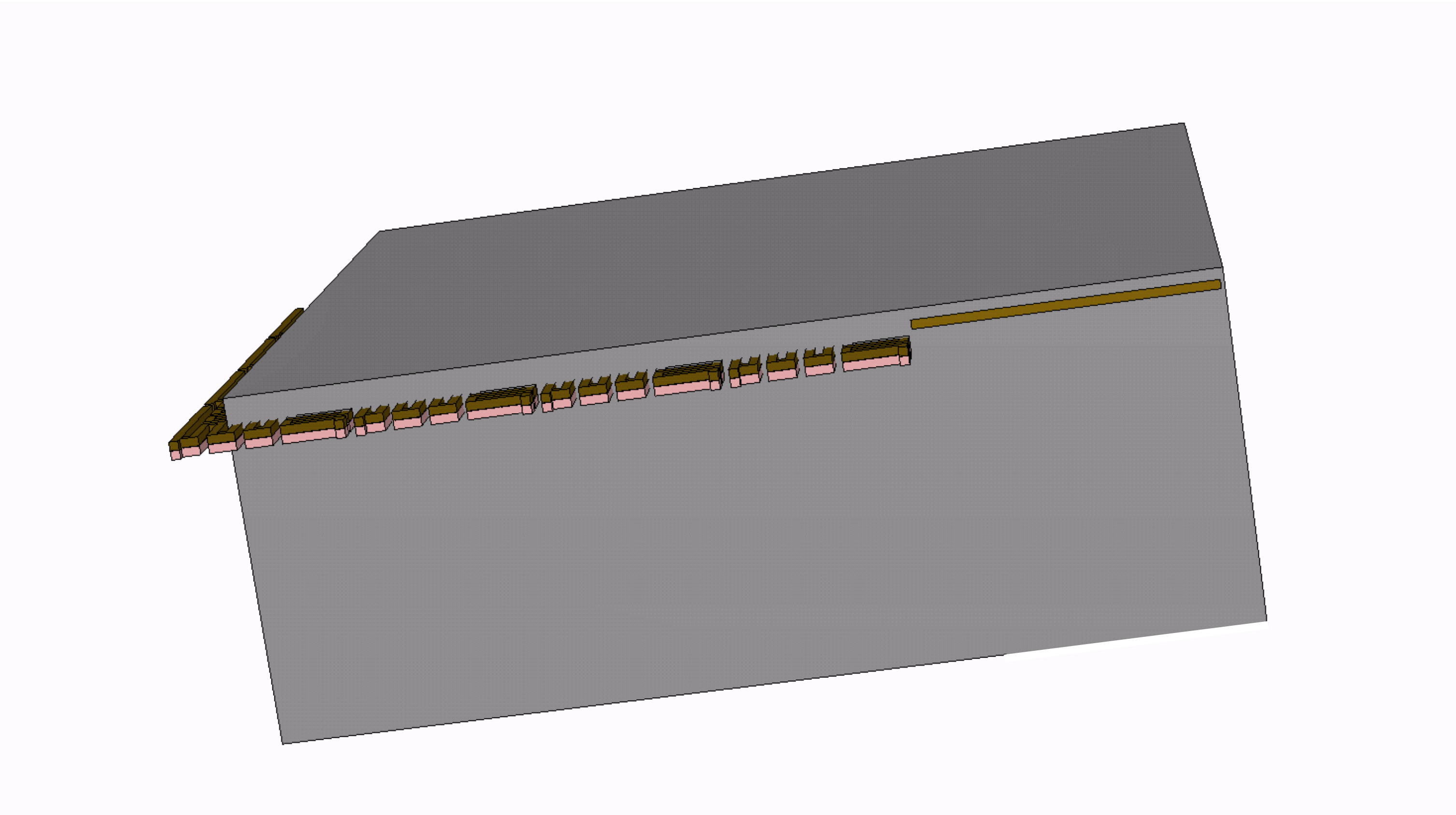
- chip as fabricated from CMOS fab
- example 3-metal CMOS process



Fabrication Sequence for CMOS Acoustic MEMS

AKUSTICA

- *start with anisotropic etch of back-side cavity*



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AKUSTICA

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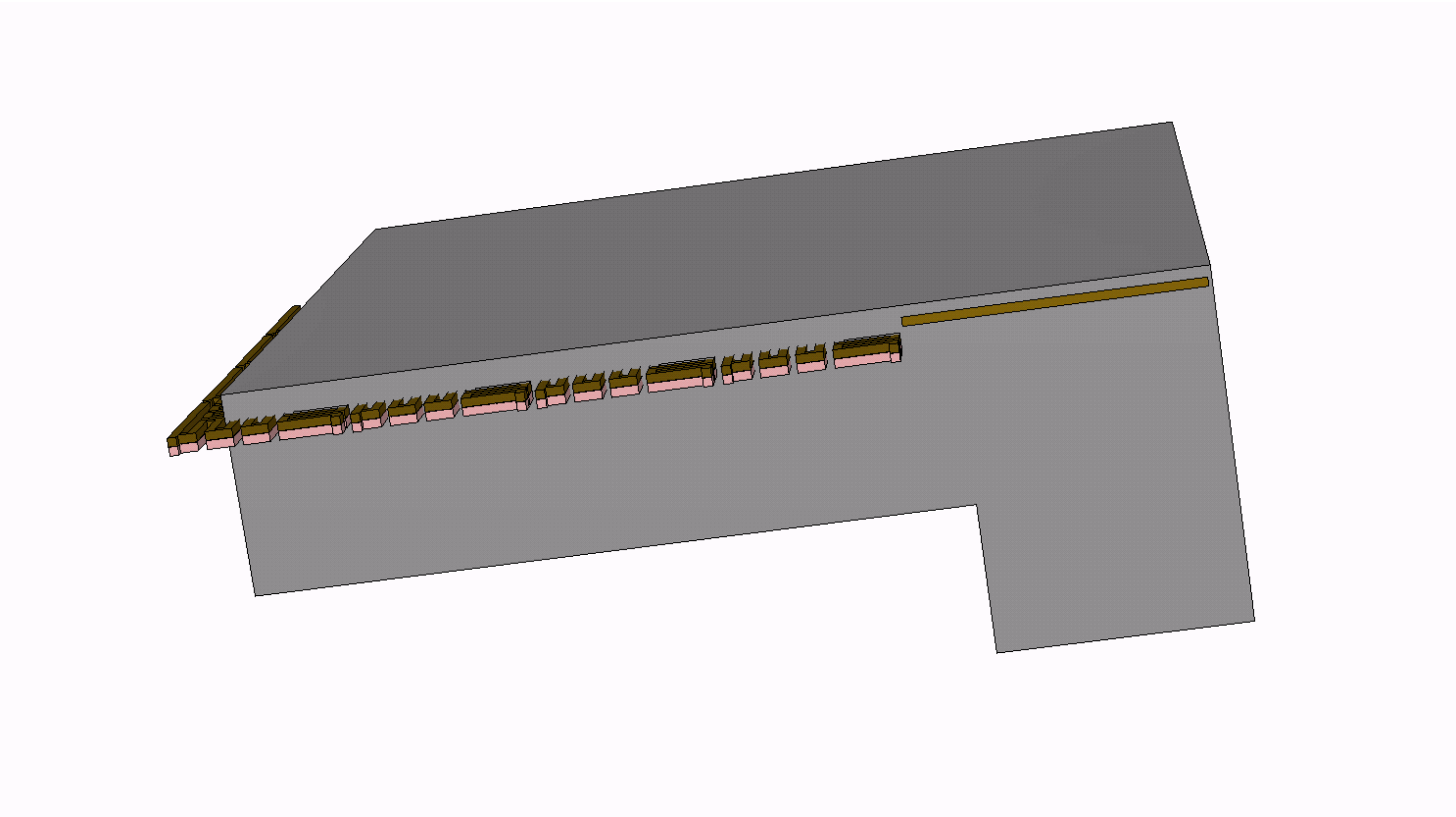

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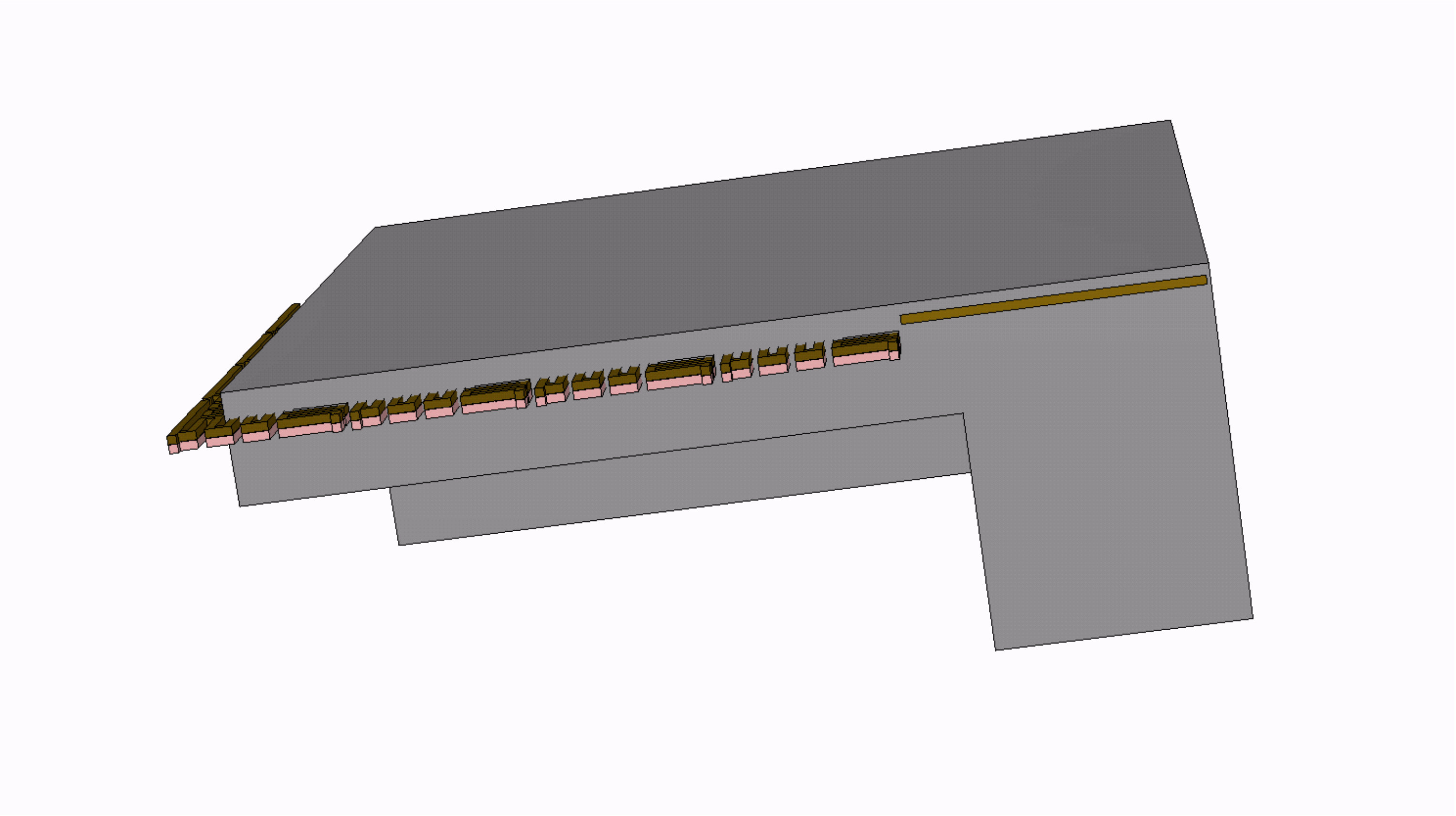
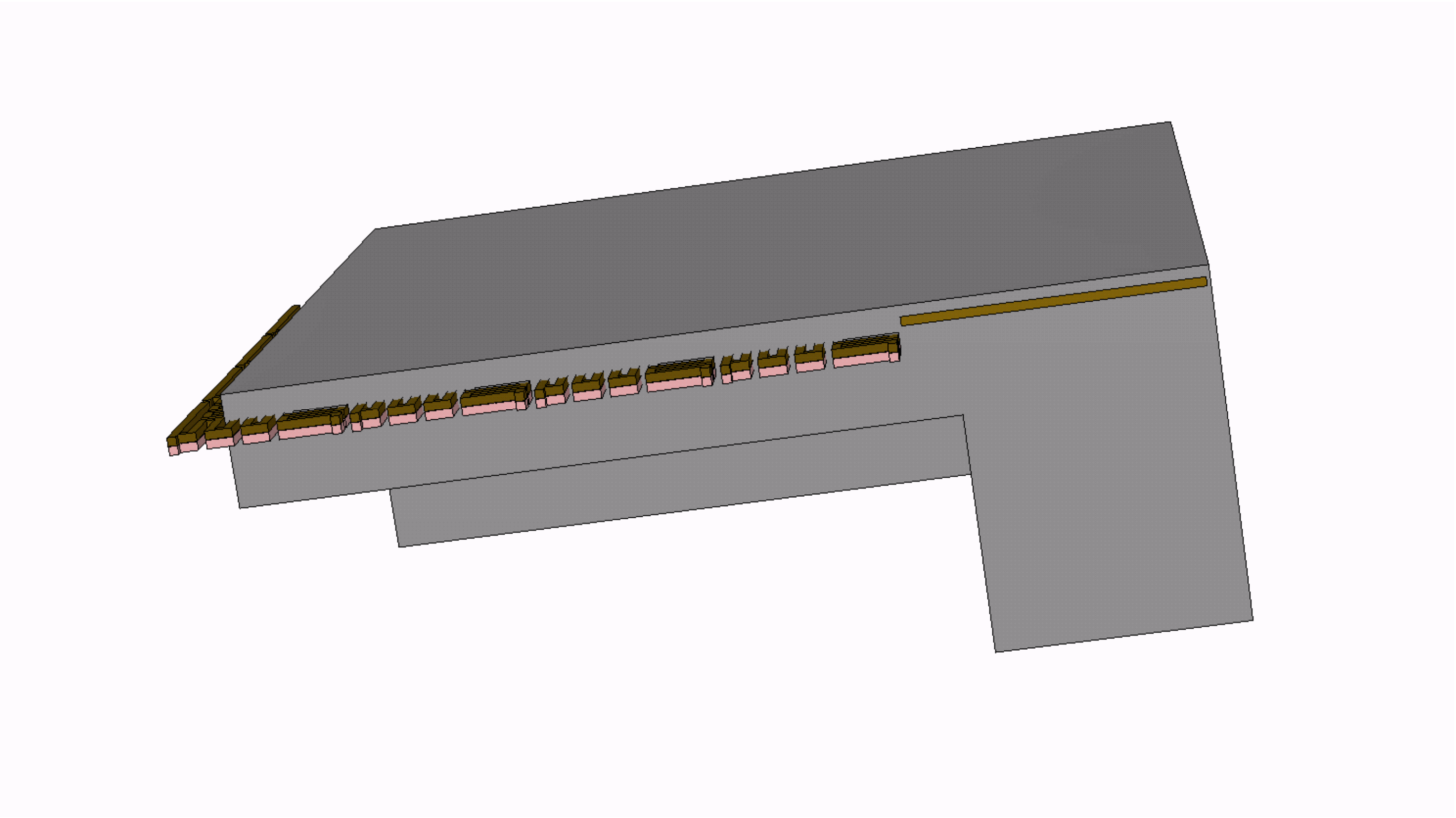


Fabrication Sequence for CMOS Acoustic MEMS

- *next a front-side directional etch of oxide from top*



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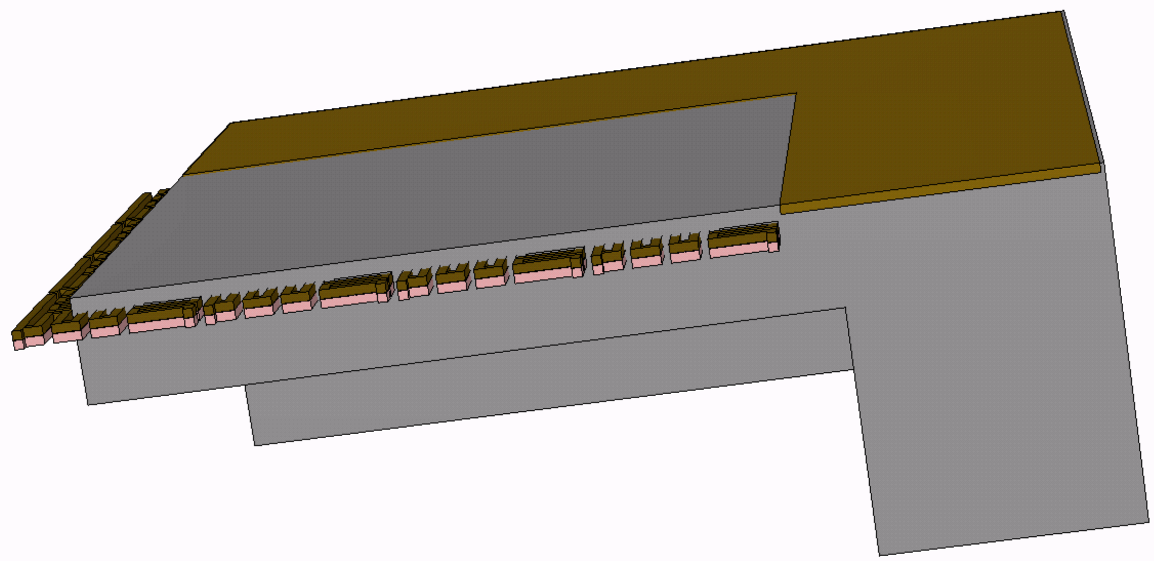

Fabrication Sequence for CMOS Acoustic MEMS

AKUSTICA

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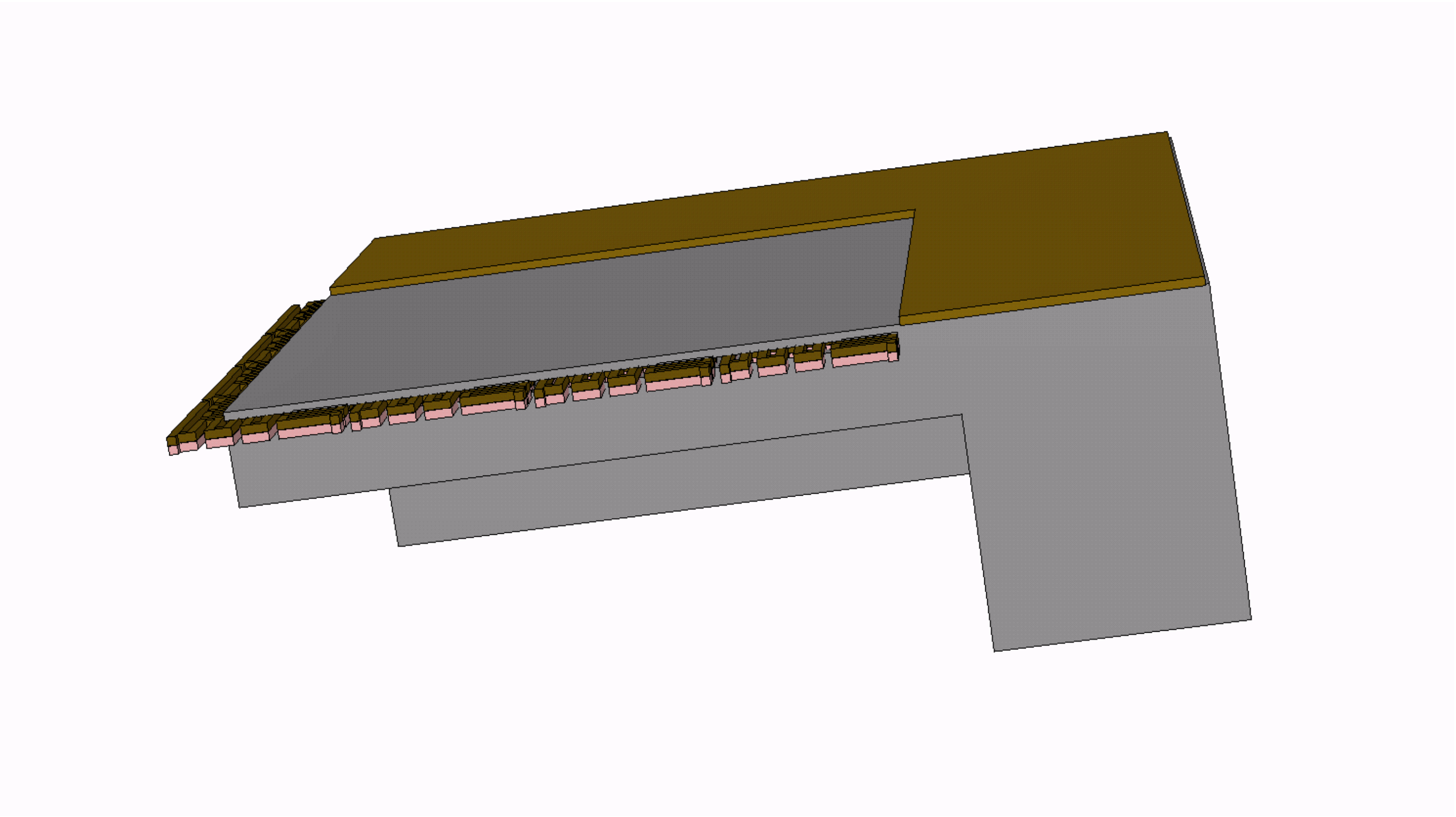
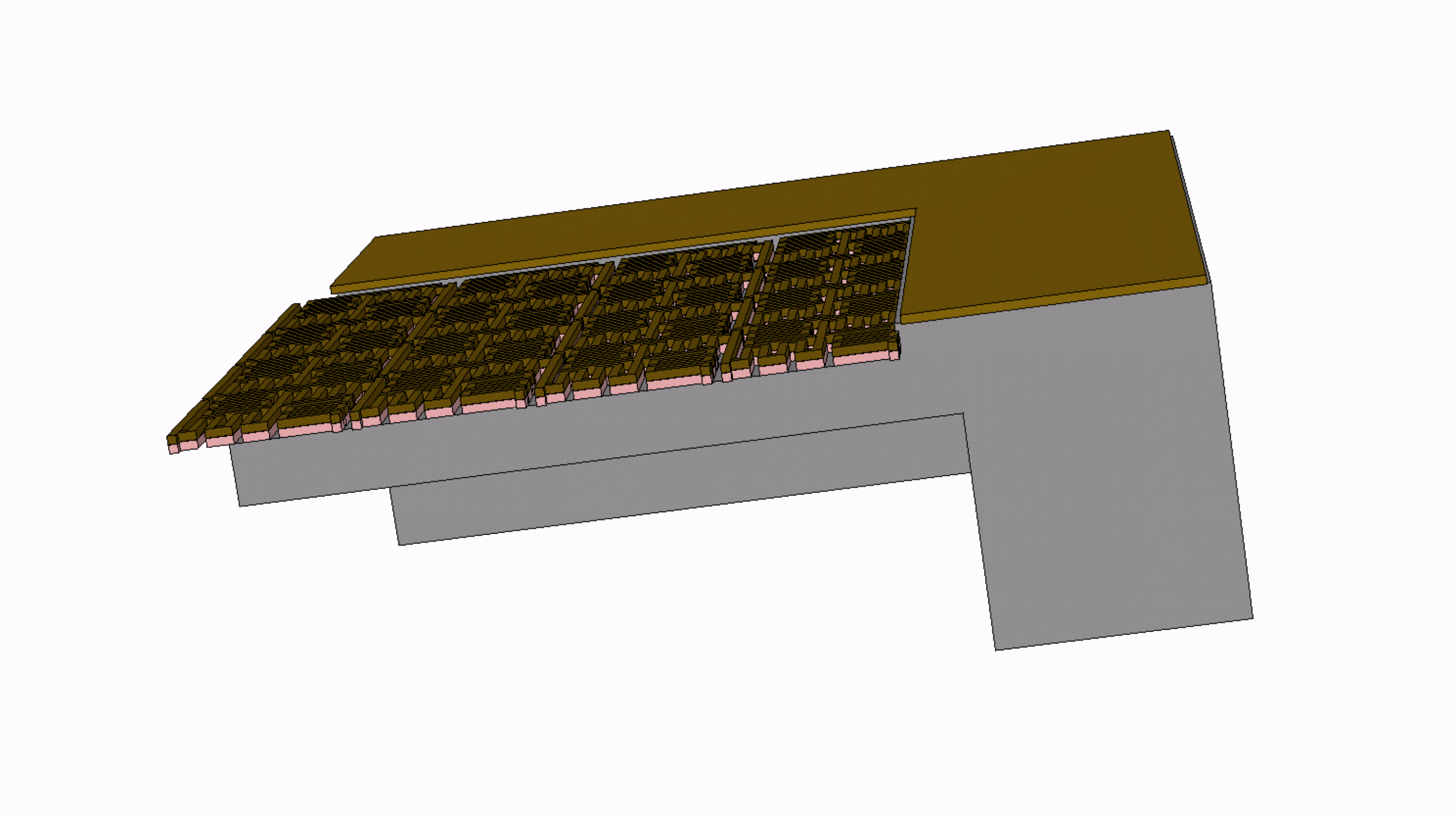


Fabrication Sequence for CMOS Acoustic MEMS

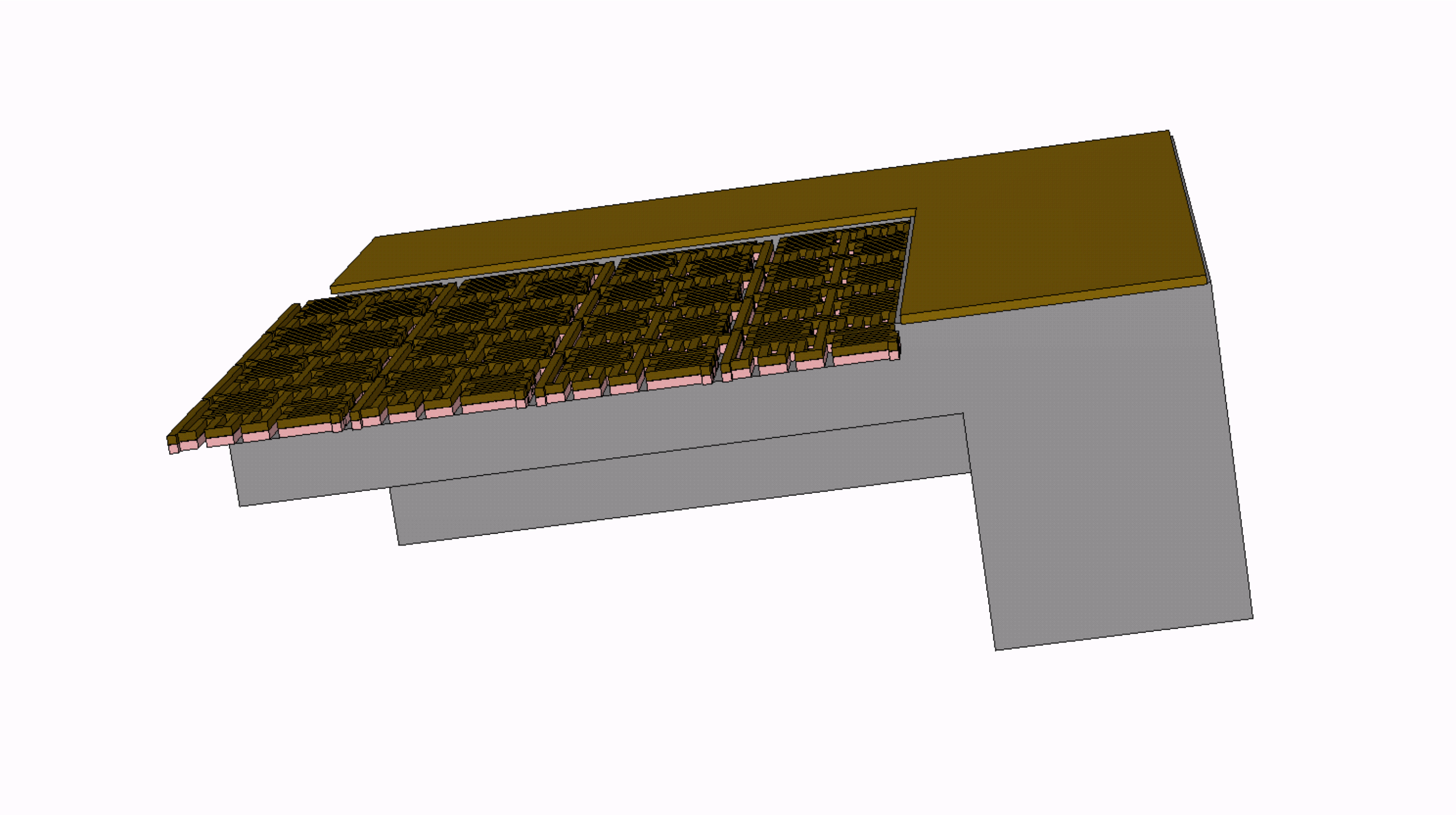
- *next a front-side directional etch of oxide from top*



Fabrication Sequence for CMOS Acoustic MEMS

AKUSTICA

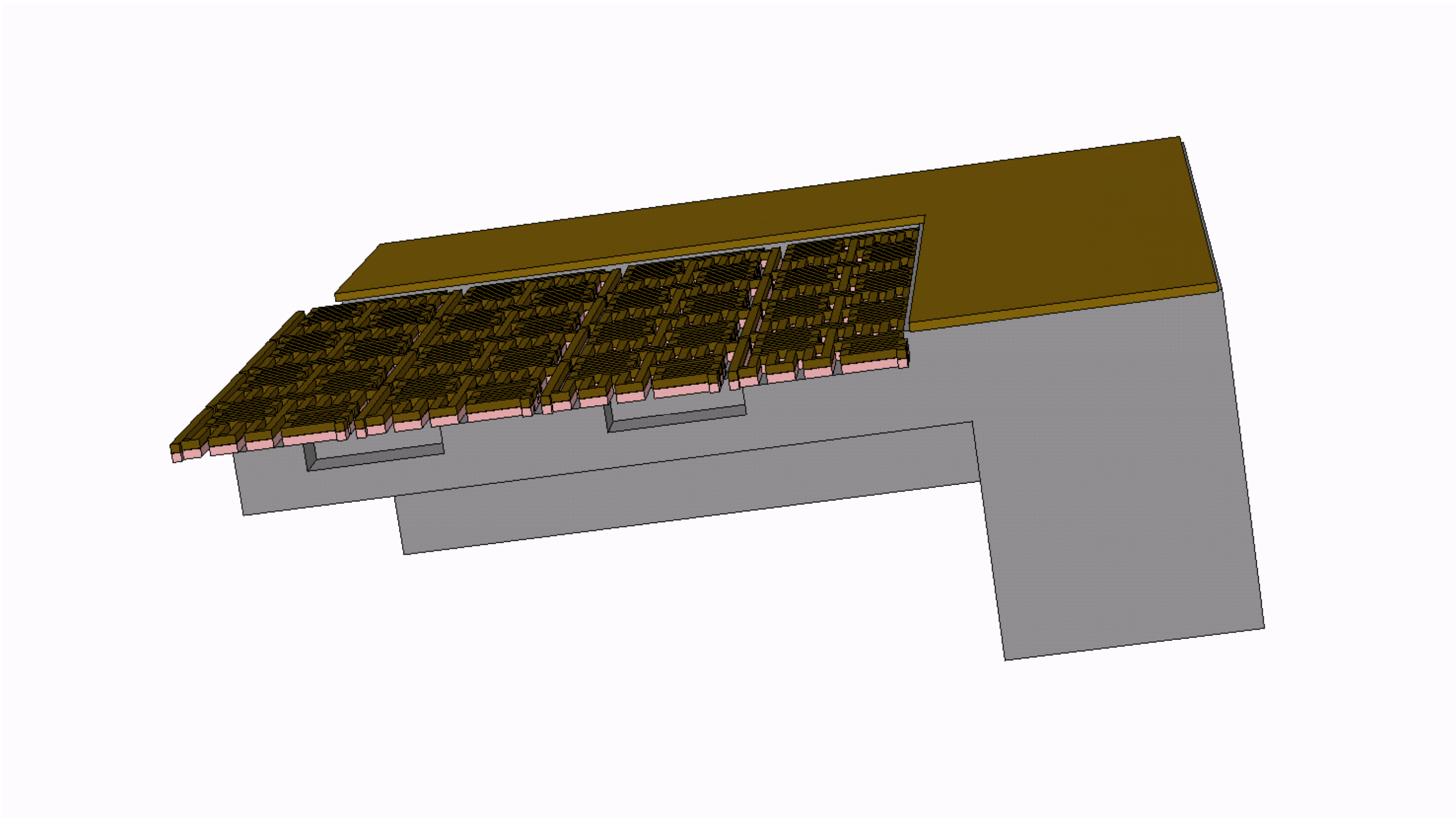
- *vent holes etched from top*



Fabrication Sequence for CMOS Acoustic MEMS

AKUSTICA

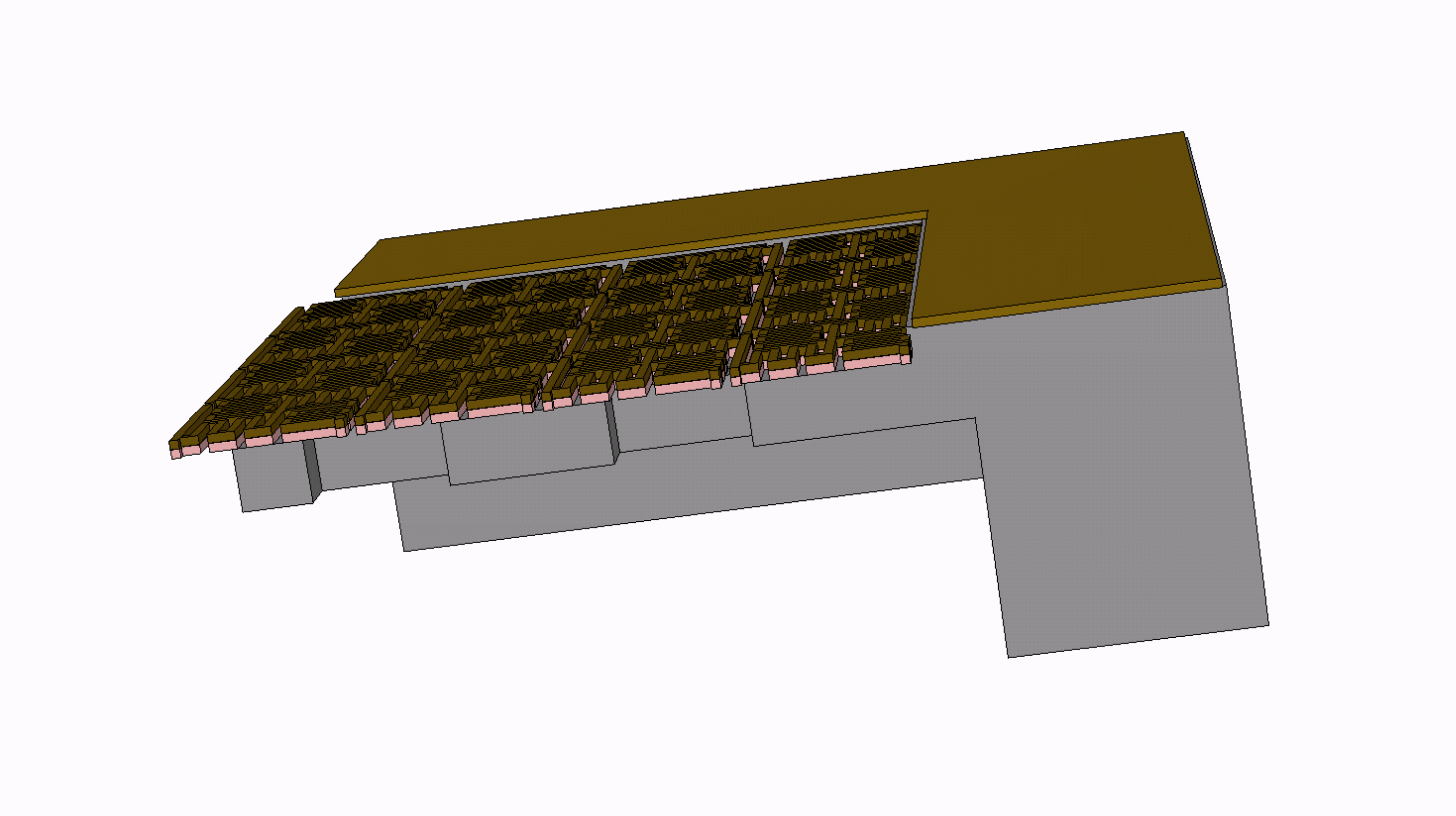
- *vent holes etched from top*



Fabrication Sequence for CMOS Acoustic MEMS

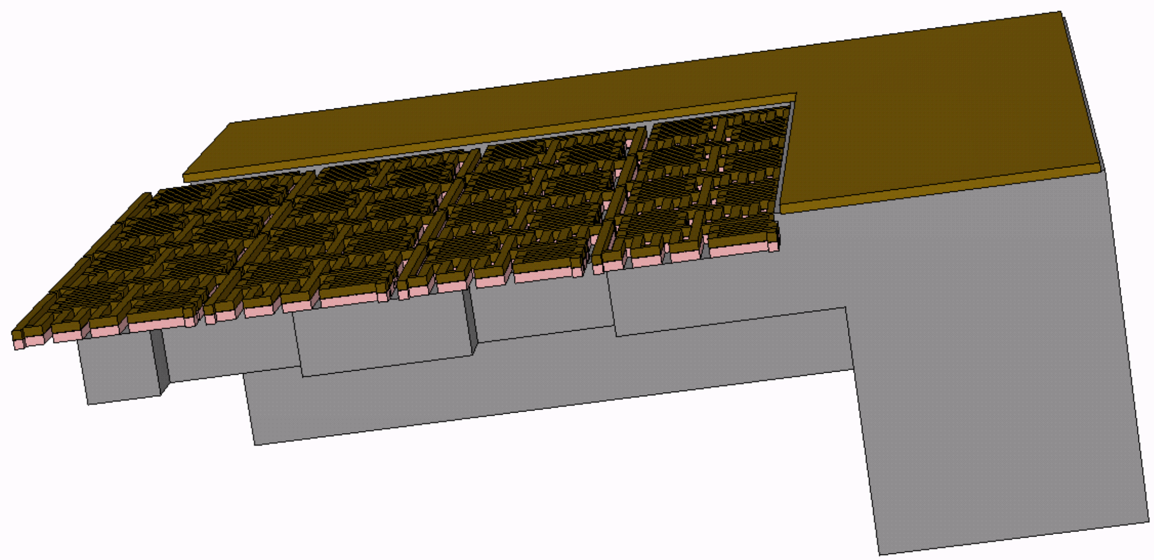
AKUSTICA

- *vent holes etched from top*



Fabrication Sequence for CMOS Acoustic MEMS

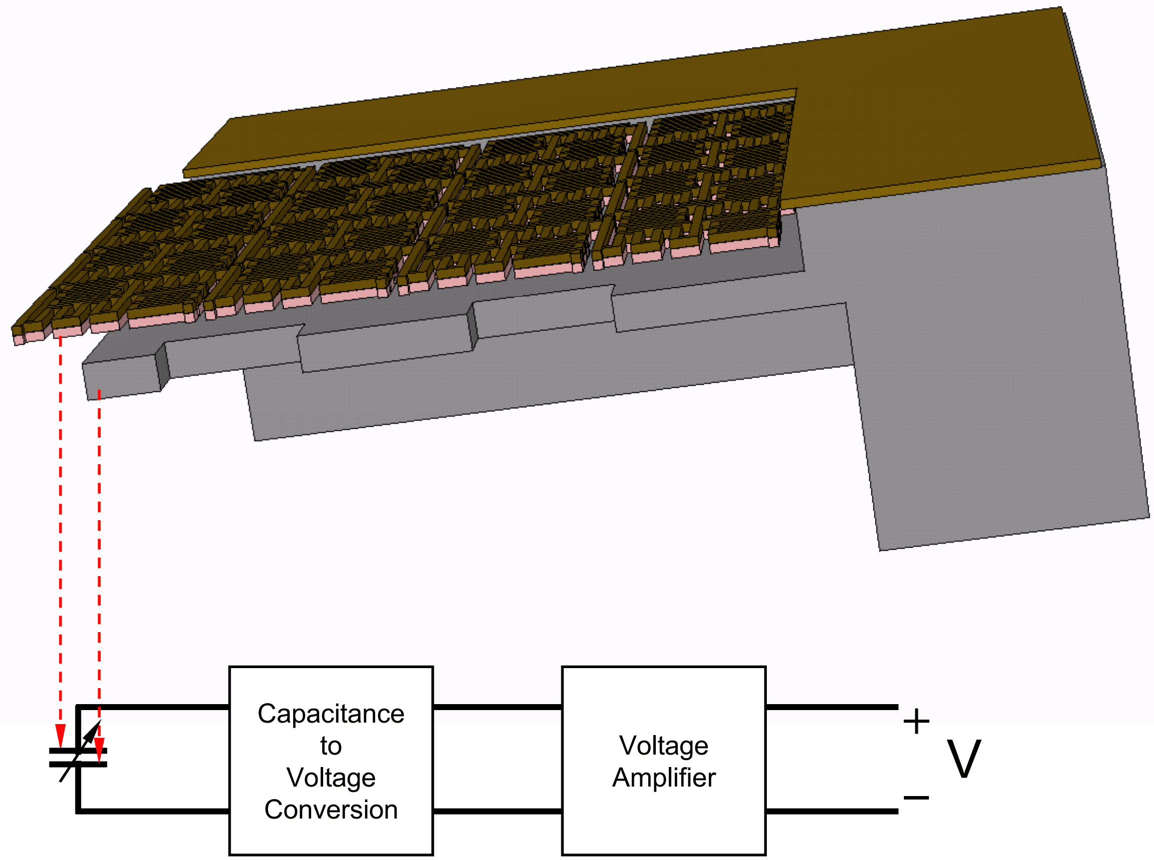
- *mesh skeleton released from substrate underneath*



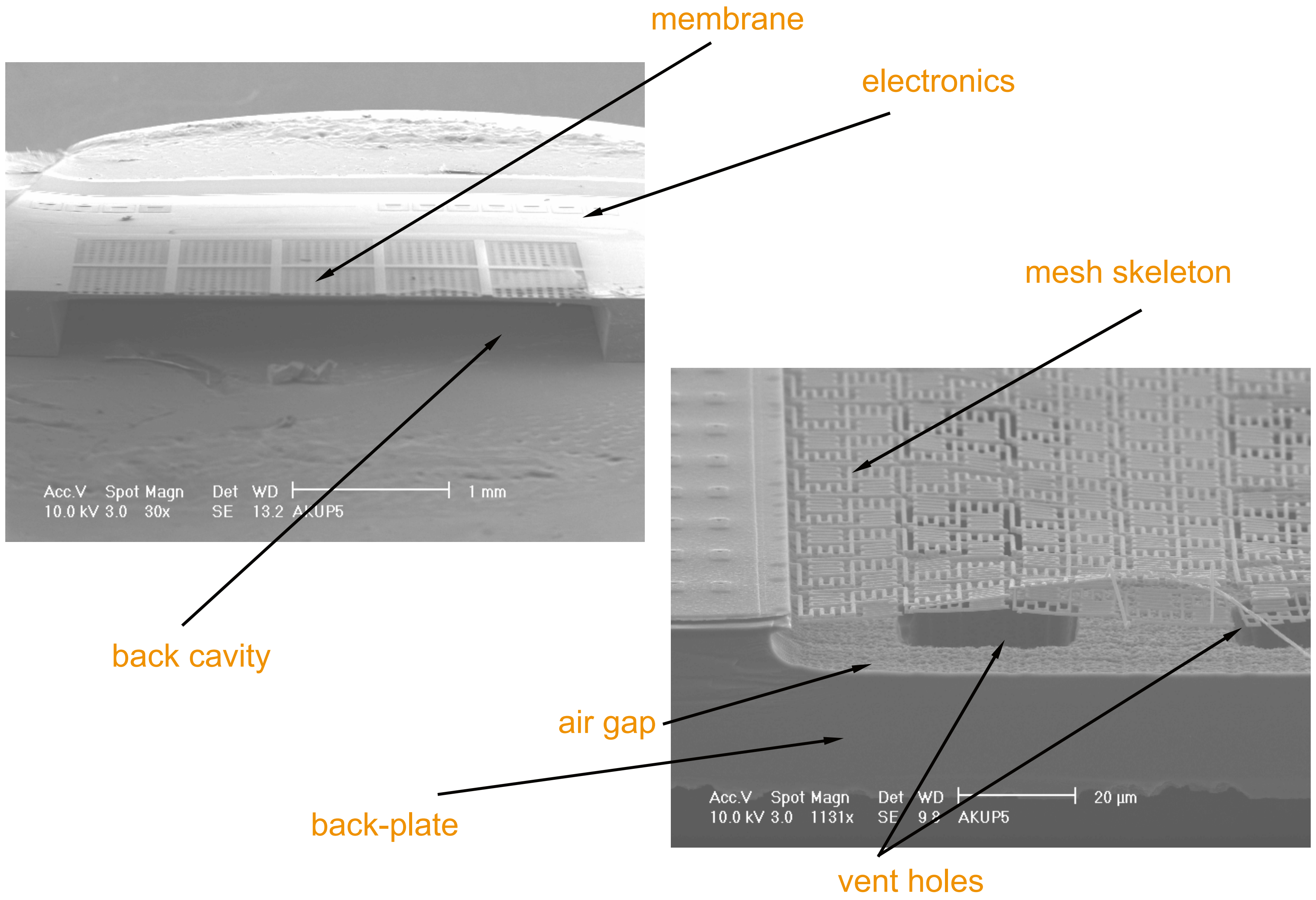
Fabrication Sequence for CMOS Acoustic MEMS

- *mesh skeleton released from substrate underneath*

$$C = \frac{\varepsilon_o A}{d}$$

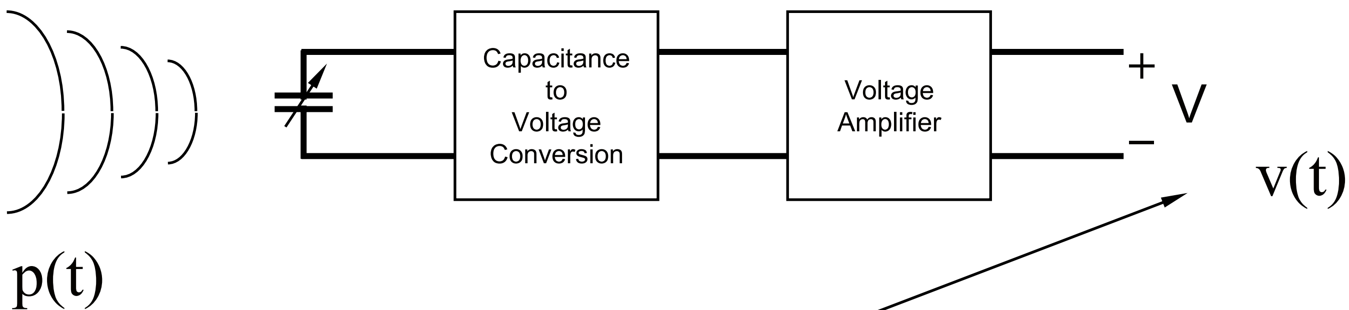


SEMs of CMOS Acoustic MEMS Chip

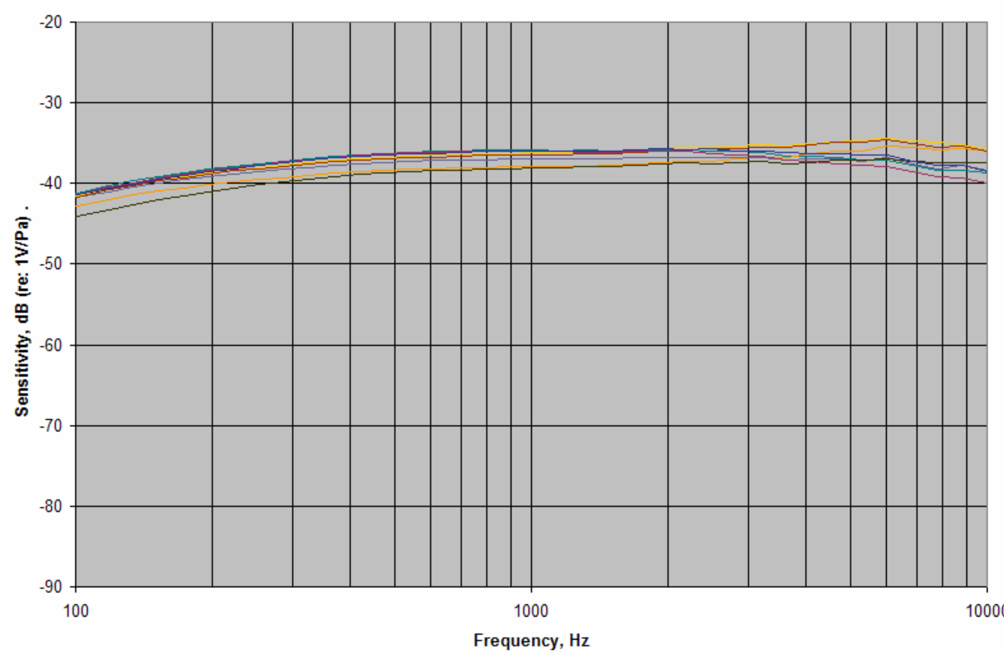


CMOS MEMS Microphone

AKUSTICA



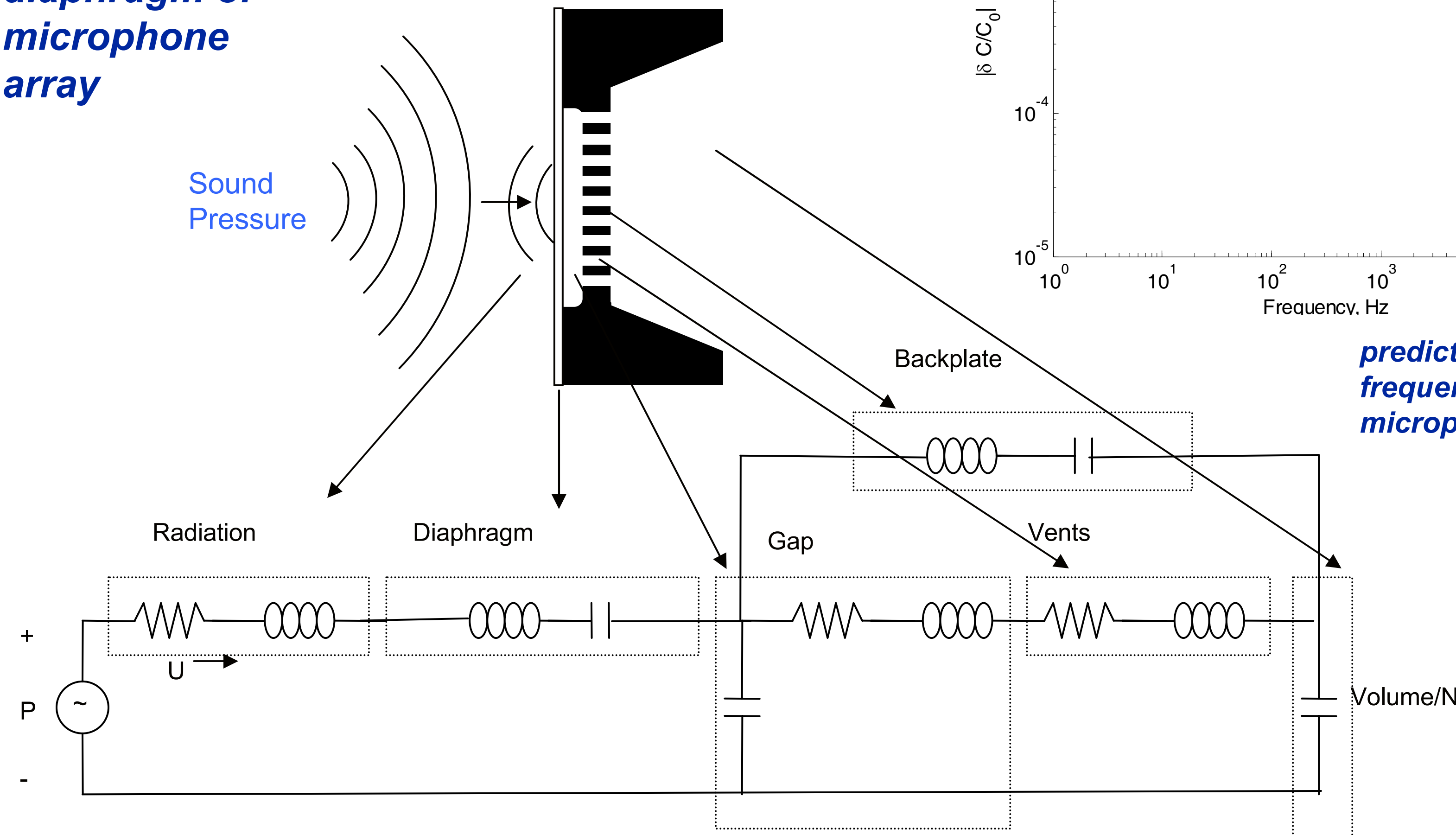
$$C[t] = \frac{\varepsilon_o A}{d[p(t)]}$$

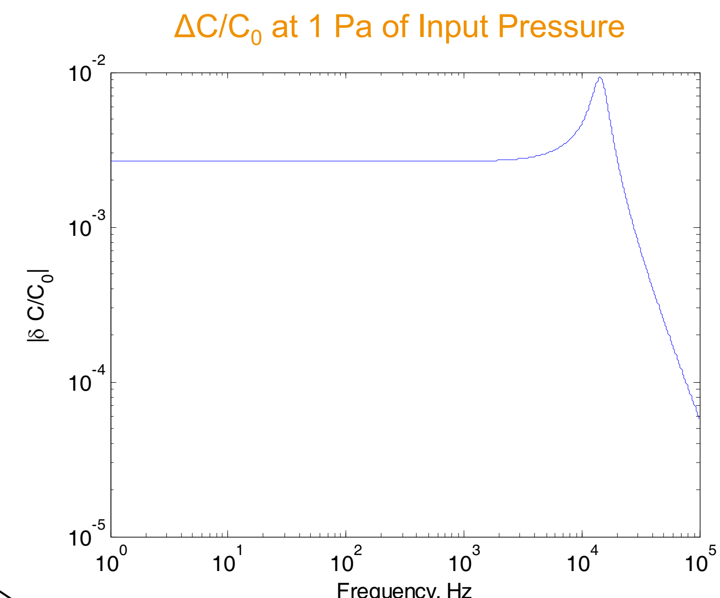


Microphone Chip Acoustic Model

AKUSTICA

acoustic impedance model for one diaphragm of microphone array

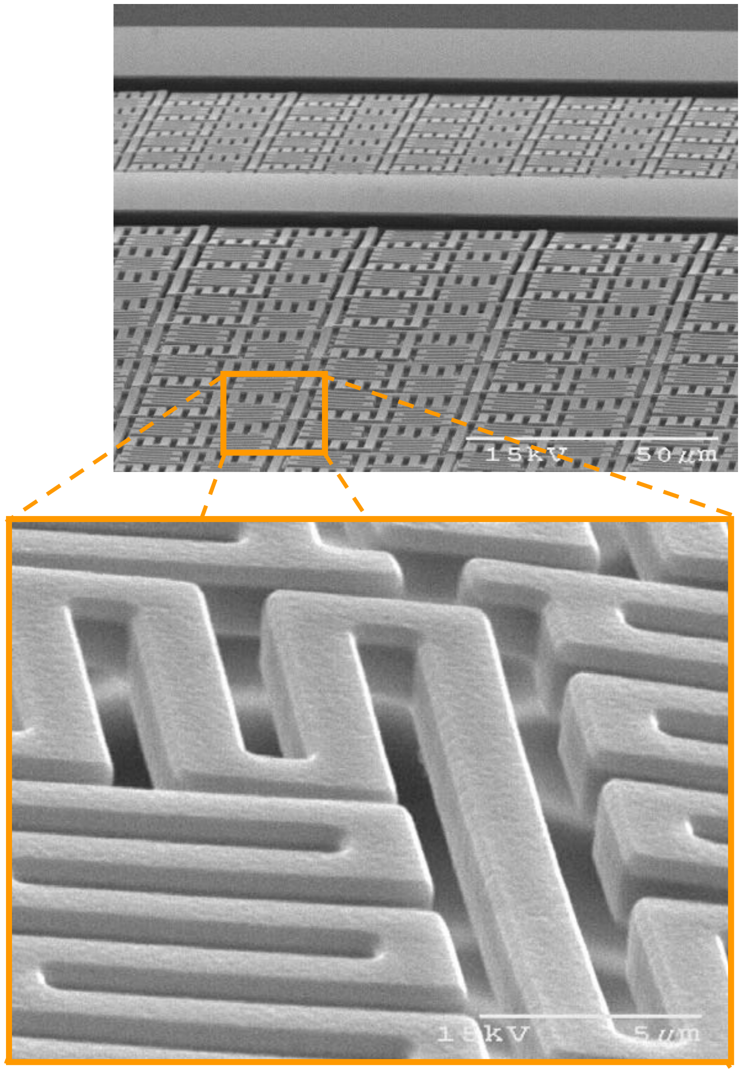




predicted mechanical frequency response of microphone

CMOS Acoustic MEMS Advantages

- Low-cost integration with CMOS
- Rapid design cycles
- Scalable manufacturing
- Low parasitic capacitance
- No piezoelectrics
- Audio to ultrasonic frequencies
- Capacitive sensing
- Low-power electrostatic actuation



MEMS Technology Trend