MEMS Retard & Impact Sensors

Principal: Walter Maurer, NAWCWD China Lake

Contributors:
Dr. Daniel Jean, NSWC Indian Head
Ryan Knight, ARDEC
Objective

- Exploit existing MEMS microfabrication and packaging technologies to realize DoD retard and impact sensors with improved performance:
  - precision
  - reliability
  - producibility
  - cost effectiveness
Potential Payoff

- Improved G-sensor performance for existing & future fuzes including:
  - FMU-139 (impact sensor; retard sensor)
  - FMU-143 (impact sensor)
  - High Reliability Fuze (impact sensor)
  - Hardened freefall weapon fuzing applications
Traditional coilspring-mass technology:

- **Wider variability in performance than MEMS**
  - wire & coil dimensional tolerances
  - coil winding stresses & annealing

- **Difficult to precisely sense low G’s with “macro world” springs**
Newer MEMS-technology appears well-suited for making improved low-G sensors per DoD exploratory work to date:

- **ARDEC**: metal G-sensors and packaging
- **NSWCNIH**: silicon G-sensors and packaging
- **NAWCWD**: precision-electroplated G-sensors
Background (cont.)

Centrifuge Test of Low-G Sensor in 1G Increments
Technical Approach

- Modify existing NSWC and ARDEC sensor designs to duplicate performance of currently-fielded non-MEMS sensors
  - low-G impact sensors (<100G)
  - very low-G retard sensors (<5G)

- Fabrication
  - ARL (NSWC sensors); HT-Micro (ARDEC sensors)

- In-House Packaging & Testing
1st-Year Progress

Requirements obtained for bomb fuze sensors

- Retard sensor: 1.9G no-go, 2.3 all-go
- Impact sensor: 40G no-go, 80G all-go. Velocity change of 2 fps will cause closure.

Production Drawings of Retard Sensor (left) & Impact Switch

Impact Switch

Switch at rest

Response to Impact
NSWCIH Retard Sensor

- **Design layout completed**
  - Deep Reactive Ion Etching (DRIE)
  - Design variations: 1.5, 2.1, 3.0, 4.0, and 5.0 G
  - Unidirectional
  - In-plane contact switch
  - Chip size 5 x 5 mm

- **Simulation completed**
  - Spring deflection under a static load ($k = 0.139$ N/m)
**NSWCIH Impact Sensor**

- **Design layout completed**
  - Deep Reactive Ion Etching (DRIE)
  - Various closure levels to bracket target performance
  - Hemispherical contacts
    - 8 in-plane, 1 out-of-plane
  - Chip size 5 x 5 mm

- **Simulation nearly completed**
  - MATLAB-based dynamic modeling
ARDEC Retard Sensor

Preliminary modeling completed

- Metal MEMS design to be made by htmicro
- 2.1 G
- Size ~ 6 x 6 x 1 mm

Interior gold contact which only detects z-direction movements (will not detect rocking motion)

Anti-rotational features. Locks to keep proofmass from rotating
ARDEC Impact Sensor

➢ Preliminary modeling completed
  - Metal MEMS design to be made by
  - Size ~ 5 x 5 x 0.67 mm
  - Scaled version of successfully demonstrated 500G Impact Sensor
    • Over 100 data points collected with Mk19 40mm MEMS Integration fuze
    • Only two known failures
    • More data points to be collected in May 2010
Design Issues:

- Tends to make contact in a rocking/rolling mode (similar to contact that a spinning penny makes as its spinning dies down). Thus, squeeze-film air damping is not utilized very well.

- This rocking motion will make contact under considerably lower inertial forces due to the moment created, thus affecting closure threshold.
Other ARDEC Design Issues

- **Sensitivity to short duration impulses**
  - increasing surface area will increase squeeze film and Couette damping, thus increasing sensor’s g-seconds
  - Higher nitrogen pressure during packaging

- **Contact sticking**
  - increase sputtered-gold contact’s rhodium concentration

- **Gap dimensions**
  - ensure that spring remains in linear bending regime
  - must be large enough to prevent lockup
G-sensor basic requirements have been identified

1st-iteration sensors have been designed & modeled

Layouts are nearly ready for fabrication

Fab contracts/delivery orders are in place

Additional info to be obtained for existing sensors:
  - Resonance & response to orientation
  - Production/Acceptance test requirements, methods & data