SAND2008-2089C

SAND2008-????

Update on the Sandia MEMS Passive Shock Sensor

John A. Mitchell
Sandia National Laboratory
Electromechanical Engineering
Org 2614

Carl W. Gustafson
National Nuclear Security Administration's Kansas City Plant
Microelectronics Engineering
Dept. 8E4

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

NNSA National Nuclear Security Administration

Sandia National Laboratories

OUTLINE

What is the MEMS passive shock sensor?

Overview of activities

Beyond Rev 1

- **Failure analysis and discovery: Rev 2**
- **New Design Revisions: Rev 3, Rev 4**
- **Queue: Rev 5**

Hermetic Packaging

Packaging for testing

Testing & Results

- **Shock table testing**
- **frequency response**

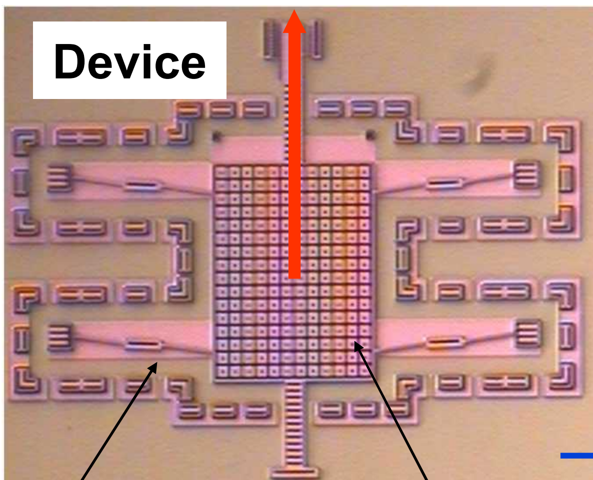
MEMS Passive Shock Sensor

*A micro-electro-mechanical switch that **detects shock**.*

Detect Shock (100 g's to 25000 g's), (mili-seconds to micro-seconds)

Passive, environmentally actuated, latching/un-latching, built-in contact test capability, low power, large range of inertial environments, batch fabrication (Sandia's SUMMiT V technology), small in size enabling retrofit/enhancements

displacement



Spring

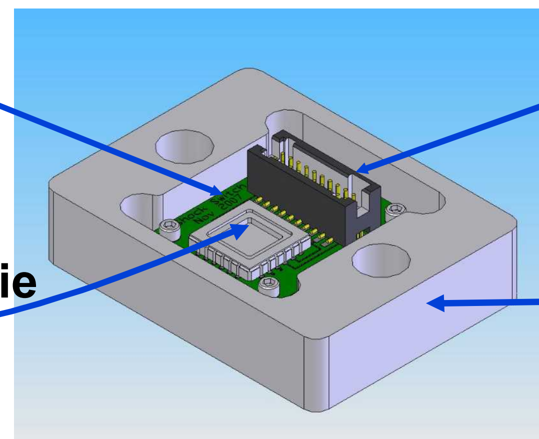
Mass

DETECT SHOCK: Use Cases

- Detecting a particular shock event
- Screening operations to identify over-shock events

PCB

Hermetic Packaging Of MEMS die



Electrical connector

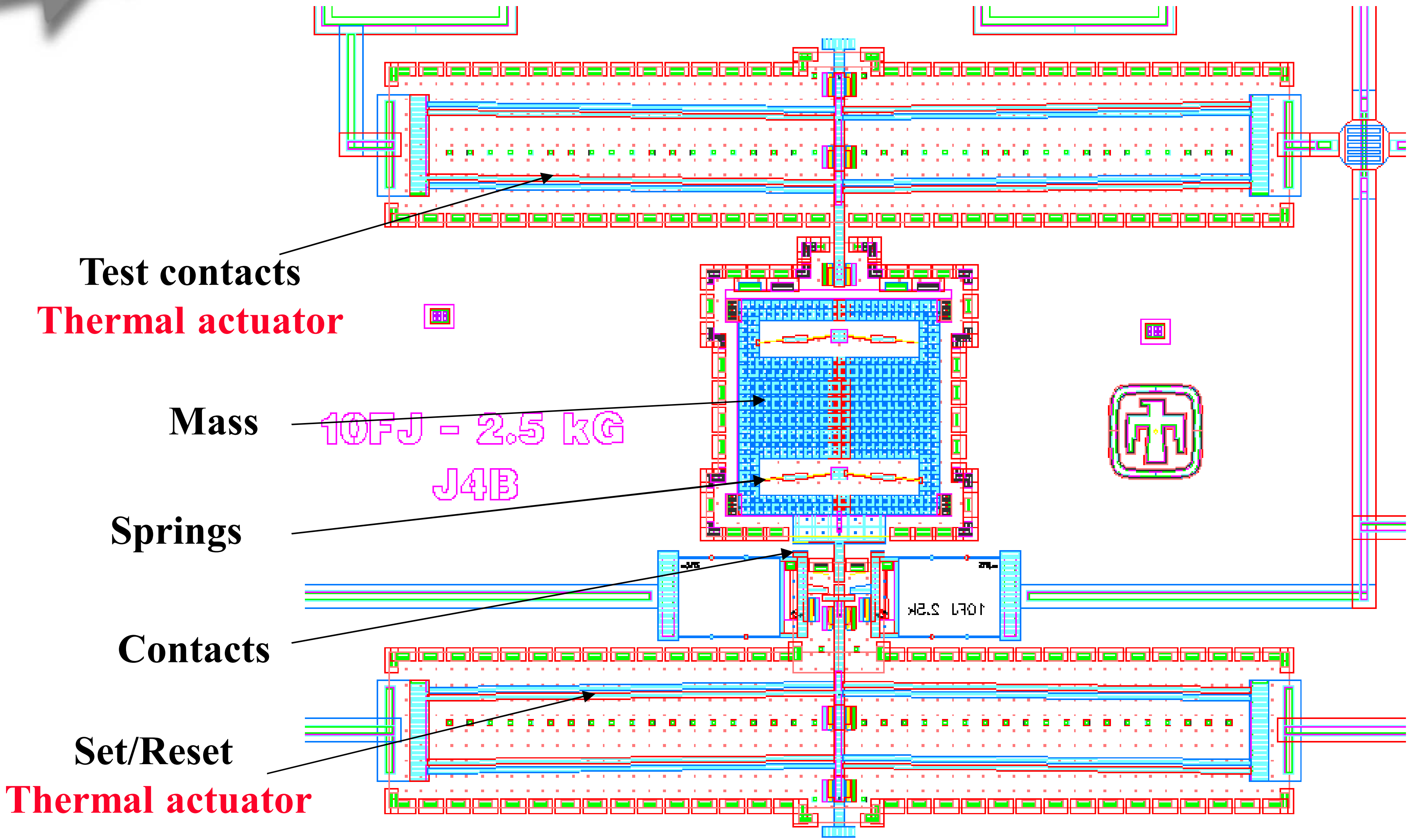
Mechanical Interface housing

NOTE: Once triggered, the MEMS passive shock sensor remains latched. Power is only required to open or read the sensor state.

Sandia National Laboratories

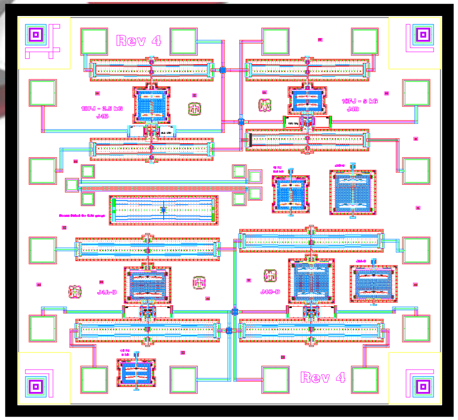
MEMS Passive Shock Sensors

J-Series Layout

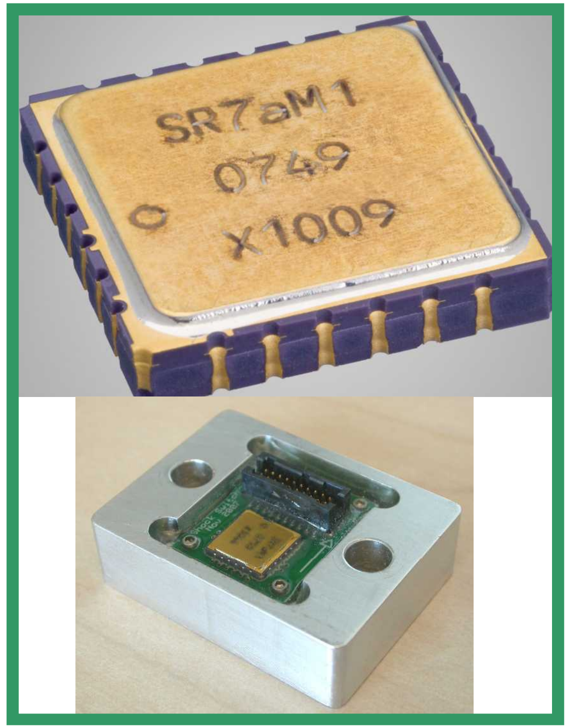


Activities

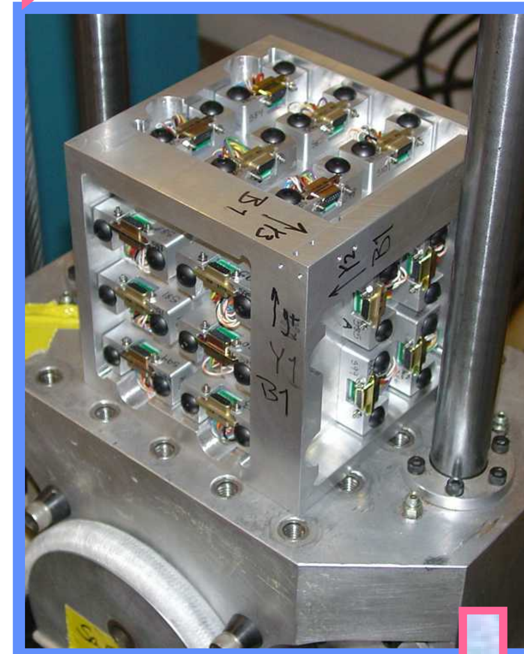
SUMMiT V Fab



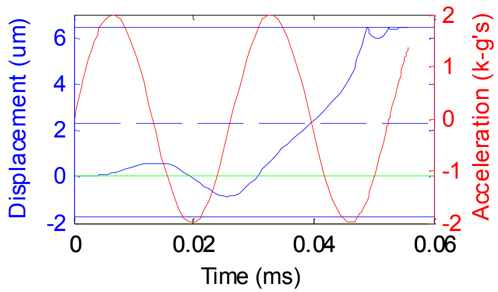
Packaging

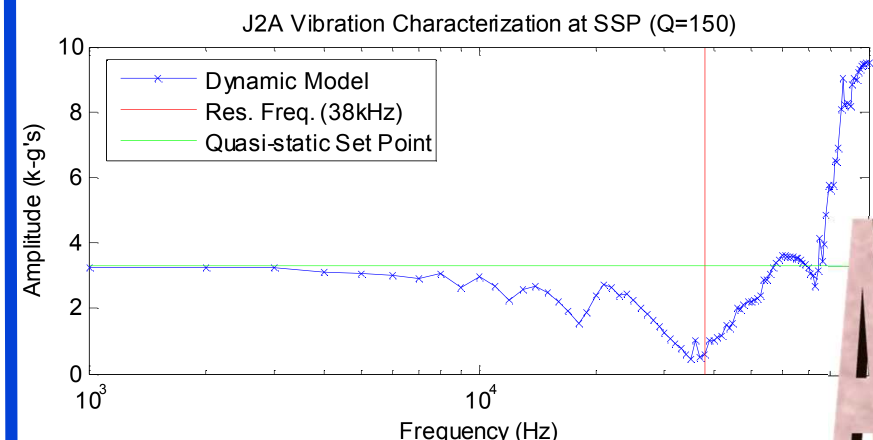


Testing

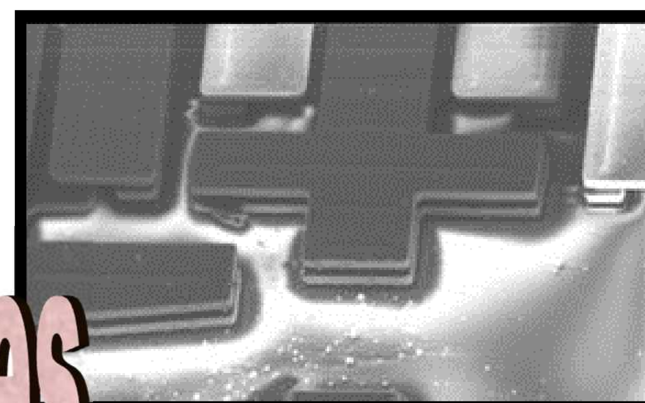


Design & Analysis





Failure Analysis



Sandia National Laboratories

MEMS Passive Shock Switch
Failure analysis and discovery: Rev 2

<u>known modes of failure</u>

--- JM7000 contamination (processing issue) [Resolved]

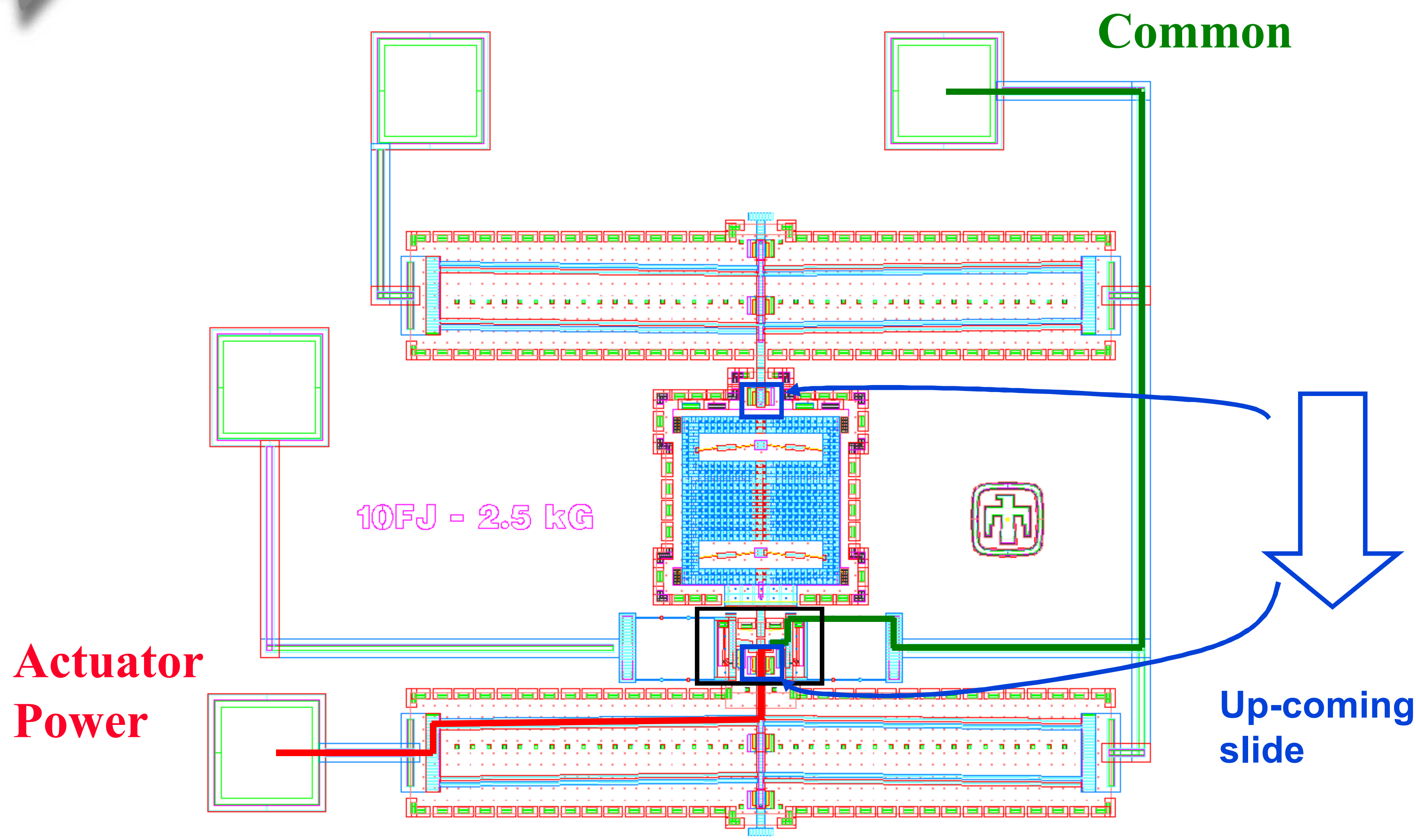
--- Particles (processing issue) [work in progress]

--- cracked/broken bond pads (process issue) [resolved but must remain vigilant]

--- silicon welding [work around, mechanism still under study]

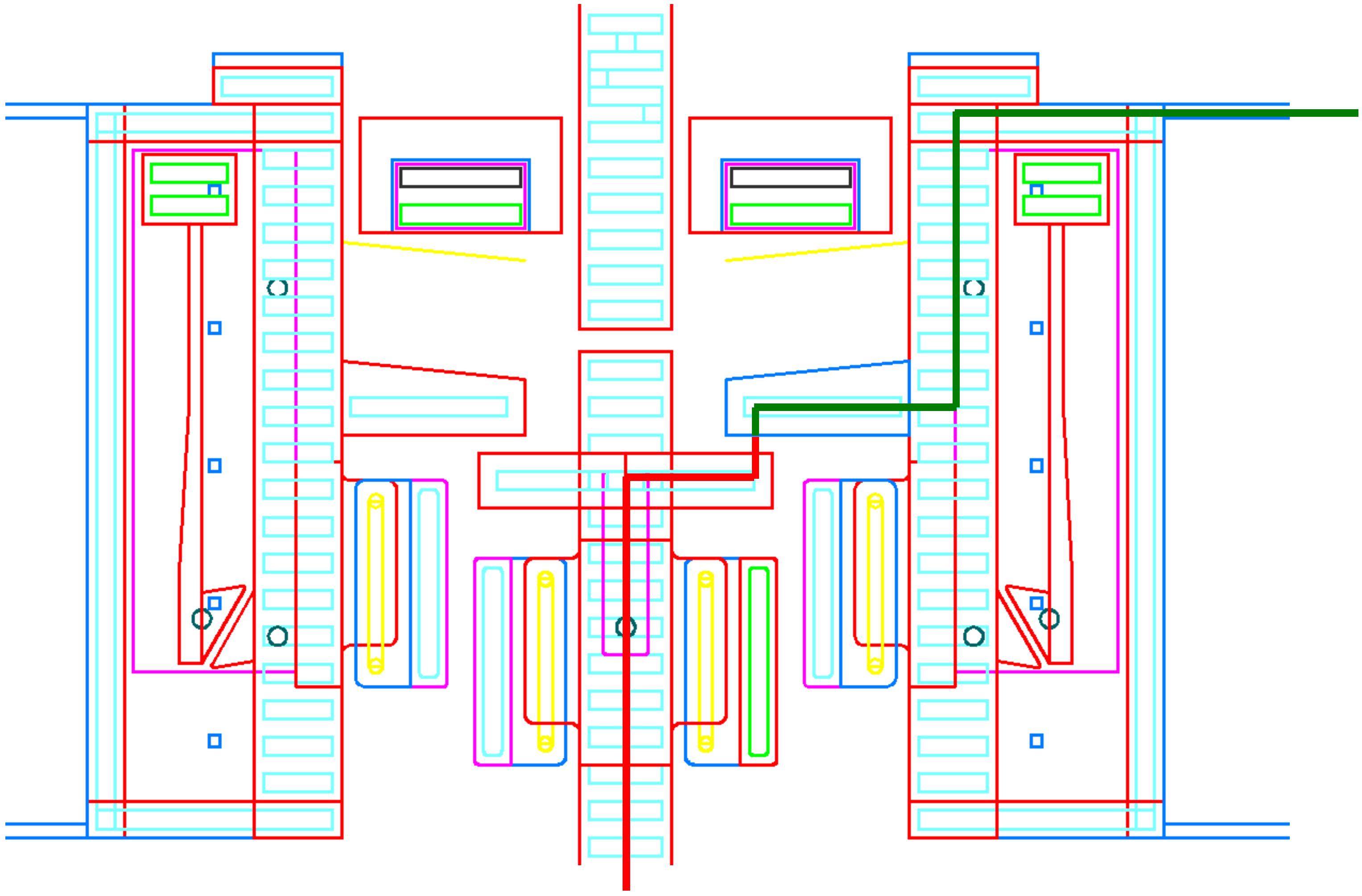
--- friction: mass/lid, mass/substrate [Resolved]

MEMS Passive Shock Switch: FA
Fusing/Welding: device AUTOCAD layout

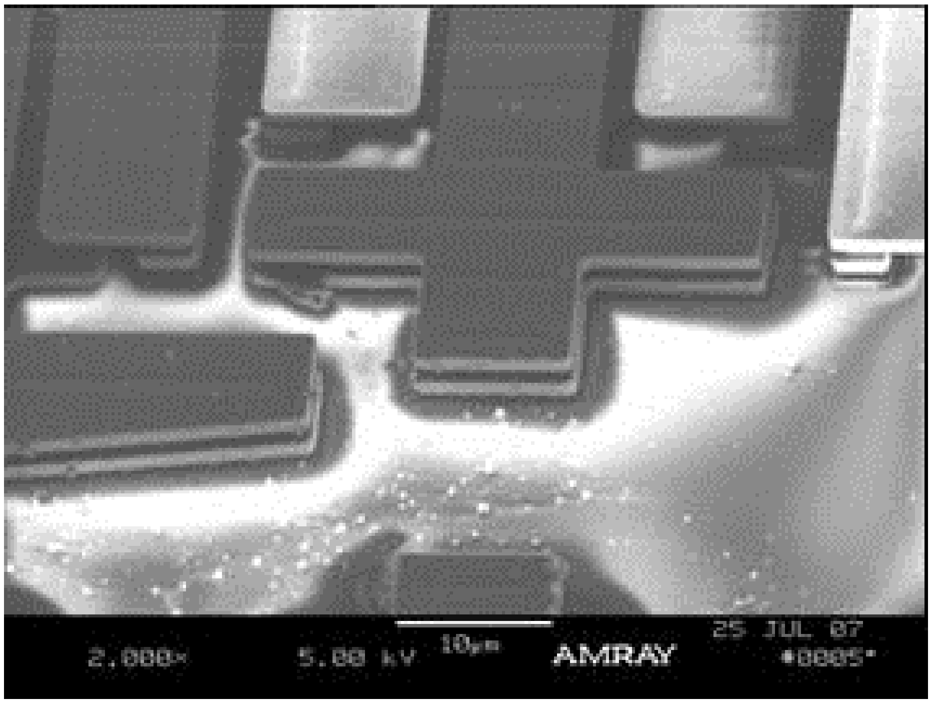


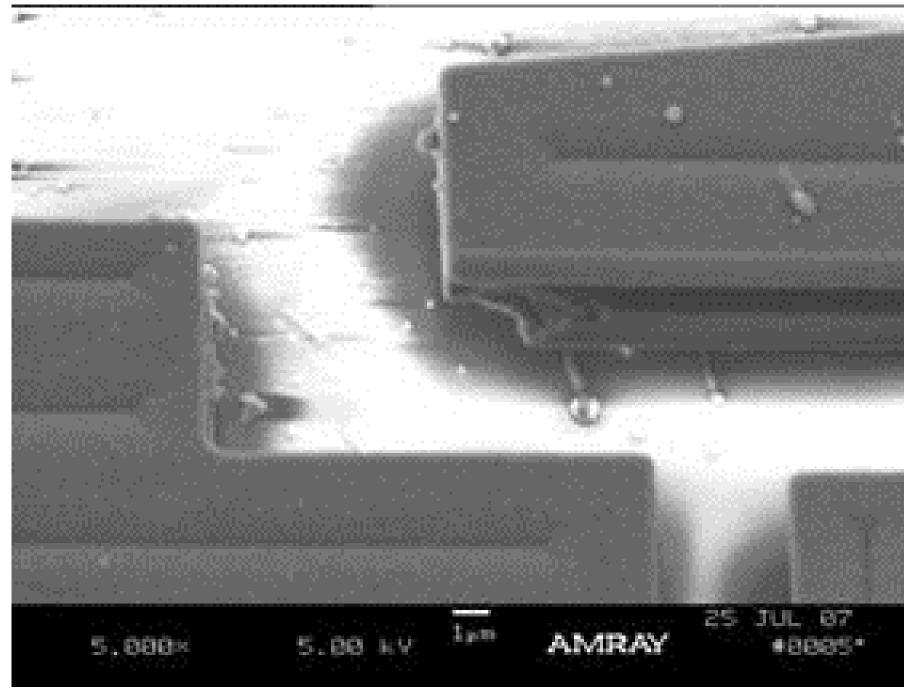
MEMS Passive Shock Switch: FA

Fusing/Welding: zoom on AUTOCAD layout



MEMS Passive Shock Switch: FA
Fusing/Welding: SEM on contact area



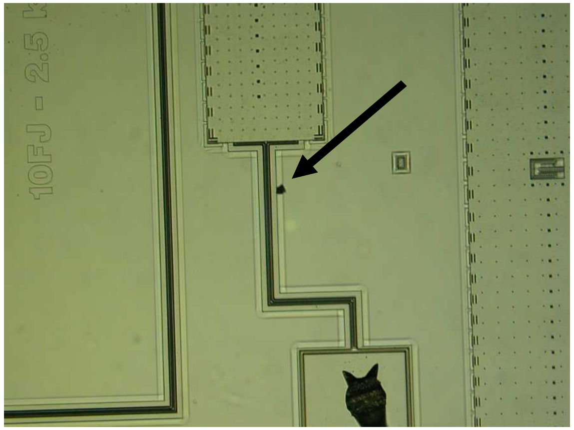


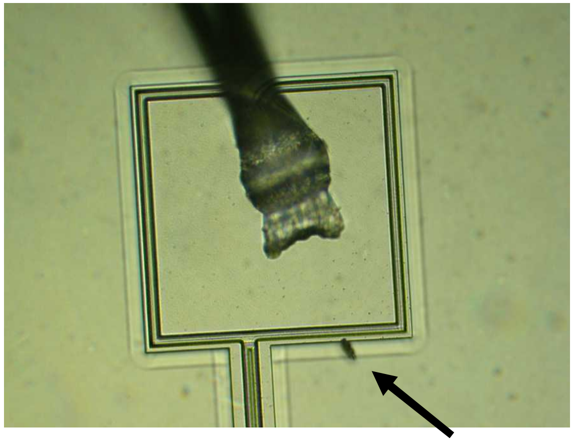
MEMS Passive Shock Switch
Particles

Particles

1 to 2 micron size particles are evident after release

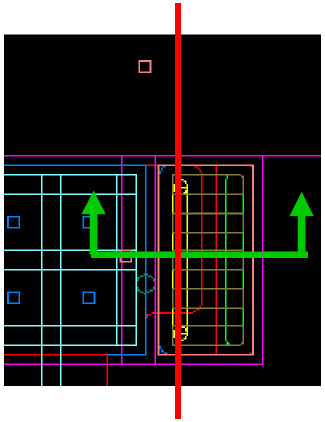
1 to 2 micron size particles are evident after metallization (handling)

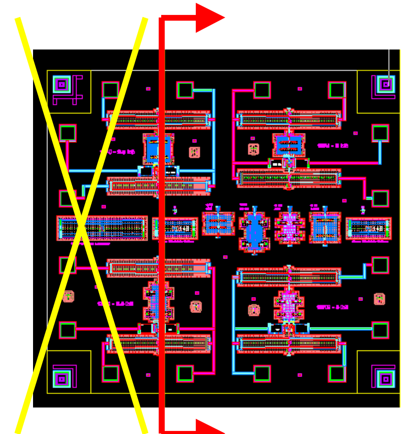


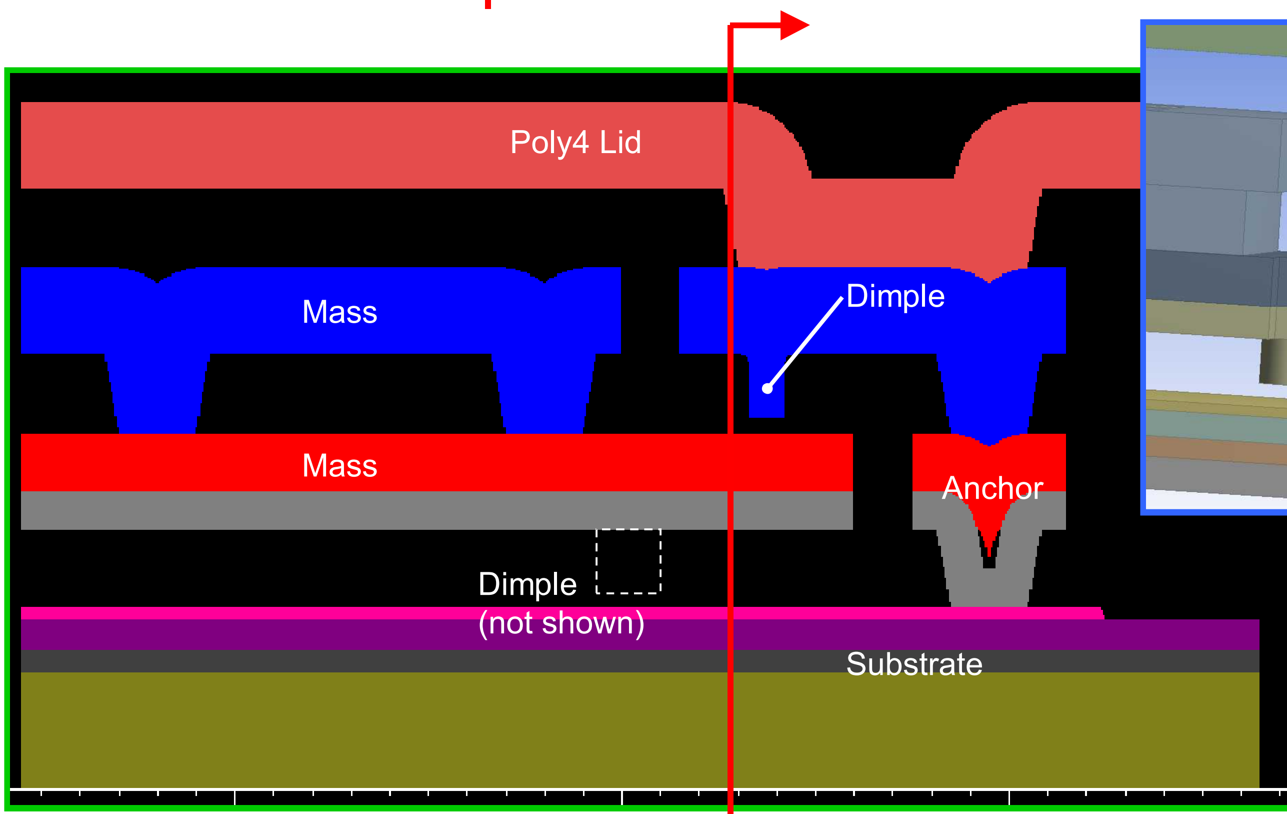


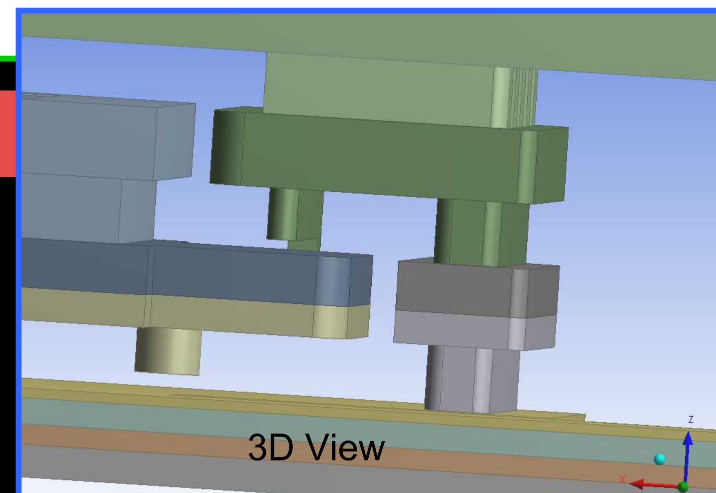
MEMS Passive Shock Switch: FA

Frictional Interaction: Dimples with mass





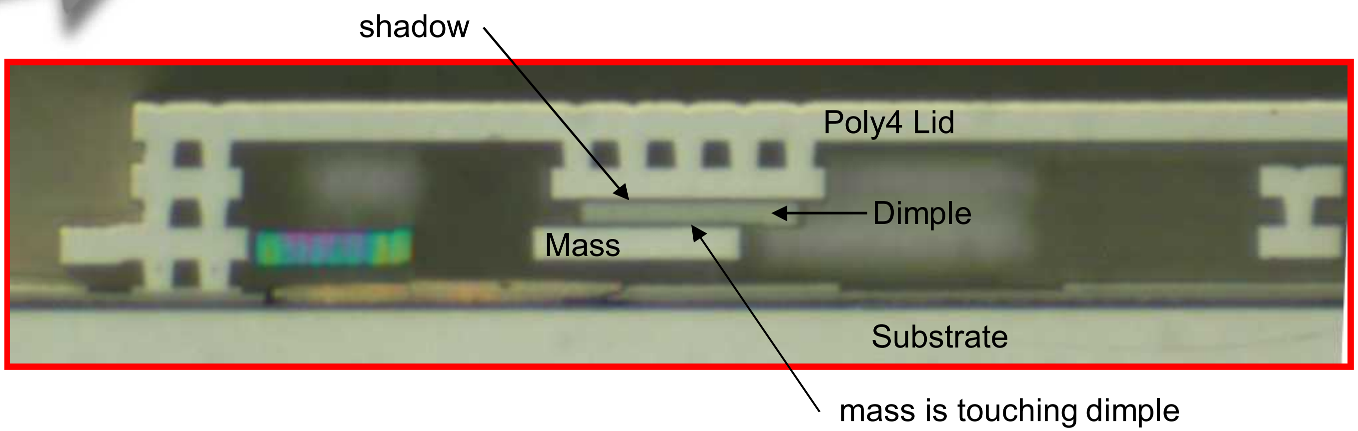


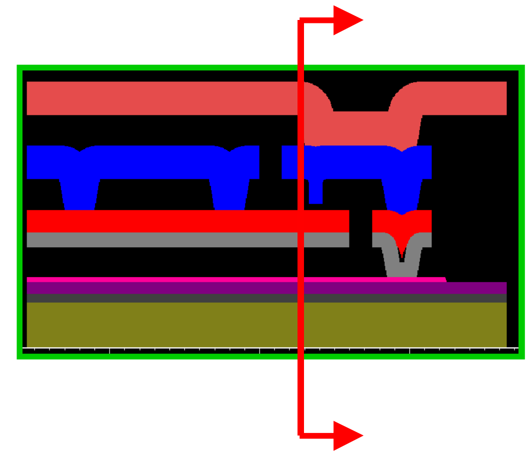


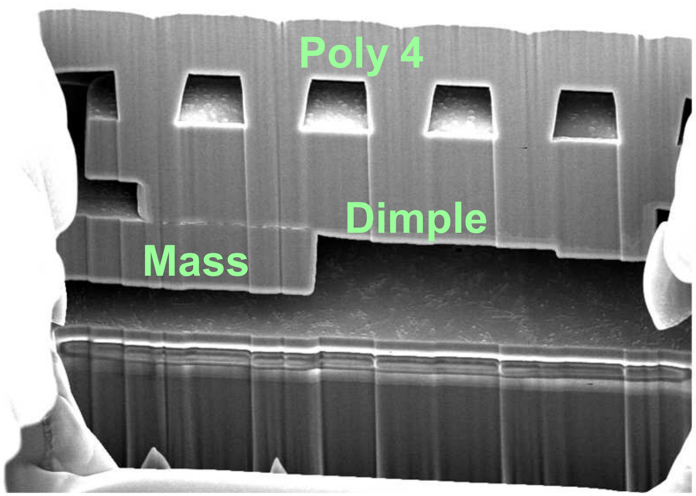
Sandia National Laboratories

MEMS Passive Shock Switch: FA

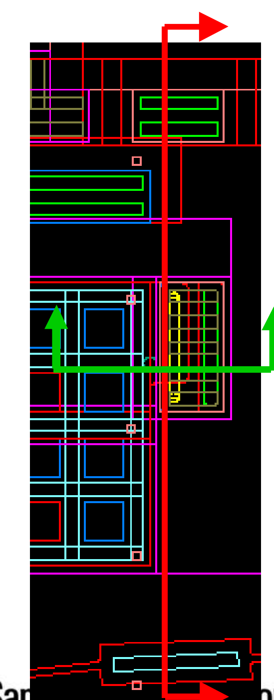
Frictional Interaction: Dimples with mass







SEM



Poly 3 dimple fabricated out of spec

MEMS Passive Shock Switch
Rev 3

<u>Goals</u>

- Reduce off-axis sensitivity: implemented using “thick poly”
- Eliminate alternate short-circuit when powering thermal actuators: strategically placed nitride layer
- Study effects of dimples: devices with and with/without dimples

<u>Outcome</u>

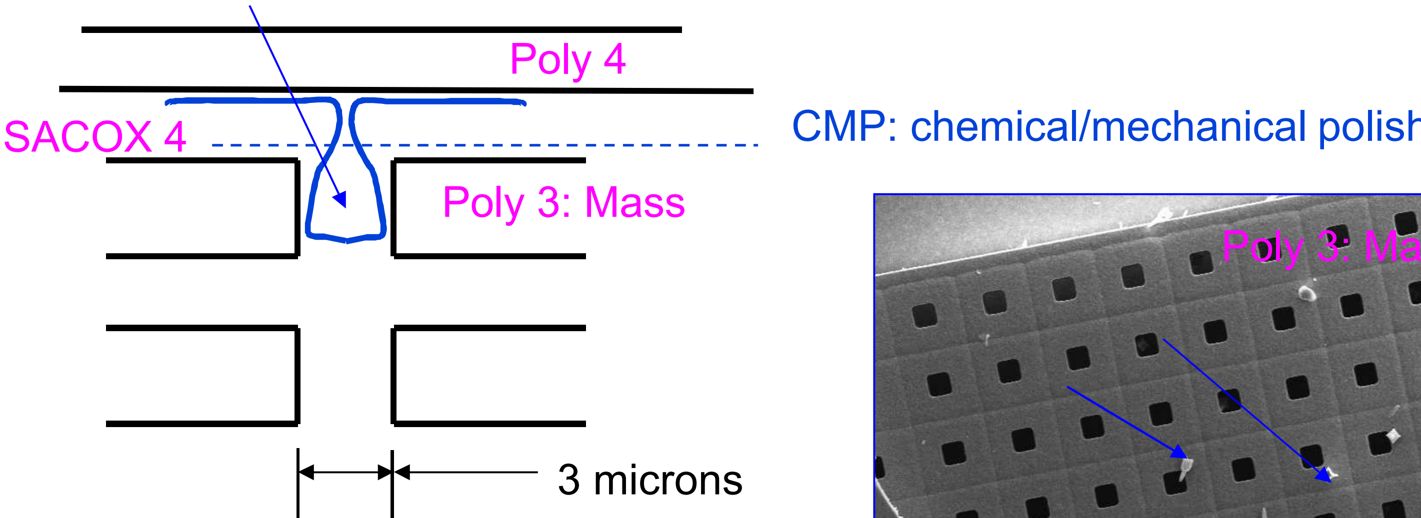
- Rev 3 failed overall: (keyhole type failure: still under study)
- Nitride isolation may have been a success

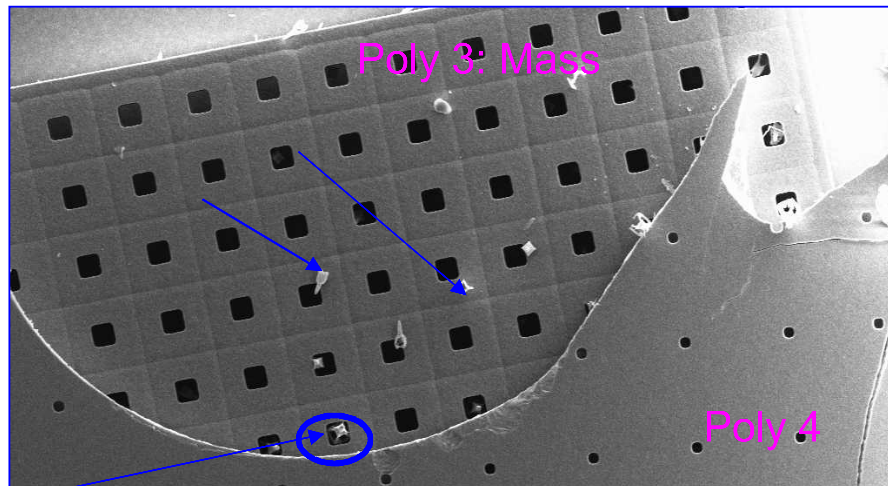
  -Si / Nitride bond strength good

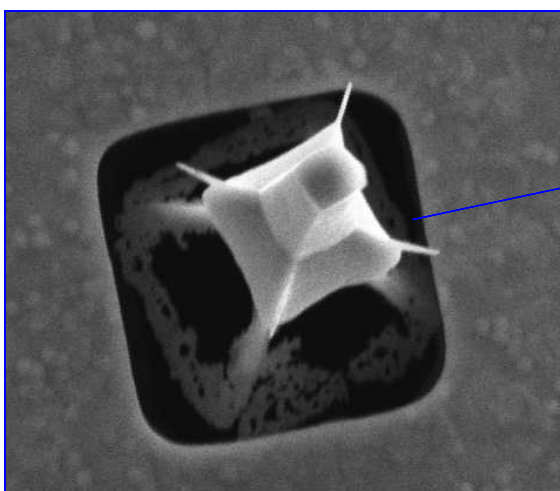
  -electrical isolation: tests not completed yet

MEMS Passive Shock Switch
Rev 3: Keyhole failure

Keyhole defect: SACOX 4 does not completely fill POLY 3 cut; then Poly 4 partially fills in leaving a stalactite



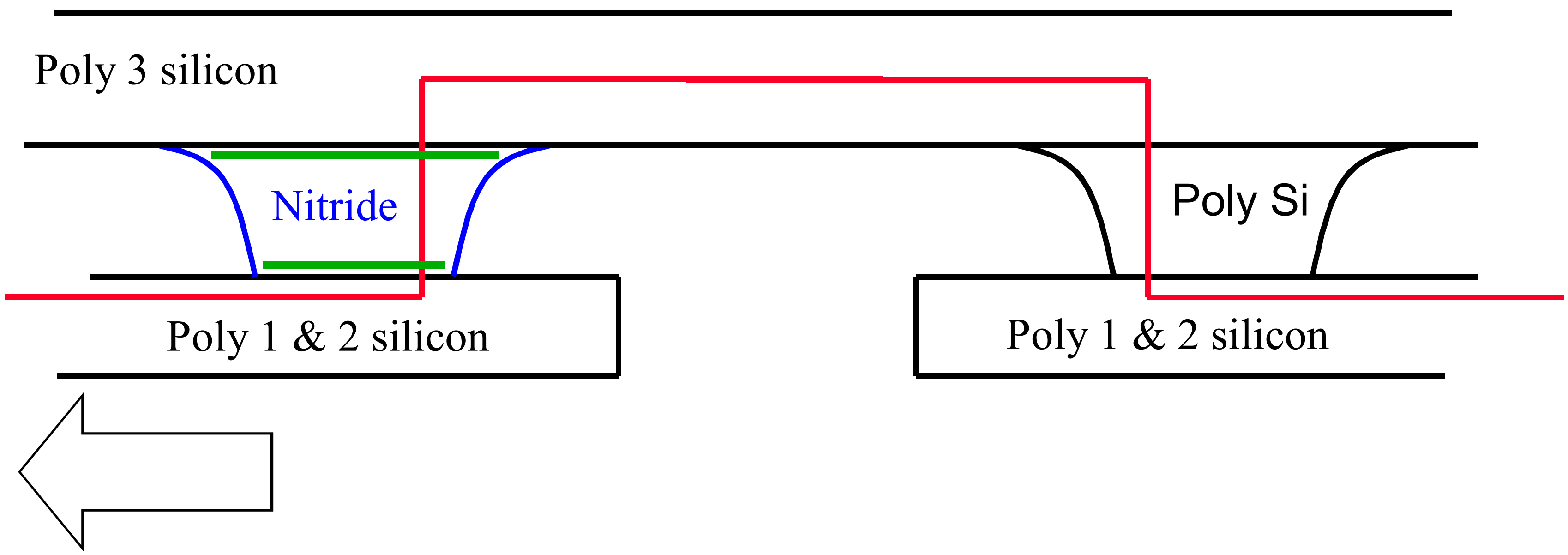




MEMS Passive Shock Switch
Rev 3: Nitride electrical isolation

Nitride: intended to block this current path

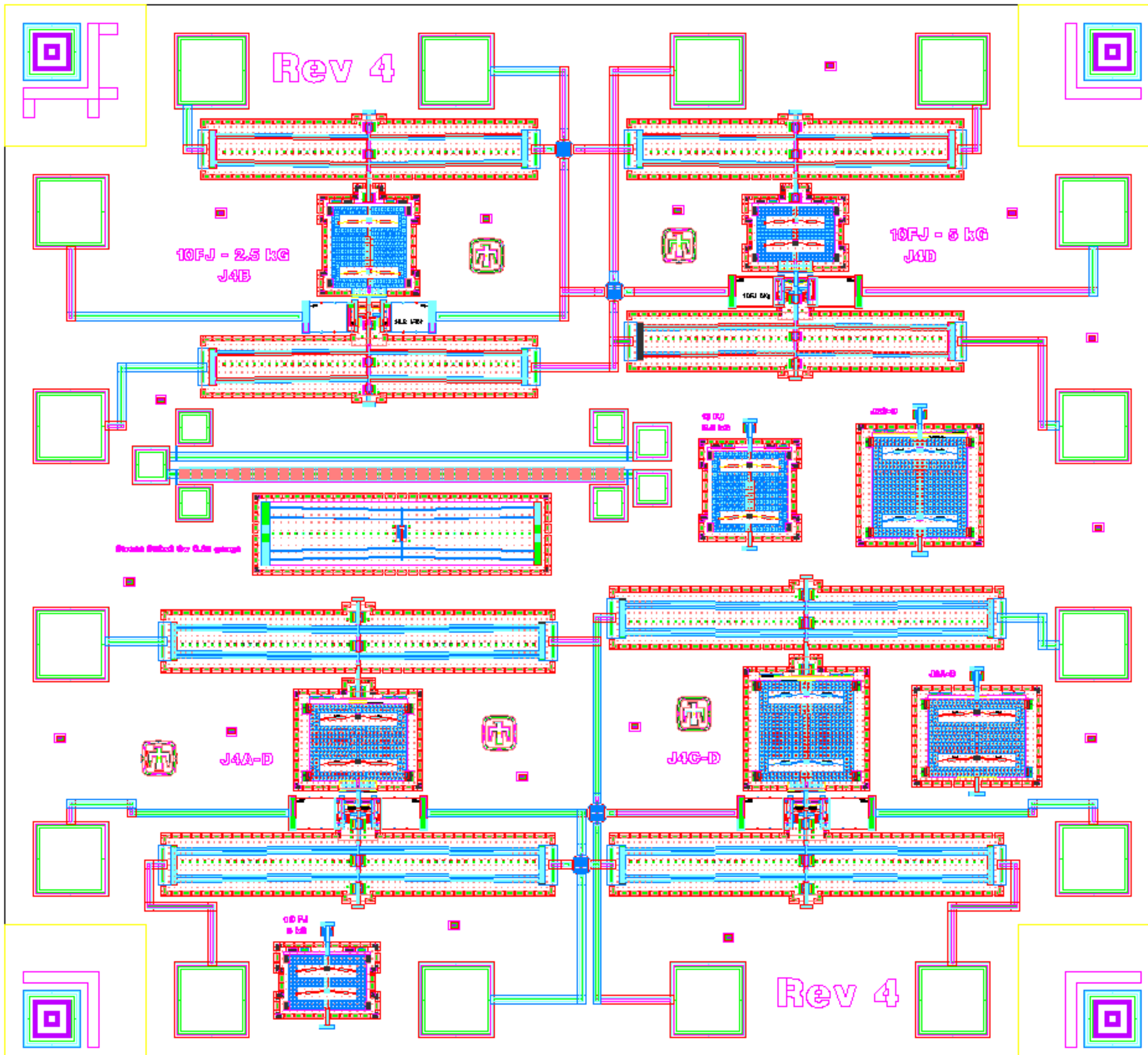
Strength of nitride/silicon interface needs to be good



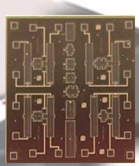
Refer to fusing/welding slide for understanding orientation

MEMS Passive Shock Switch

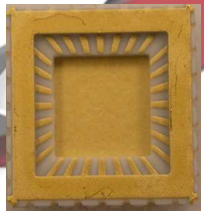
Rev 4: float contacts and remove poly 3 dimples



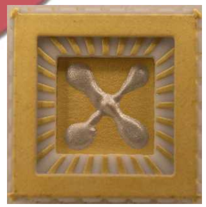
Rev 4



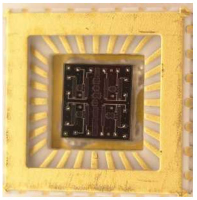
MEMS Die



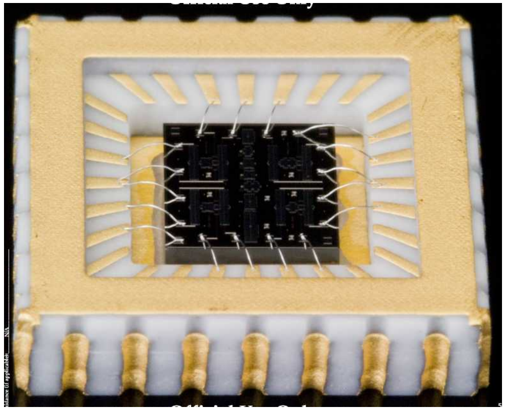
Hermetic Die Carrier



JM7000 Applied for Die Attach

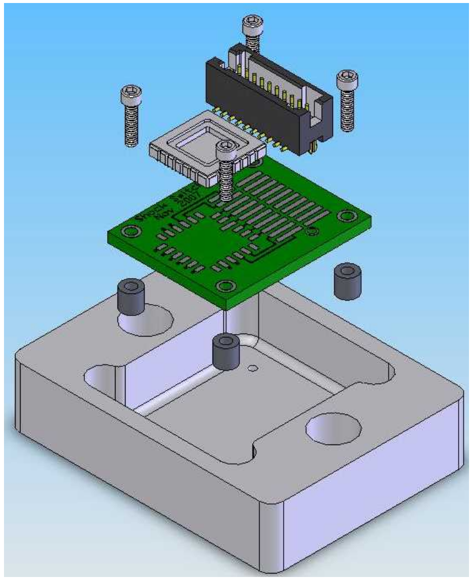


Die placement and attach (cure)

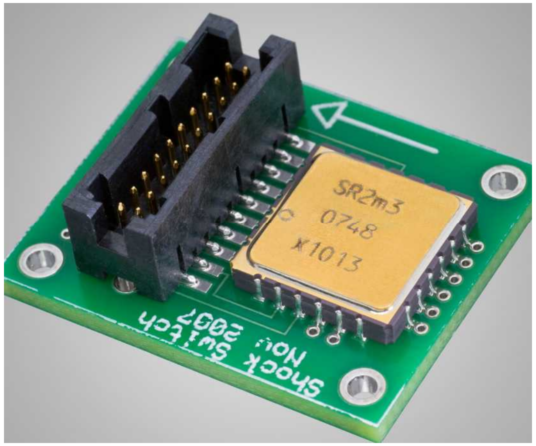


Wire bonding

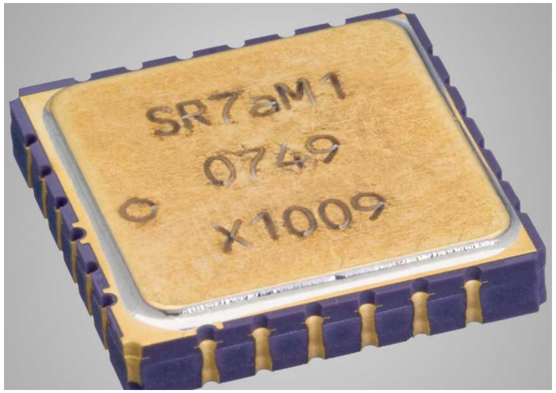
Packaging



Aluminum housing

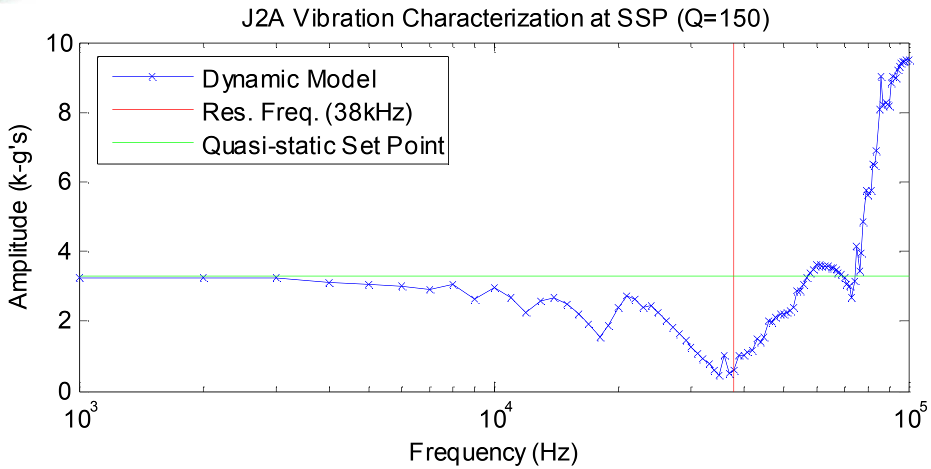


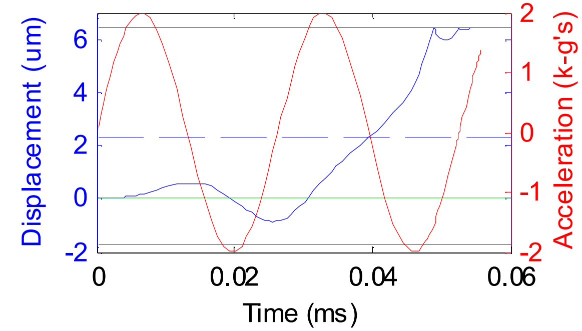
PCB, LCC, electrical connector



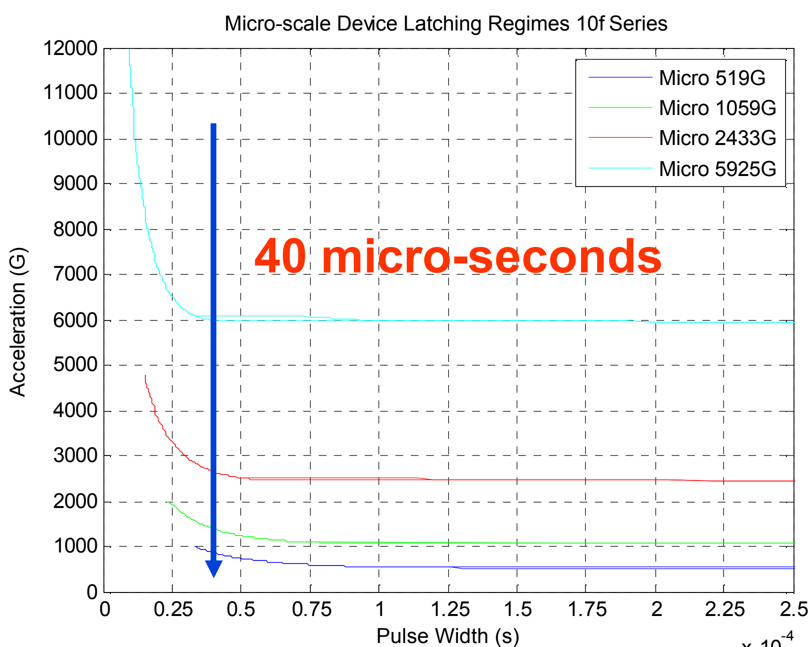
Hermetic package (lid seal)

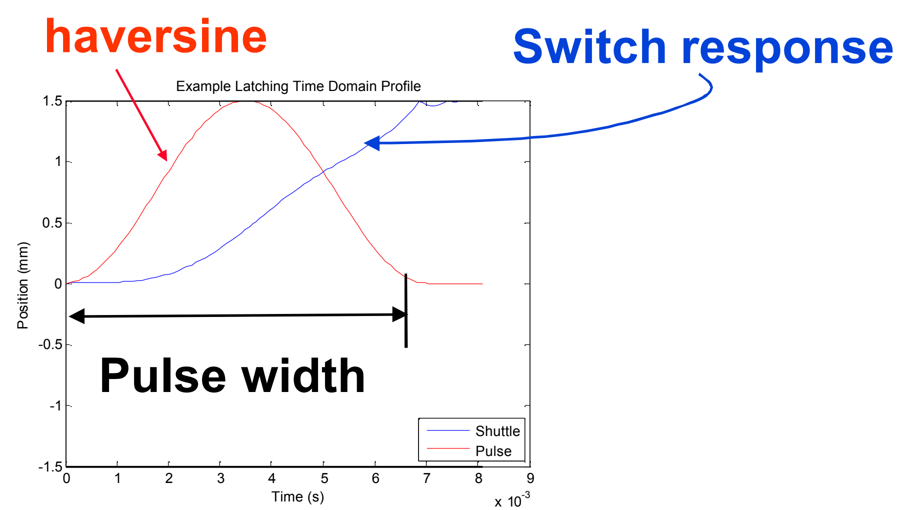
MEMS Passive Shock Switch
Modeling the dynamic response





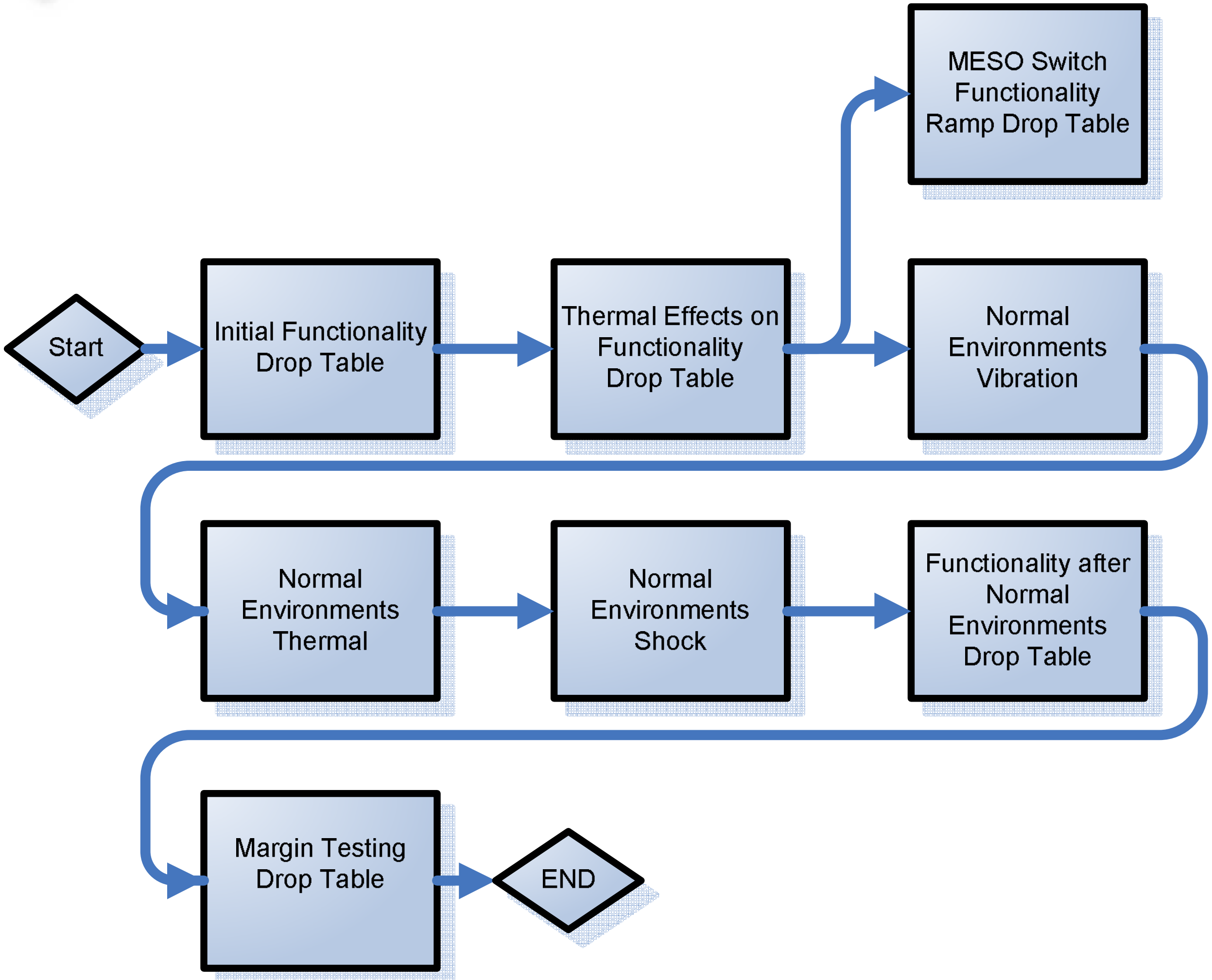
Frequency response: shock contains a broad band of frequency content – sensors are ultra-sensitive over particular frequency ranges and may close at shock levels lower than quasi-static set points

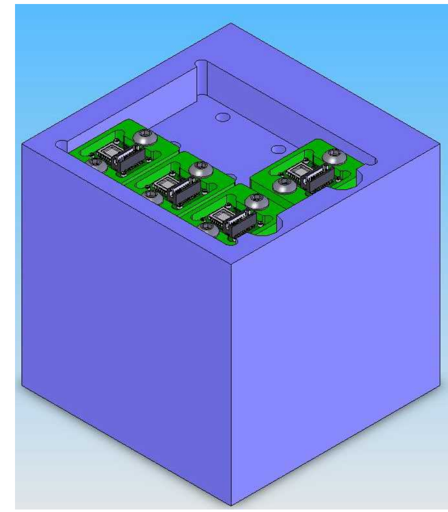


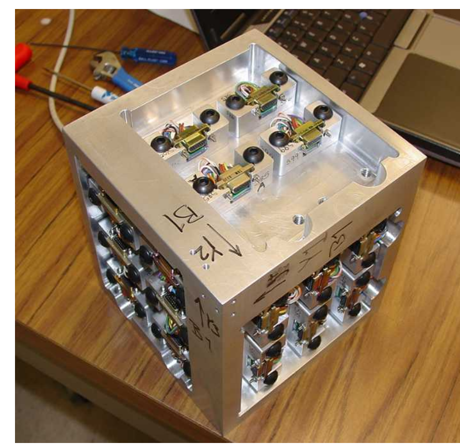


Sandia National Laboratories

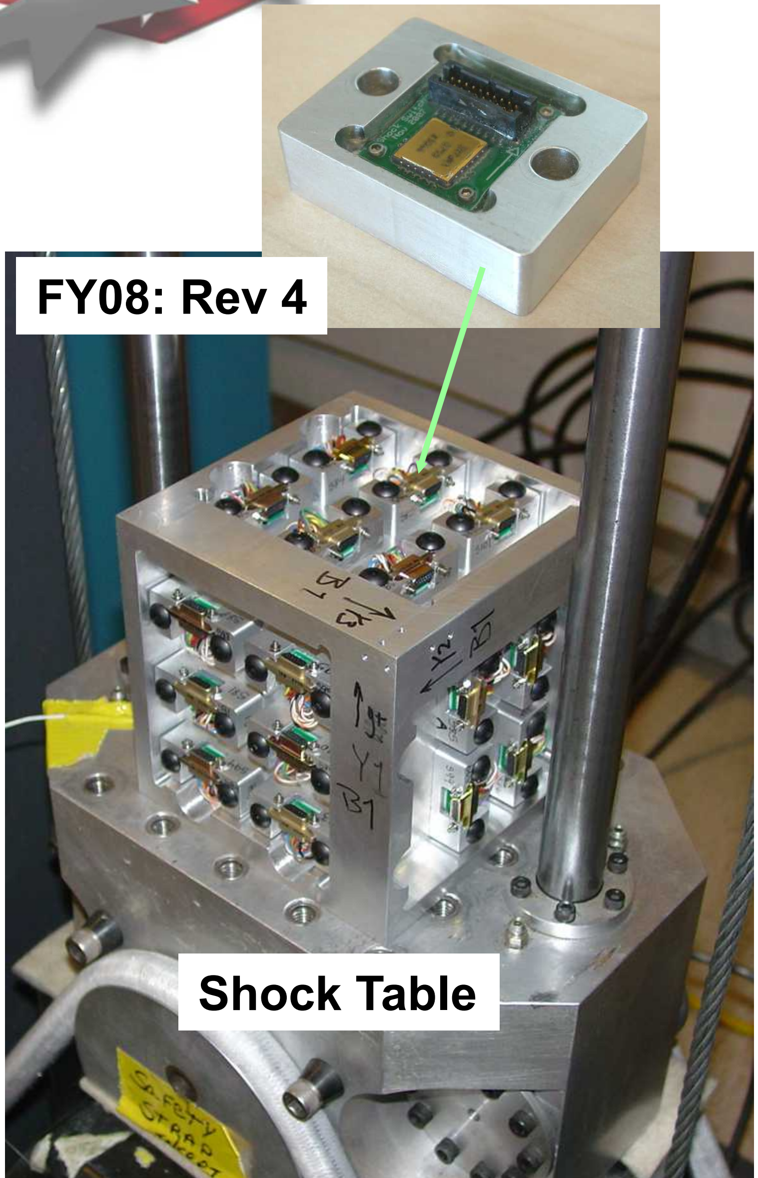
MEMS Passive Shock Switch
test plan/flow



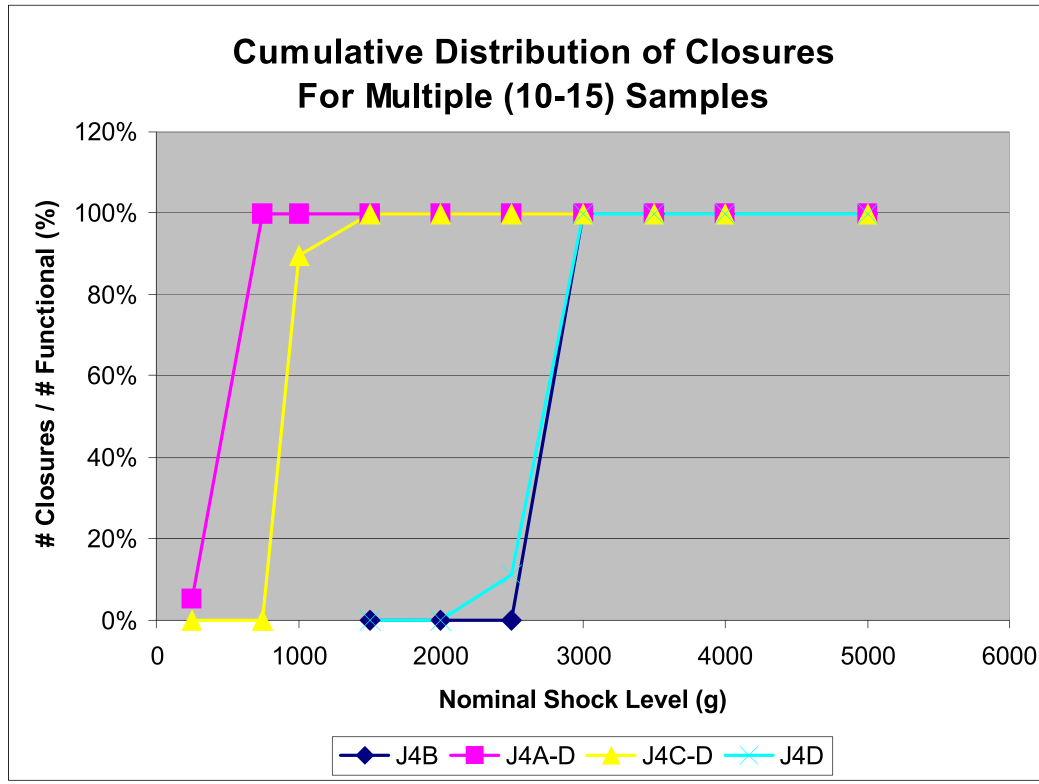




MEMS Passive Shock Switch
shock table testing



Results shown include using rubber isolation material to filter frequency content reaching switches



MEMS Passive Shock Switch
preliminary thermal environmental testing results

Functionality: Initial set of tests were run to check for survival

Rev 4 packaged devices were soaked for 1 hr at -70

-- 250g, 500g, 2500g, 2500g

-- 250g and 500g devices failed to operate (contact open/close) at -70F

-- All other devices self-tested normally

Rev 4 packages soaked for 1hr at 185F: drop table tests were run within 5 minutes to look for changes in set point

-- set points showed no change relative to ambient temperatures previously obtained

MEMS Passive Shock Switch
Conclusions

What is the MEMS passive shock sensor?

Passive, lower power, environmentally actuated, latching/un-latching

FY08 Status and activities

New die revisions; packaging prototypes; functional and environmental testing; modes of failure;