MEMS Fuze-on-a-Chip

- Low-Cost Fuzes
- Scalable Production Process
- Enormous Silicon Manufacturing Infrastructure
Team

- Navy: Design, Prototype, Pilot Production
- Army: Explosive Train
- MicroAssembly/Laserlith: FEA, Packaging and Integration, Production
- Stresau Laboratory: Loading, Testing

Progress

- Low-Temperature Wafer Scale Packaging
- Fabrication Iterations of Navy S&A Design
- High-G Results of Navy S&A Design
MicroAssembly

- Operating since 1998
- Partnership
  - Navy S&A Design
  - Army EDF-11 Integration
  - Room-Temperature Hermetic Sealing Process Compatible with Energetic Materials
- Technology Transition
  - New MEMS Manufacturing Cleanroom
  - Loading and Packaging Facility for Volume Production
Outline

- Fabrication of Navy S&A Design
  - Packaging
  - Cost and Capacity
  - Manufacturing
  - Next Steps
# Fuze Approaches

<table>
<thead>
<tr>
<th>Approach</th>
<th>Safe &amp; Arm</th>
<th>Hermetic Packaging for Long Shelf Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>Watchmaker</td>
<td>One at a Time</td>
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<tr>
<td>Navy/MicroAssembly</td>
<td>COTS Silicon DRIE</td>
<td>Batch</td>
</tr>
<tr>
<td>Other Approaches</td>
<td>LIGA Multilayer Metal</td>
<td>One at a Time</td>
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</tbody>
</table>
Navy Design << $30
- Enabler: COTS Deep Reactive Ion Etcher (DRIE)
- Driver: MEMS Gyroscopes

Industry Base
- At Least 1 COTS DRIE Etcher per Foundry
- Team Owns 2 Etchers

MEMS Gyroscopes
- Millions of Units per Year
- Cell phones, Automotive Stability
- InvenSense, Seiko Epson, STMicroelectronics, Analog Devices
Key Milestone

- Hermetically Packaged MEMS S&A With Scalable Packaging Process
3 Chip Architecture

- Top Lid
- MEMS S&A
- Bottom Lid
- Fully Packaged Fuze Device
Key Milestone 2

- Small Business Gun Test
Outline

- Fabrication of Navy S&A Design
- Packaging
  - Cost and Capacity
  - Manufacturing Facility
  - Next Steps
Low Cost Wafer Level Package

- Packaging is Expensive
  - Each Part Must Undergo Many Steps

- Unique Capability
  - Compatible with Energetic Materials
  - One Hundred Steps Instead of Tens of Thousands
  - Yield >90%: Reduce Cost by >10X

Conventional One-at-a-Time  vs  Our Solution: Thousands-at-a Time
2-Substrate MEMS Process

- Used in Many Device Designs
  - >90% Yield
  - Integrated Hermetic Packaging
  - Eliminates >80% of Production Cost
Wafer-Level Packaged Yield

- **Initial Application: RF MEMS Switch**

<table>
<thead>
<tr>
<th></th>
<th>Initial Run</th>
<th>Second Run*</th>
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</thead>
<tbody>
<tr>
<td># of Working Devices</td>
<td>98</td>
<td>117</td>
</tr>
<tr>
<td>Total # of Devices</td>
<td>192</td>
<td>136</td>
</tr>
<tr>
<td>Overall Yield*</td>
<td>51%</td>
<td>86%</td>
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</table>

*Process improvements were made and a second run was performed 3 months after the initial run.*
### Hermetic Packaging Yield

<table>
<thead>
<tr>
<th># of Hermetic Packages</th>
<th>45</th>
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<tbody>
<tr>
<td>Total # of Packages</td>
<td>50</td>
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<tr>
<td>Yield</td>
<td>90%</td>
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</tbody>
</table>
Outline

- Fabrication of Navy S&A Design
- Packaging
- **Cost and Capacity**
- Manufacturing Facility
- Next Steps
Navy Cost Estimate
- 500 Wafers per Year
- 6” Wafer Size (MEMS Fab)
- Small Scale Production
- Goal: $30 each
Capacity

• 4” Pilot Line Q4 2010 – 45,000/year
  – 3 Wafers/Day (1 shift)
  – 300 Days/Yr
  – 250 Devices/Wafer (4” wafers)

• Simple 6” Manufacturing Line: 675,000/year
  – 9 Wafers/Day (3 shifts)
  – 300 Days/Yr
  – 250 Devices/Wafer (6” wafers)
  – Wafer bonder needs to be upgraded to 6”
Outline

- Fabrication of Navy S&A Design
- Packaging
- Cost and Capacity
- **Manufacturing Facility**
- Next Steps
MEMS Production Cleanroom

- **Cleanroom Qualified**

- **Equipment Set**
  - DRIE Etch (4”, 6”)
  - Metallization (4”, 6”)
  - Lithography (4”, 6”)
  - Resist Coating (4”, 6”)
  - Resist Developing (4”, 6”)
  - Wafer Bonding (4”): 6” to be built
  - Dicing (4” and 6”)

![Cleanroom Equipment Images]
Outline

- Fabrication of Navy S&A Design
- Packaging
- Cost and Capacity
- Manufacturing Facility

**Next Steps**
Next Steps

- Low Cost Scalable Production
  - Wafer-Scale 6” Ramp-Up

- Fuze Development
  - DoD Gun Tests
  - Explosive Train and Flyer
  - Battery/Power, G-Sensors, Control, …