Radiation Effects in MEMS Devices

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Examples of MEMS Structures

Cantilevered Beams

Lateral Beams

- Capacitors in accelerometers

Deformable Membrane

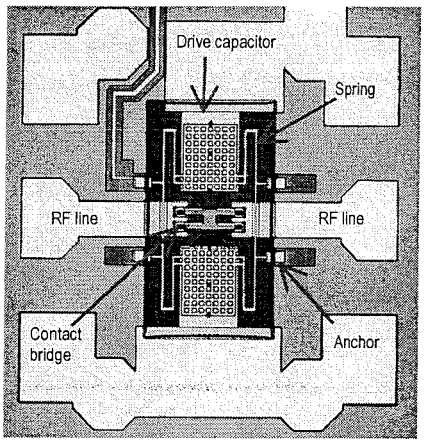
- Electrostatically driven
- Usually requires voltages above 50 V

Spring-Isolated Floating Contact

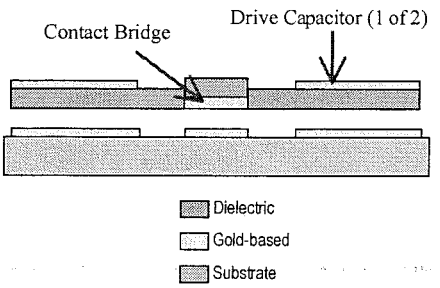
Technologies

- Bulk CMOS
- GaAs

Physical Diagram of RF MEMS Switch



Vertical-cut Cross Section Schematic



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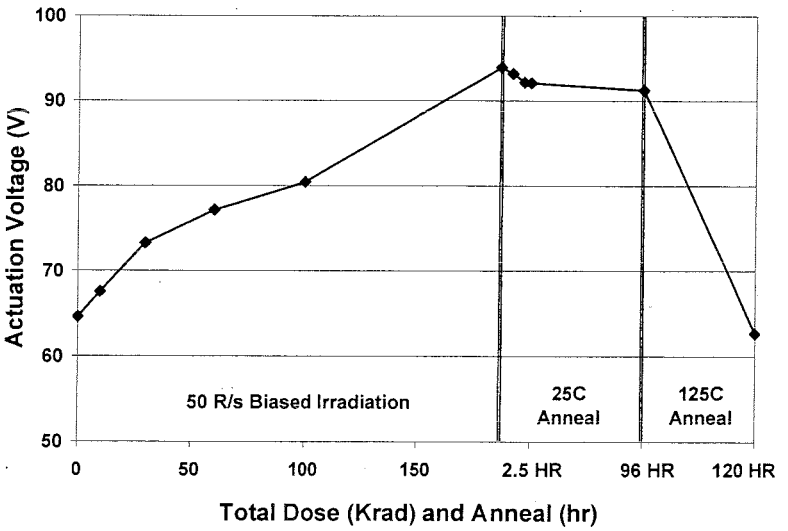
Effect of Total Dose on Actuation Voltage



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GaAs MEMS Switches

Measurements Were Straightforward

- Basically a mechanical switch with exotic transmission line

Specification Limit Exceeded at 30 krad

- Effect in basic MEMS structure
- Damage appeared stable at room temperature
- No supporting circuitry

Proton Tests Planned in May

Technical Paper Accepted for NSREC-02

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MEMS Radiation Testing

Measurements of Physical Properties Require Special Instrumentation

- Accelerometers: rotating fixture
- Deformable structures: special microscopes or interferometers to measure deflection

Need to Separate Degradation in CMOS or Other Support Circuitry from Effects in Basic MEMS Structures

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Deformable Mirrors

Manufactured by Boston Micromachines

Matrix of 144 Mirrors

- Adaptive optics applications
- Mirror properties depend on voltage (somewhat nonlinear)
- Maximum actuation voltage 240 V
- "Bare" device with no associated electronics

Testing Requires Precision Optical Measurements

- Stereo interferometric microscope to measure mirror deflections
- Resolves deflections of about 0. 02 nm

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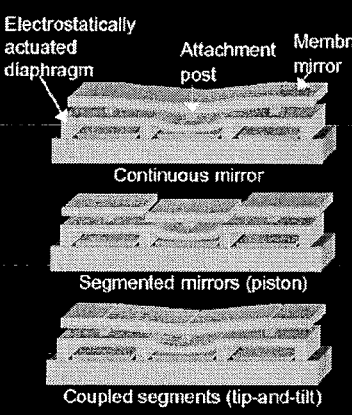
μDM

- **Fabrication:** Silicon micromachining (structural silicon and sacrificial oxide)
- **Actuation:** Electrostatic parallel plates, individual addressing of identical actuators in an array
- **Configuration:** 140 actuators (12 x 12 w/o corners), square grid, 300 μm spacing



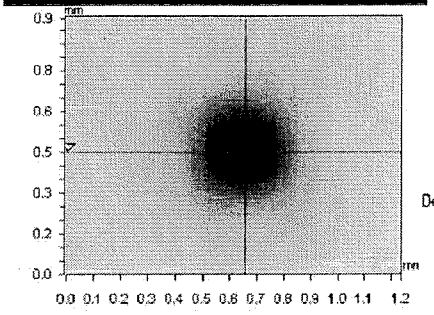
Cross sectional schematics of three μDM designs, each showing three actuators

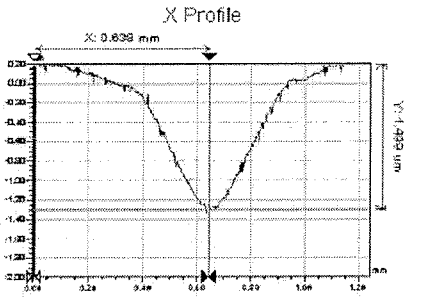
BMC
Boston Micromachines Corp.

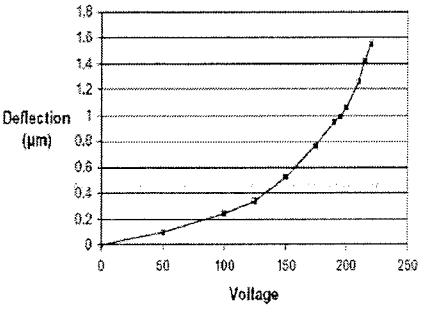
Mirror segment actuation

Influence function: 15%

Actuation limit: 2μm @ 240V







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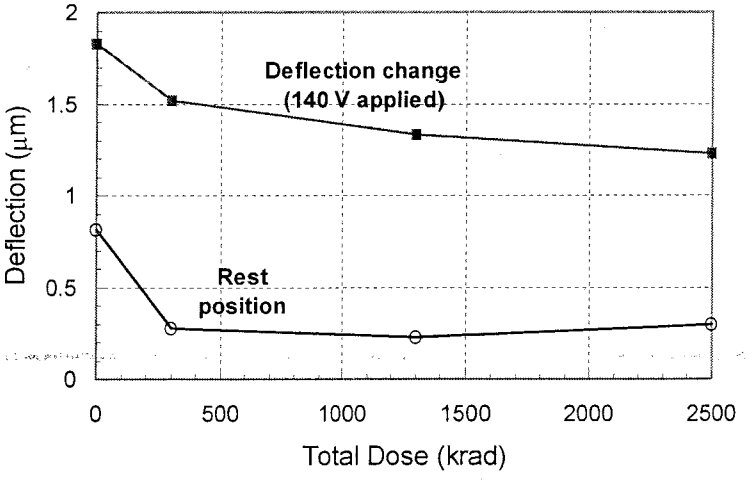
Initial Test Results



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Older Results for Commercial Accelerometers

Devices Failed at 25 krad(Si)

- "Stiction" in capacitor structure
- Temporary recovery once acceleration exceeded certain limit
- Reverted to stuck mode if power was removed
- Damage was stable over periods of several months

Other Factors

- Also observed change in voltage output
- Direction of change was opposite for proton and electron irradiation
- Attributed to secondary emission that created charge in capacitor beams
- Structure integrated into complex CMOS support circuitry

Technical Paper Published on Model for Charge Buildup

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Conclusions

Significant Changes in MEMS Structures Can Occur at Moderate Levels

- 10 – 100 krad
- Damage is usually stable with little or no annealing
- Changes appear to be caused by charge buildup in MEMS structures
- Protons and electrons sometimes cause different effects

Radiation Effects in Associated Electronics Can Also Be Important

MEMS Devices for Space

- Some commercial devices are useful (e.g., optical MEMS)
- Custom MEMS devices such as microgravitometers
  - MEMS technology is relatively inexpensive
  - Many possible sources of custom devices
  - Can be key components in instruments

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