SAND2007-7374C

MEMS Packaging and Testing

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October 24th, 2007

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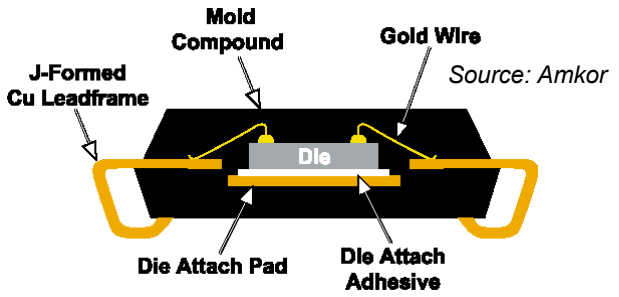
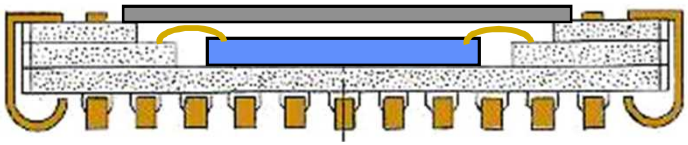
MEMS Packaging Considerations

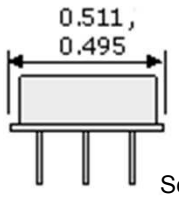
Plastic Leaded Chip Carrier



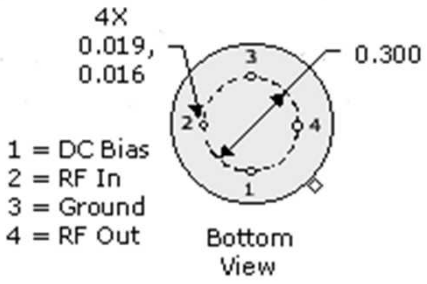
Ceramic Package



TO-8 Can



Source: rfcafe.com



http://www.amkor.com

- Estimated that 50%-70% of MEMS cost is in packaging
- I/C and MEMS Packaging Complexities
  - Electrical (I/O)
  - Thermal (heat dissipation)
  - Mechanical (stress, shock and vibration)
  - Reliability (of both package and device)
- Additional MEMS Specific Concerns
  - Package induced stress and effect on MEMS performance
  - Cleanliness and hermeticity
  - MEMS specific inputs and outputs (optical, fluidic, gas, etc).
  - Very high I/O count (optical)
  - Integration with CMOS

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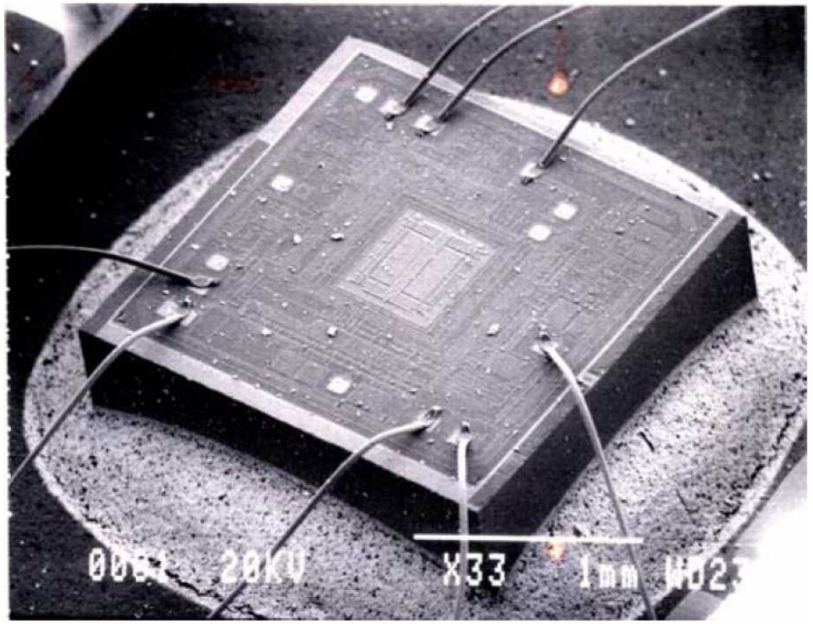
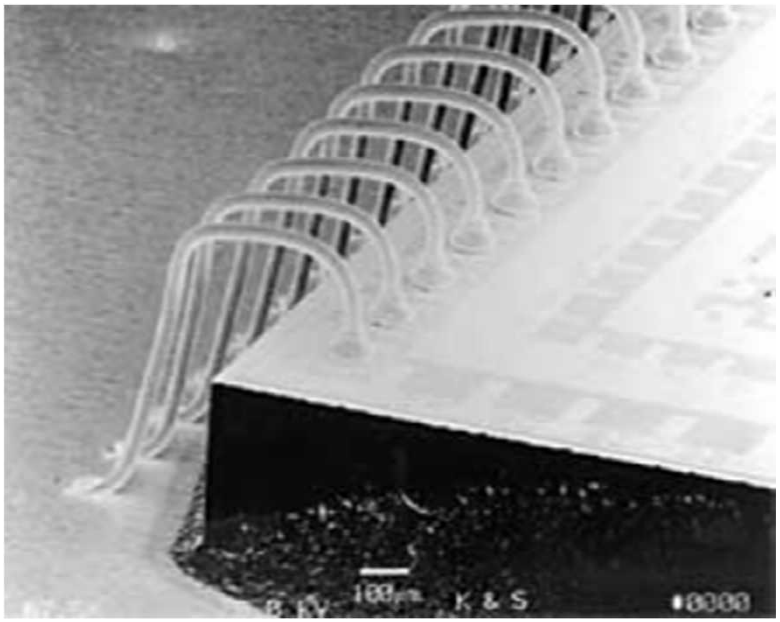
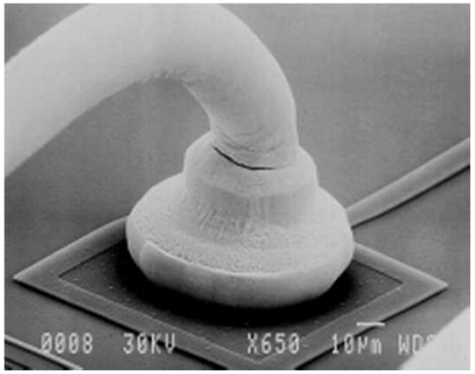
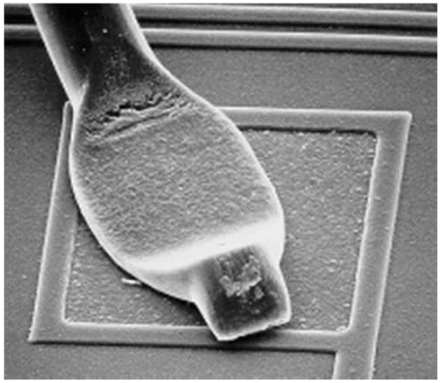
Die attach and wire bond is still the same

Analog Devices ADXL50









http://www.amkor.com

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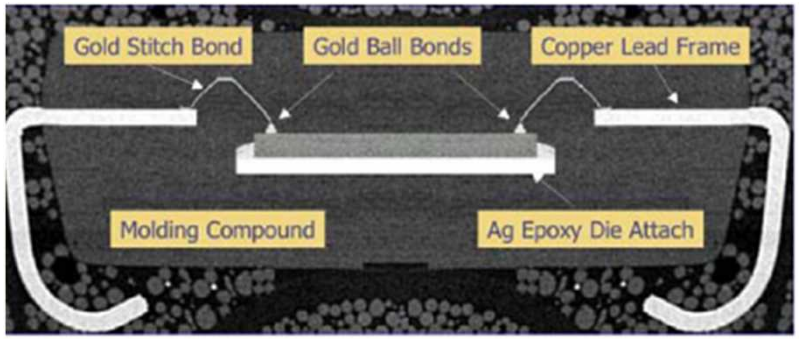
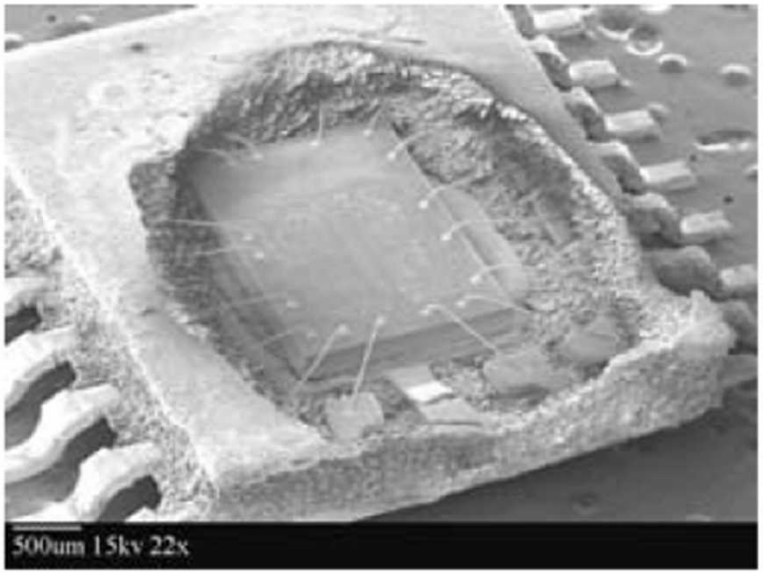
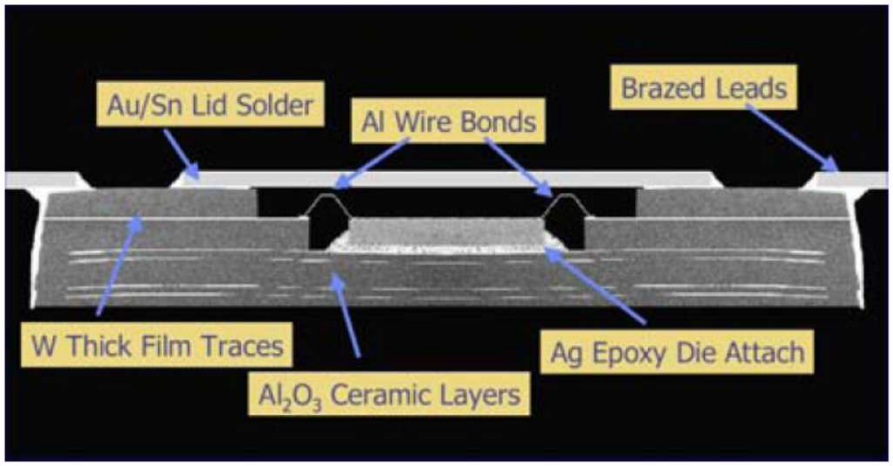
Plastic Packages vs. Ceramic Packages

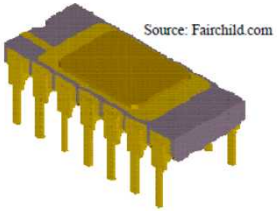


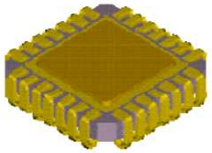
Analytical Solutions

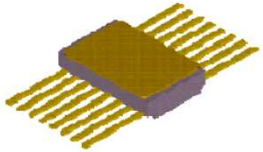


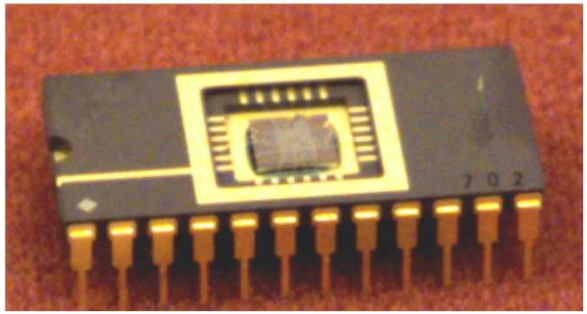


Analytical Solutions









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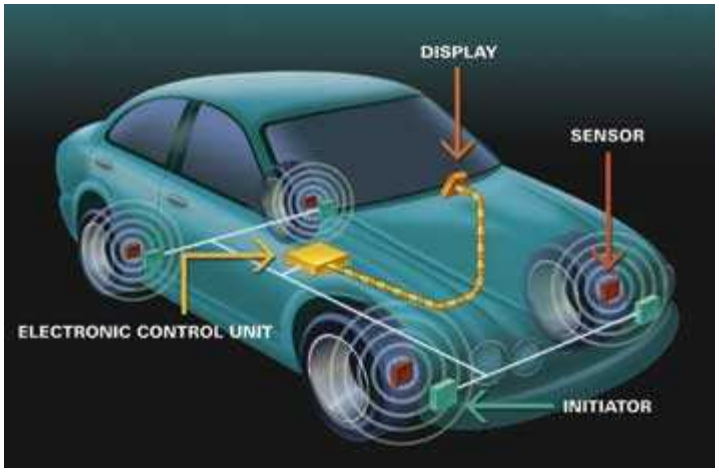
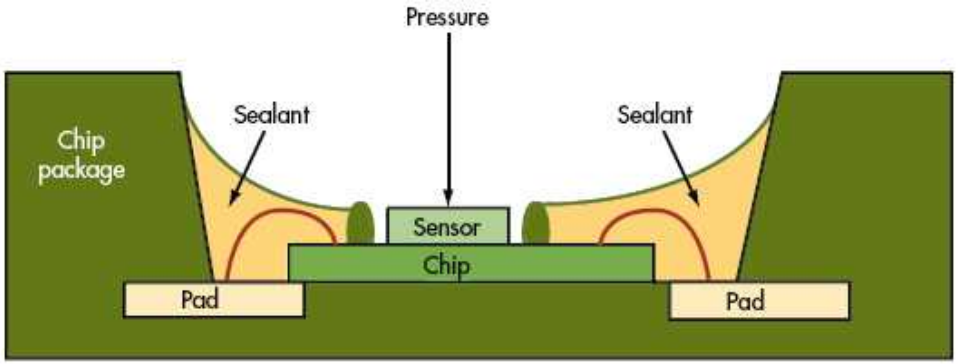
Tire Pressure Monitoring System (TPMS)

John DeGaspari, Mechanical Engineering, ASME, 2005
http://www.memagazine.org

MEMS Specific Inputs (gas/pressure)





2. The pressure sensor is the only part of the chip that is exposed. A sealant that is bonded to the chip package protects the components from the harsh environment.

http://www.electronicdesign.com and http://www.freescale.com

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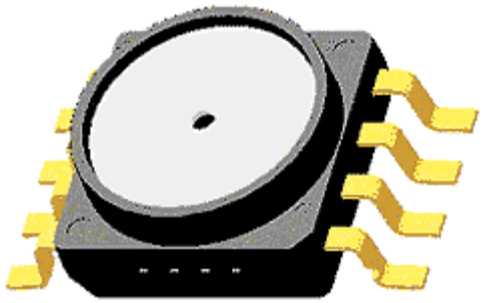
Pressure and Gas Sensors

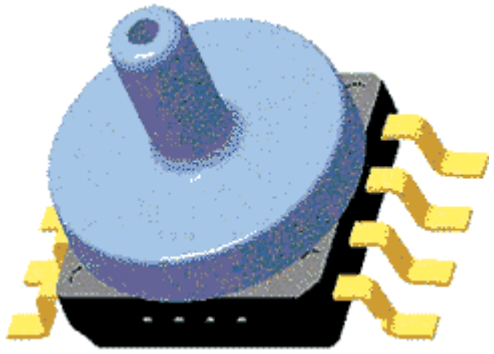
http://www.bosch.com

Mass Air Flow Sensor

Air Pressure Sensor

- **Automotive industry is one of the largest users of MEMS sensors.**





http://www.motorola.com

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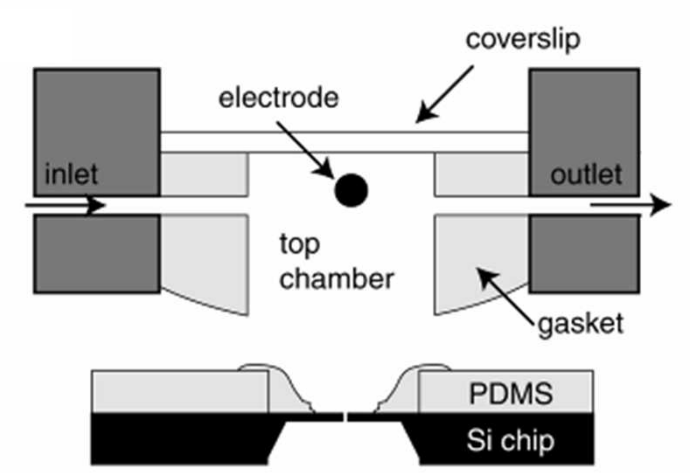
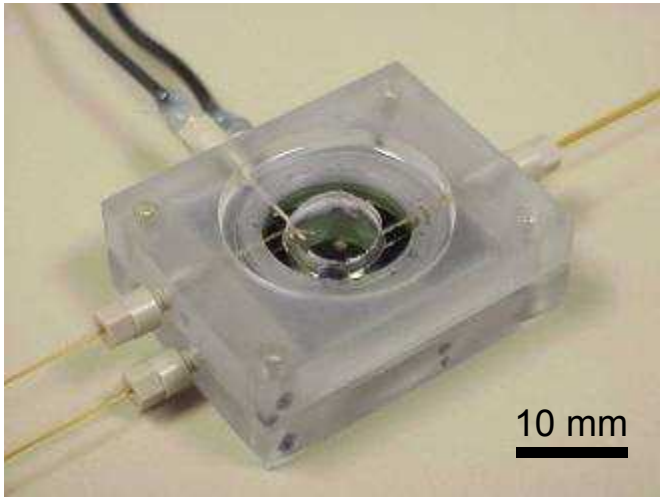
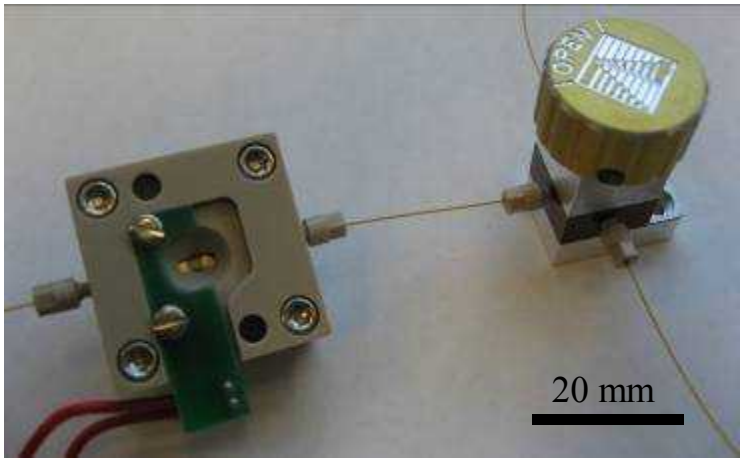
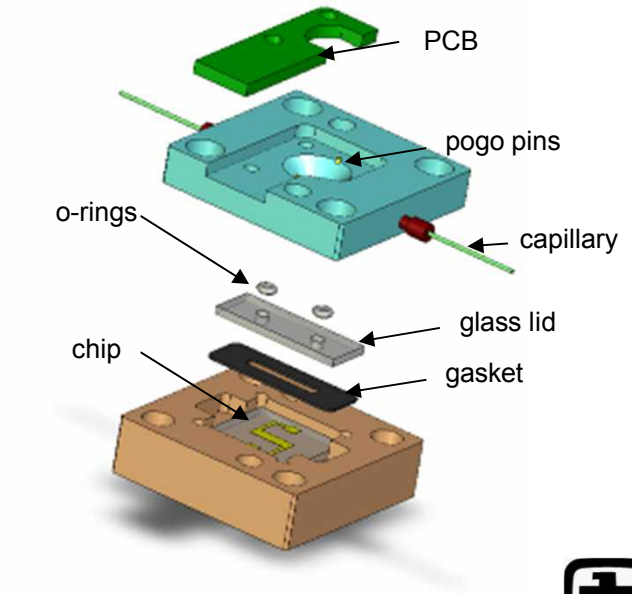
Micro-Fluidics

MEMS Specific Inputs (liquids)









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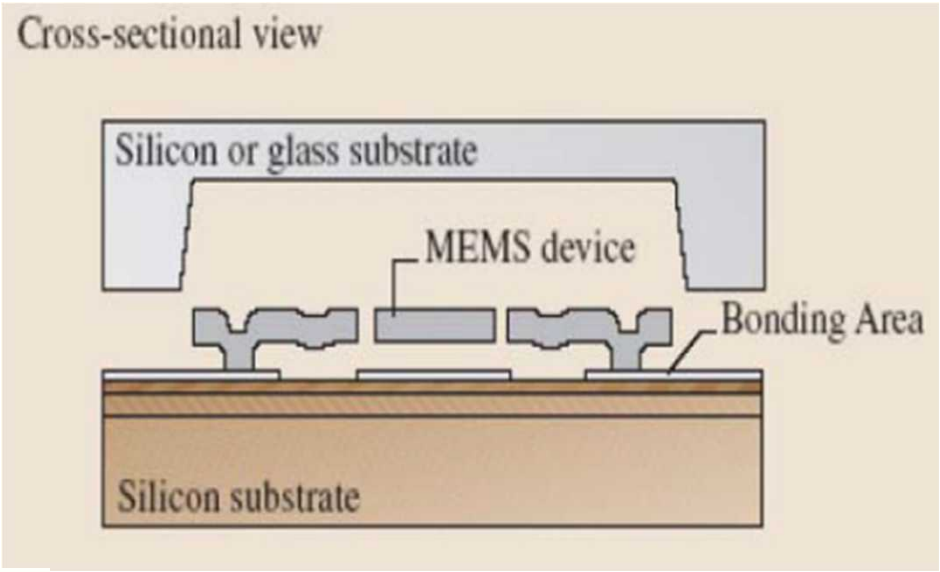
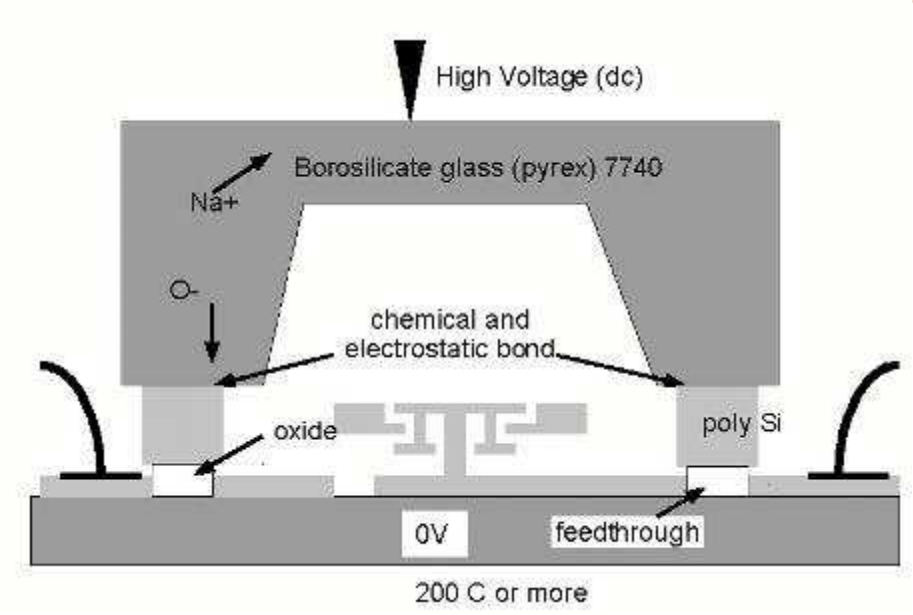
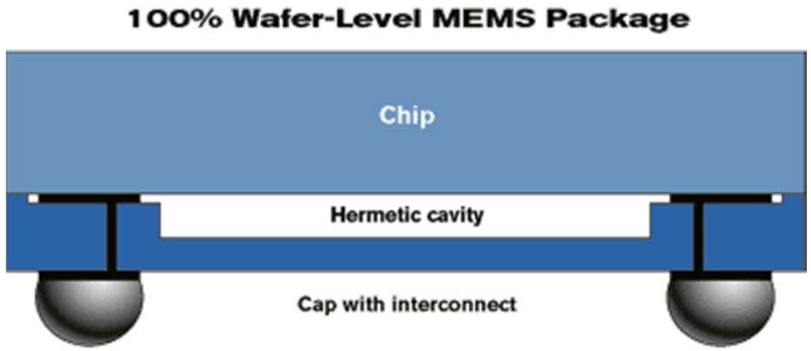
Die/Wafer level packaging

- Die or wafer level
- Protects released MEMS structures from subsequent packaging (plastic packages)
- May allow for wafer level release







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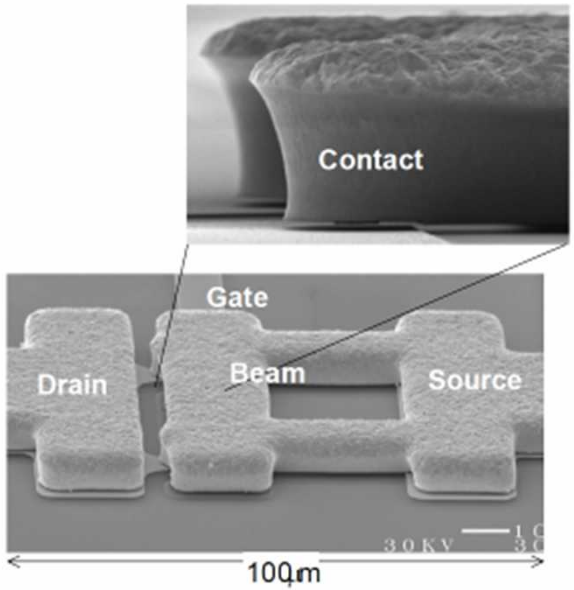
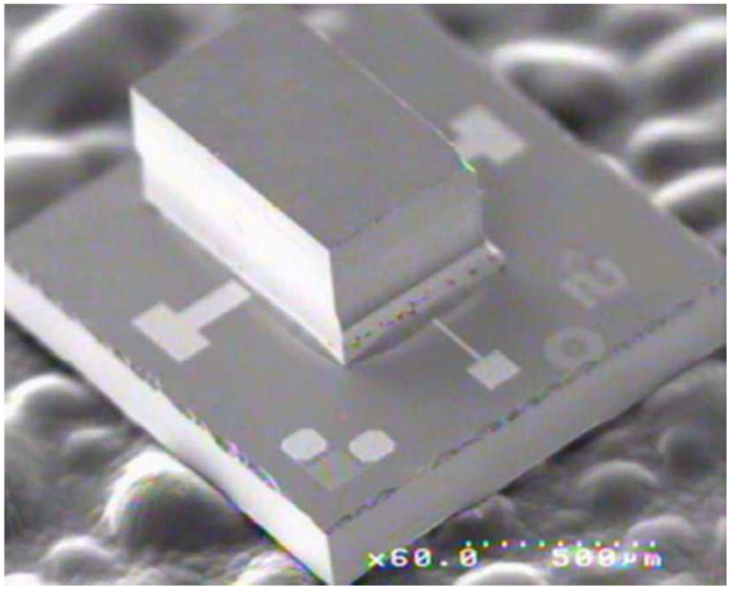
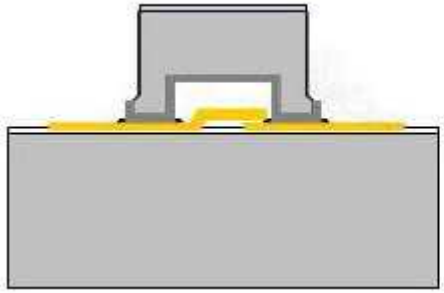
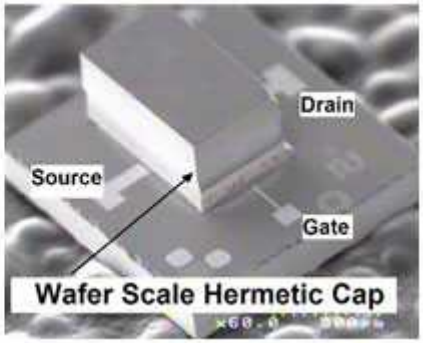
RF MEMS

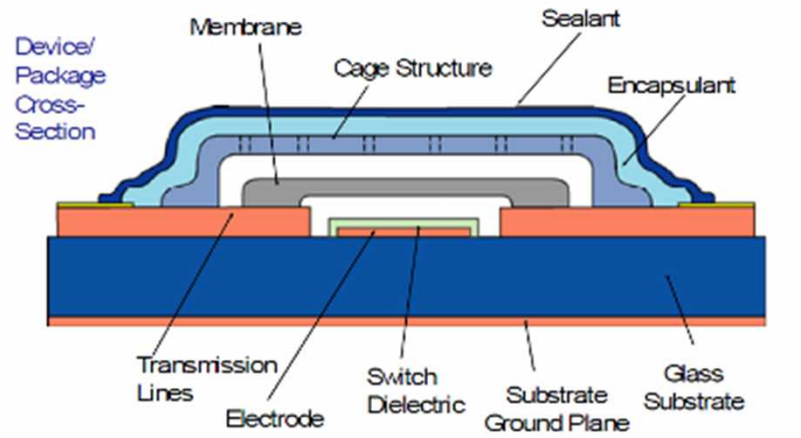
http://www.radantmems.com











Cleanliness and Hermeticity

http://www.memtronics.com

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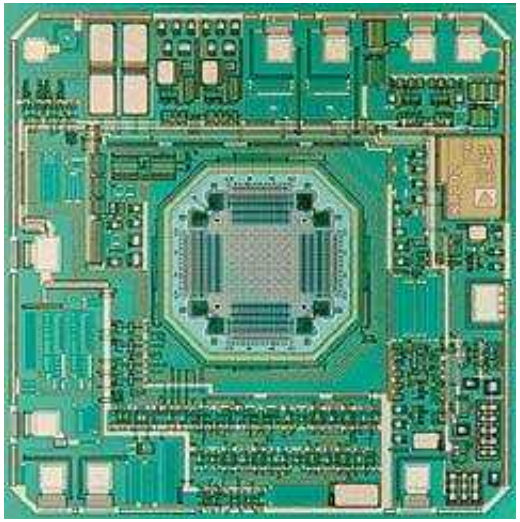
Analog Devices Accelerometers and Gyro's

- **ADXL330 – 3 axis accelerometer. Package is 4 mm x 4 mm x 1.45 mm, priced below $2 in volume.**
- **Used in automotive safety systems (airbags)**



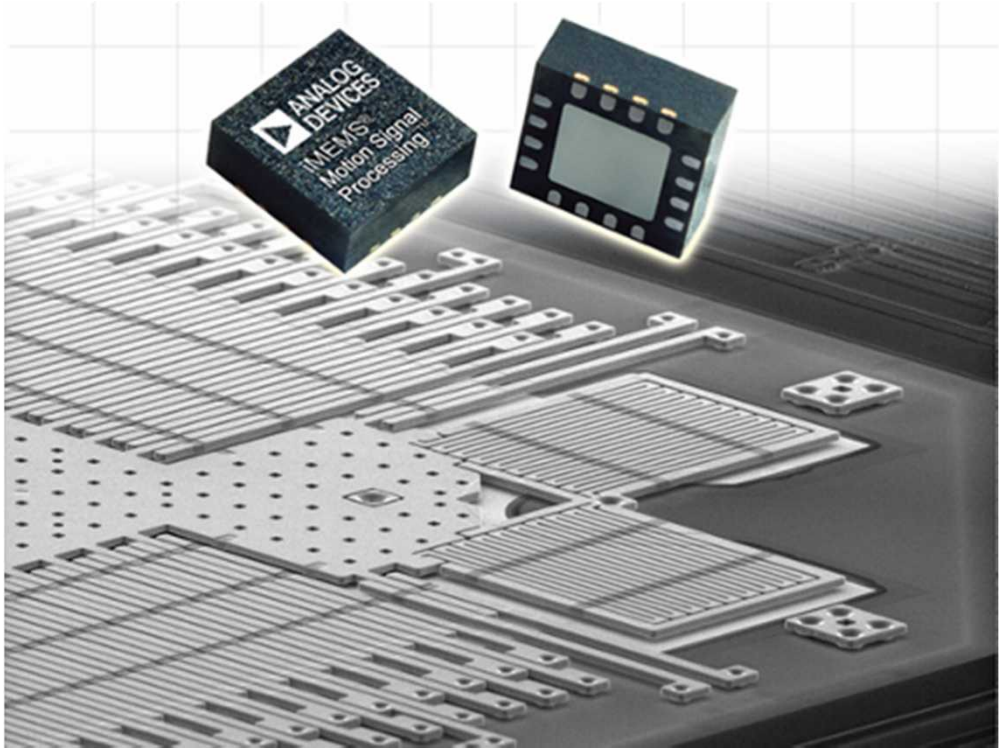


Figure 6. iMEMS accelerometer in surface mount package

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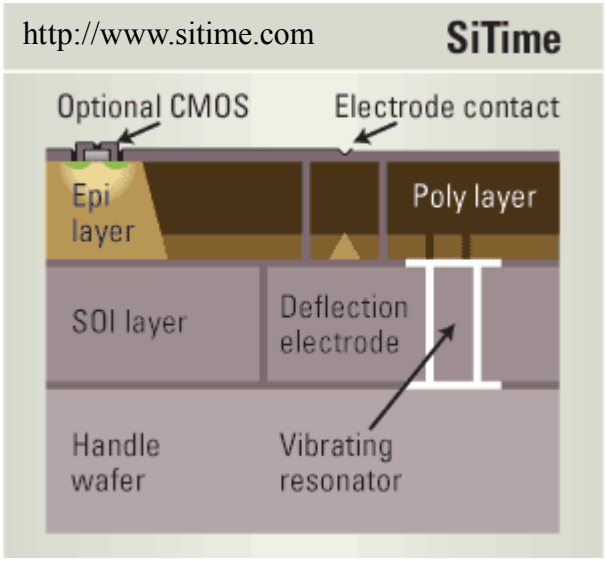
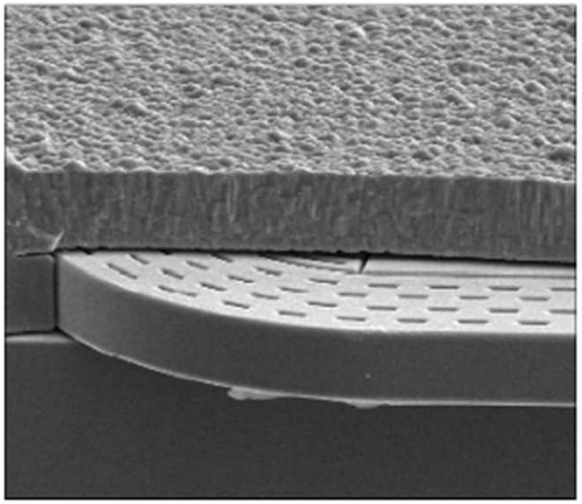
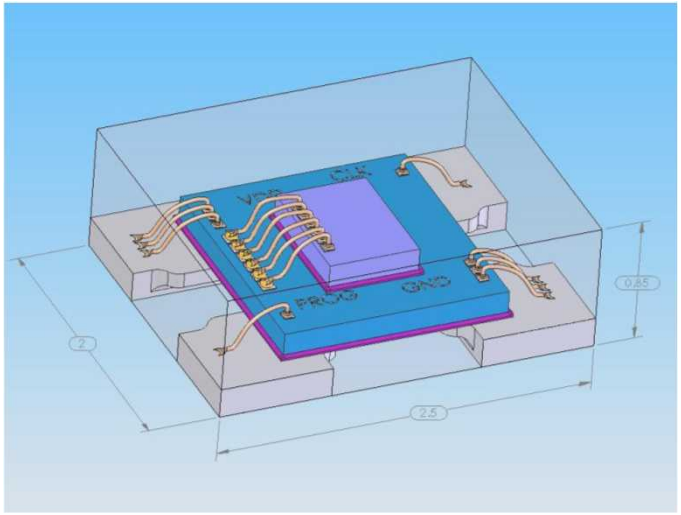
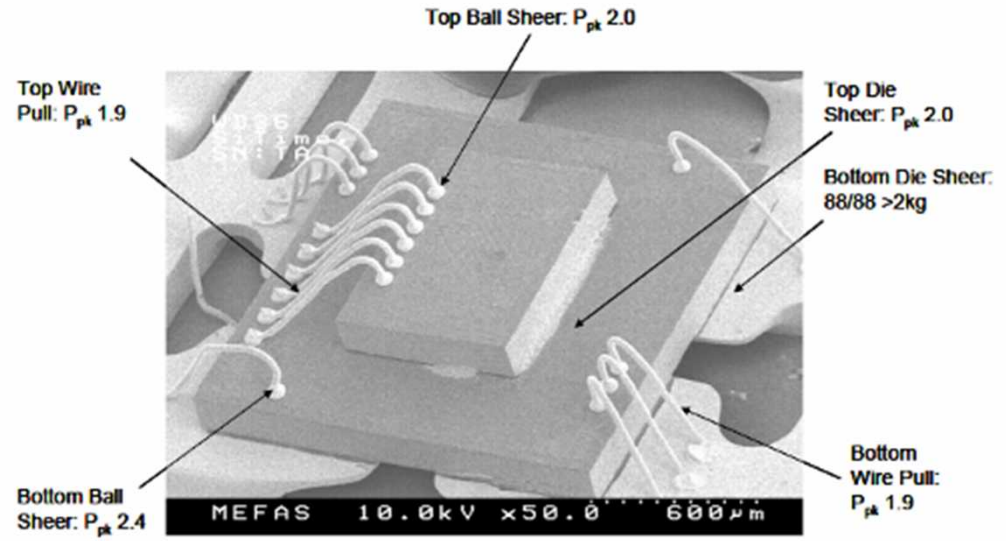
SiTime Micro-Resonator









Cleanliness and Hermeticity

Integration with CMOS

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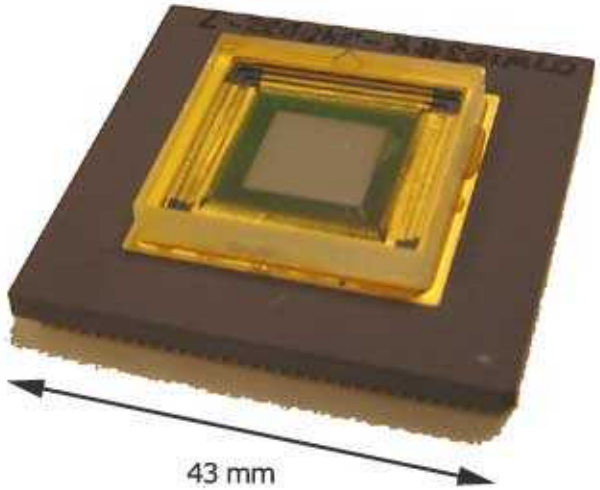
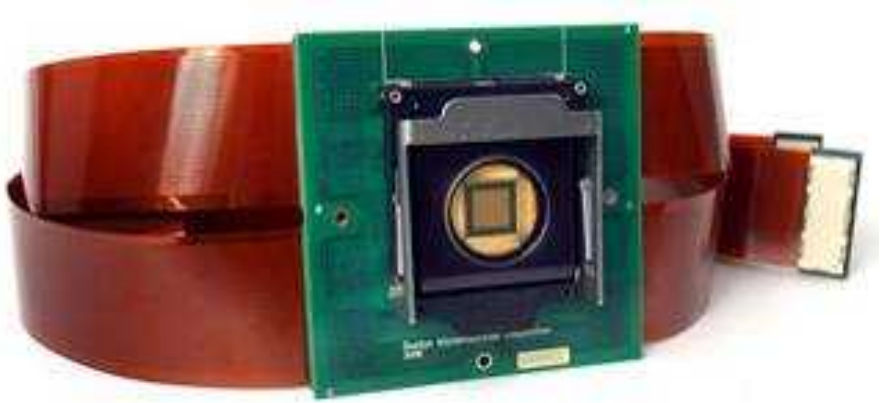
Optical MEMS

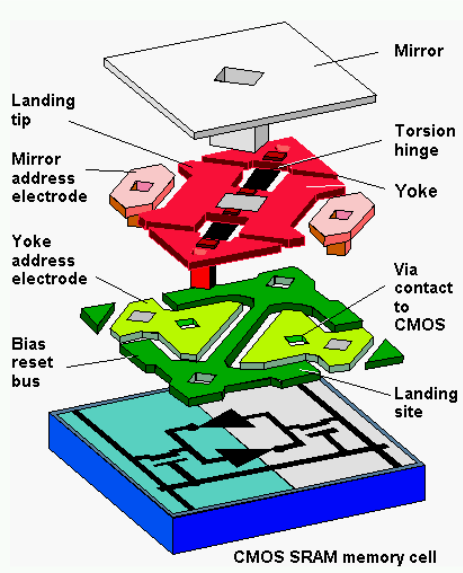
MEMS Specific Inputs/Outputs (optical)



http://www.bostonmmicromachines.com

http





Large I/O count

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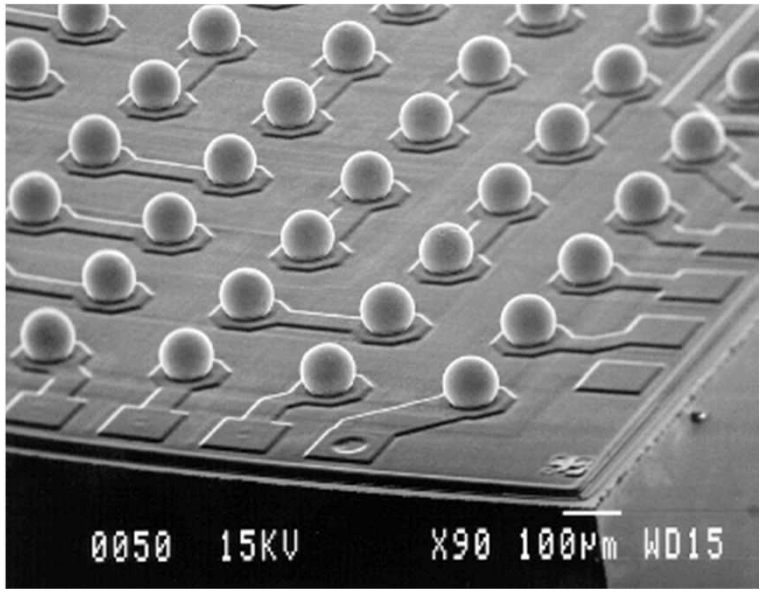
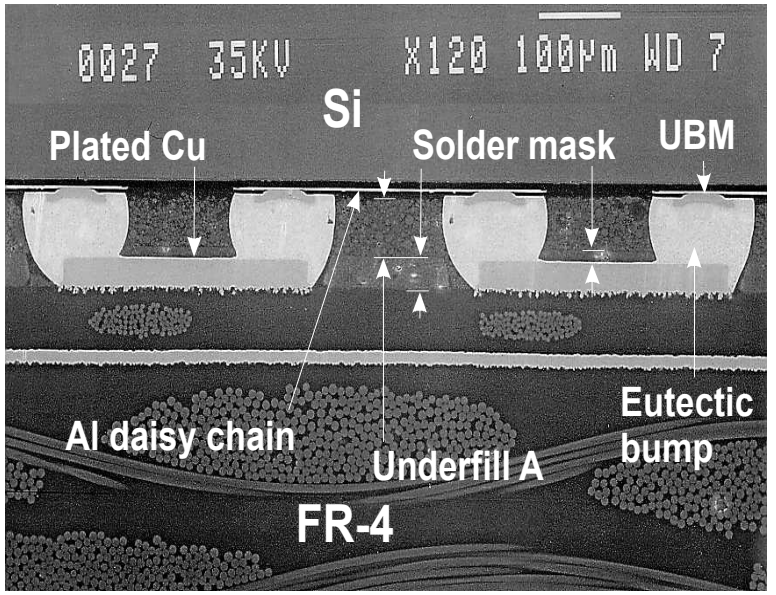
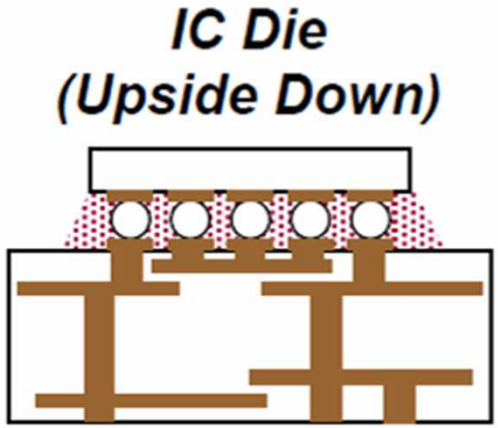
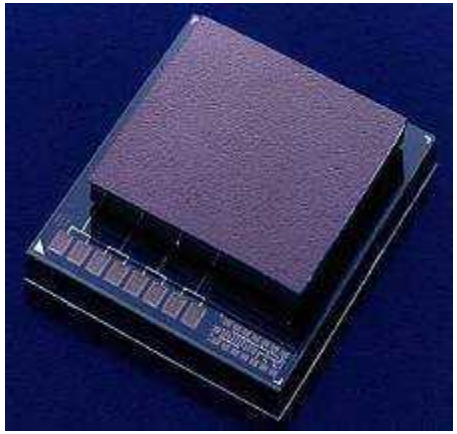
Flip-chip bonding/Integration





Solder Balls With Underfill





http://www.wtec.org

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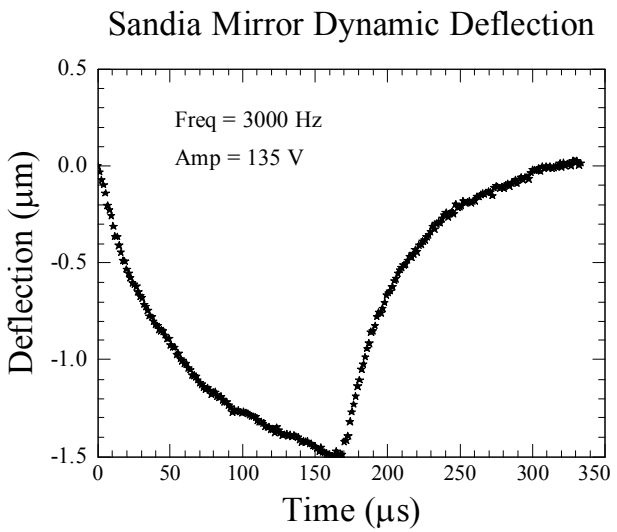
Testing Considerations

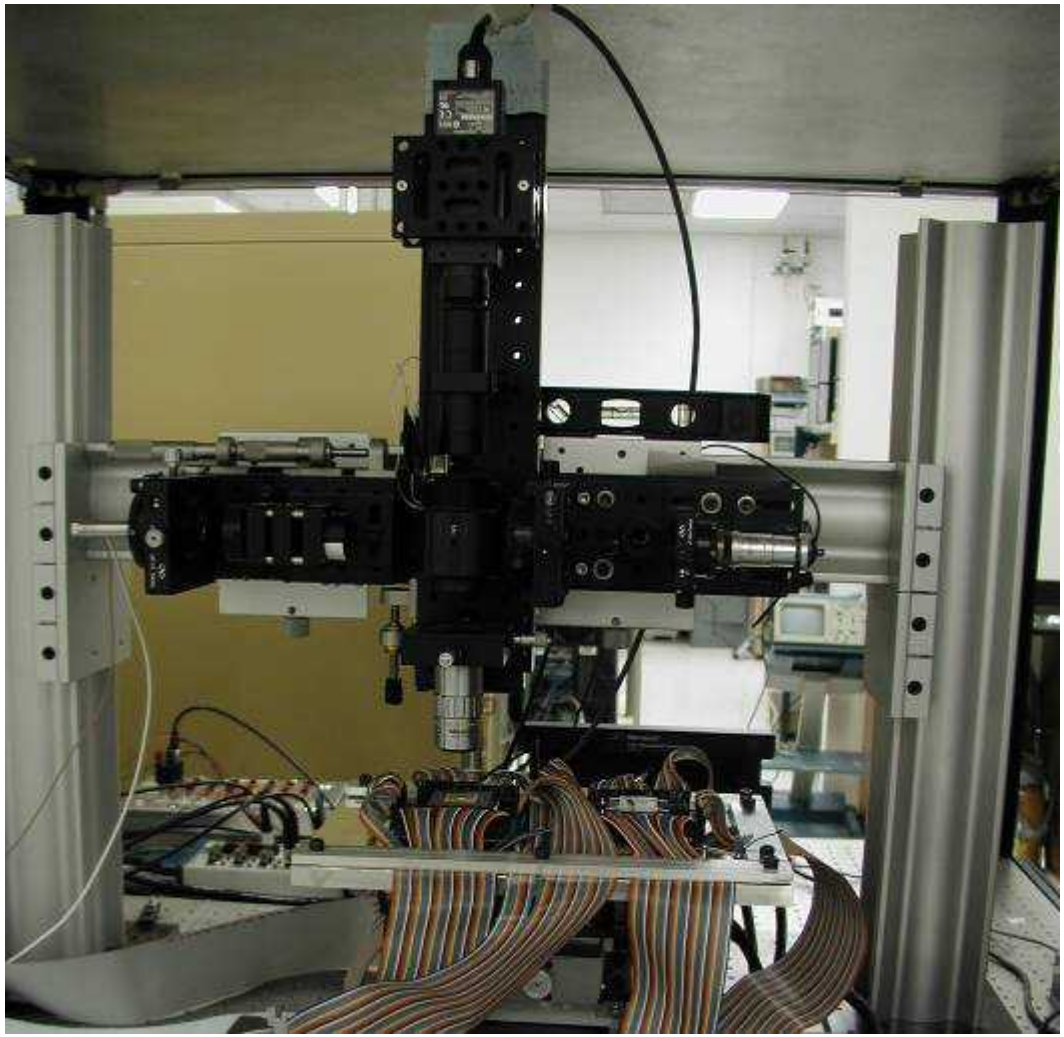
- Testing performed at:
  - Wafer (automated electrical tests)
  - Die
  - Package (full system tests, sometimes required for MEMS I/O)
- MEMS Specific Concerns
  - Test for function, durability, and reliability in various environments
    - Shock and vibration
    - Thermal (and thermal stresses)
    - Exposed ambient (pressure and flow sensors, optical, package environment)
    - Radiation
- As with Packaging, testing is as varied as the application
  - Optical (mirror arrays)
  - Fluidic (gas or liquid)
  - Electrical (RF MEMS)
  - Acceleration/vibration/shock (accelerometers)

Different applications drive new capability development

Custom built long working distance stroboscopic interferometer used to measure mirror stroke at operating frequency



(A. Corwin)



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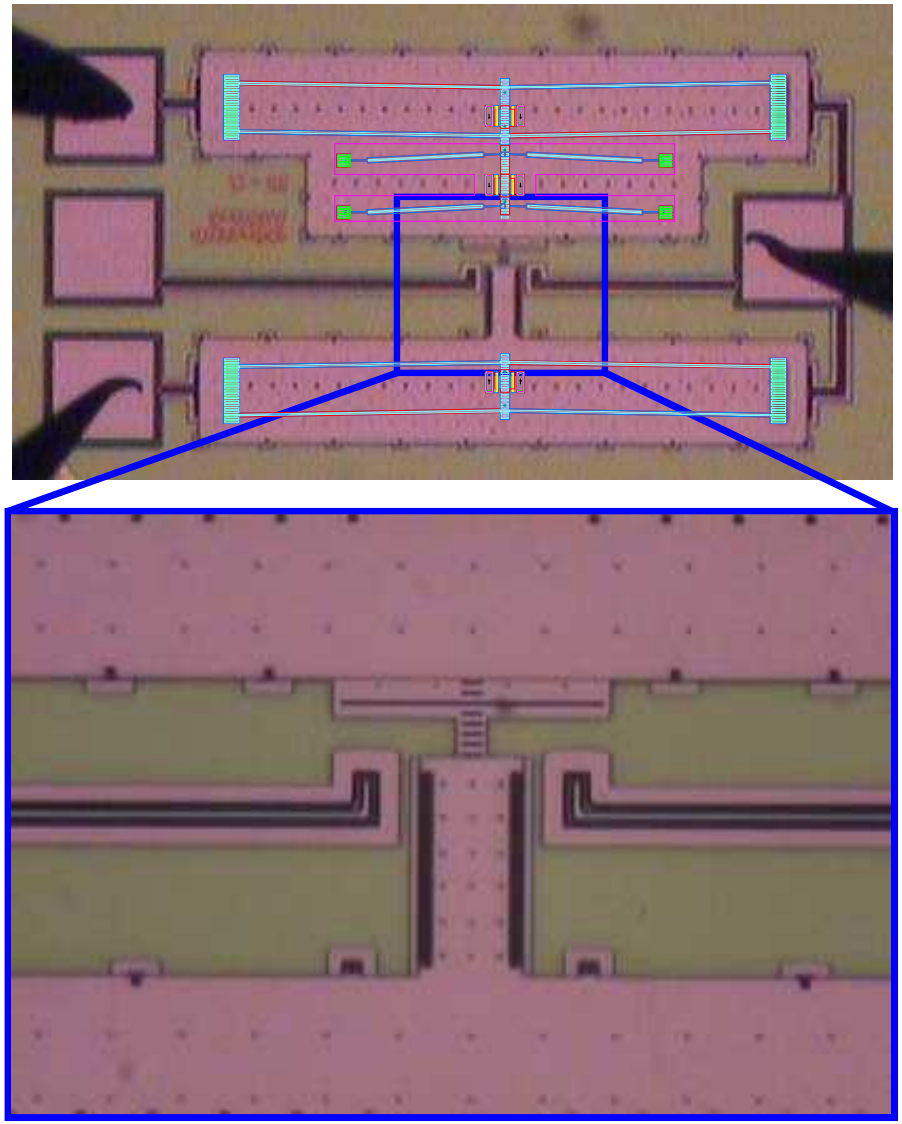
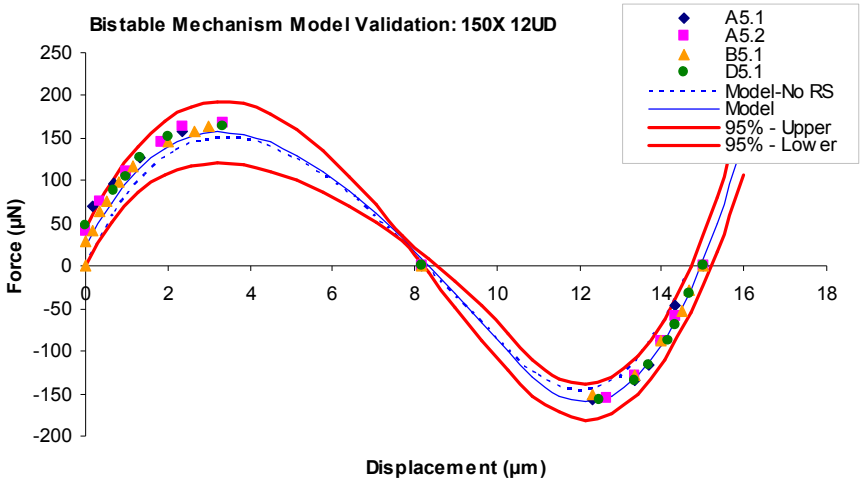
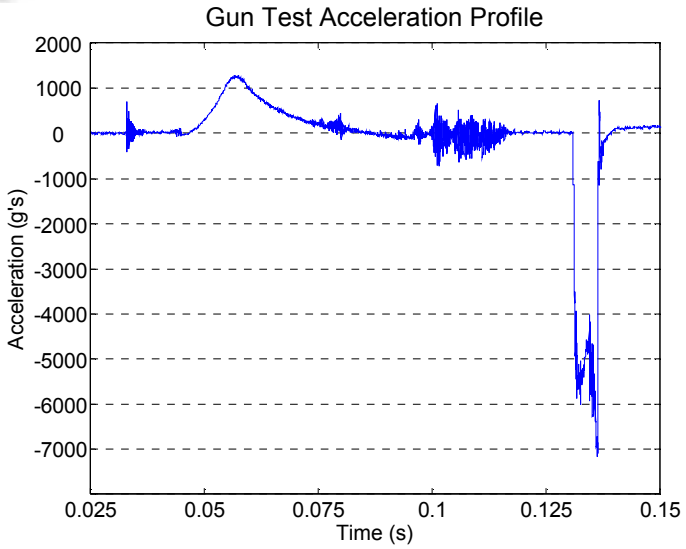
Example: MEMS Latching DC Relay

- **Purpose: Develop a low power, shock/rad hardened, latching DC relay**
- **Technical Challenges**
  - **Performance of metal contacts with cycle count, both hot and cold switched.**

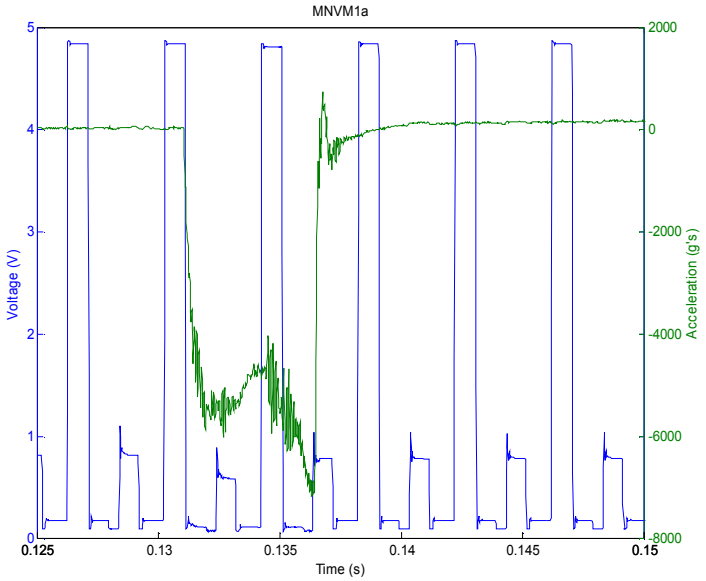


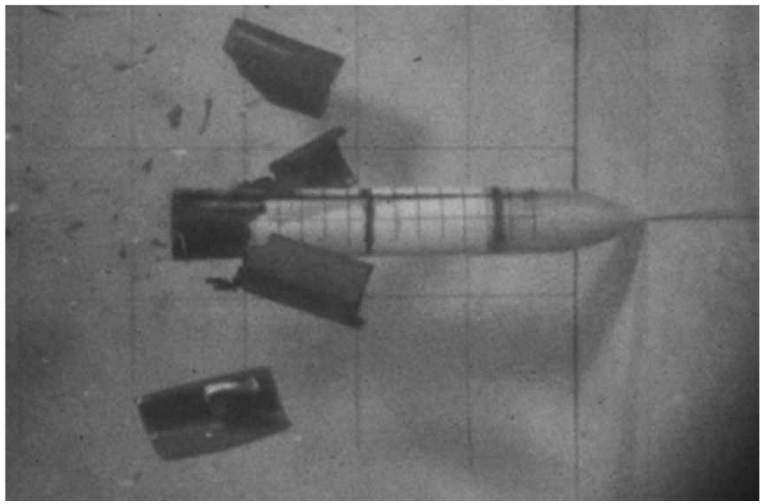


Penetrator Test Results



Impact at 7200 g's over 5.5 milliseconds





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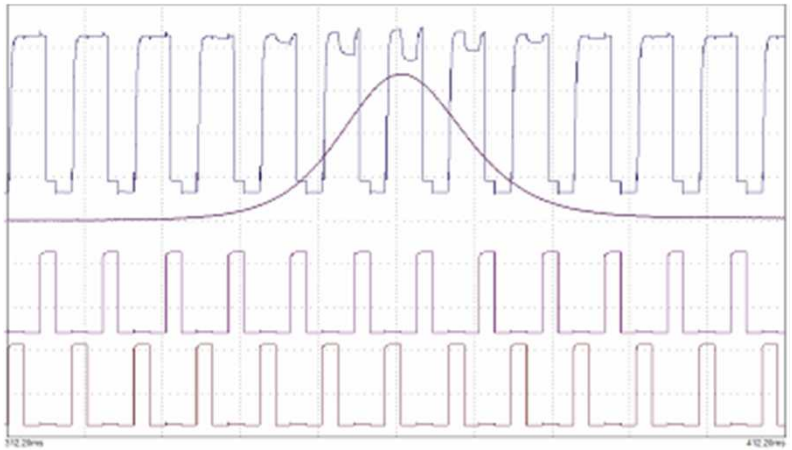
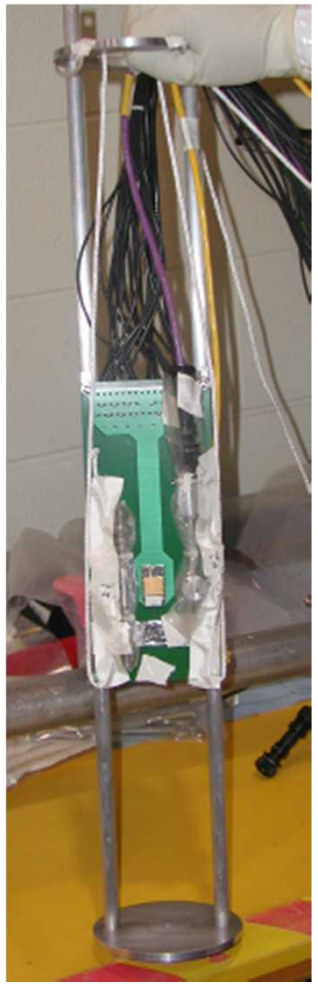
ACRR Radiation Testing

- **Operated through both a max-pulse and a steady-state run free-field.**
  - **16.5 Mrad(Si) total dose at steady-state**
  - **100 Mrad(Si)/s peak dose rate from pulse**
  - **$1x10^{16}$ n/cm^2 max fluence**





Mike Luker – Org. 1384, 2007

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Questions?

Michael S. Baker
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msbaker@sandia.gov

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Unused slide

- 40-80 people
- Govt. technical professionals, non MEMS. Includes defense and security.
- Give thorough technical and historical background as well as review of state of art, relevant research, production, or use trends.
- 25 minute talk. Half intro/background and general observations. Then own research. 10 minutes additional time at end for questions.

Unused slide

- General topics
  - Existing or potential impacts for national security/defense
  - R&D status and outlook. What's coming down the pipe esp. for defense.
- Packaging and testing
  - Unique packaging requirements for mems
  - Robustness and reliability
  - Case studies as examples of unique.