Use of Conductive Adhesive in Fuze Applications

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Outline

• Background and motivation.
• Conductive adhesive.
• Experiments.
• Characterization.
• Conclusion.
Background and motivation

- The electronic components in a fuze are exposed to severe mechanical forces during firing.

- For 30 mm ammunition, setback acceleration exceeds 60,000 g and the centripetal acceleration is 9000 g/mm out of center.

- In 30 mm ammunition, the electronic components should not occupy more than 1-3 cm³.
Mounting of MEMS to PCB

- It is advantageous to mount the MEMS chip directly to PCB omitting extra packaging level. This will require less space and cost saving is possible.
- Using wire bonding for direct contact between MEMS and PCB is not a favorable option.
- Using isotropic conductive adhesive (ICA) for interconnection between MEMS and PCB could be a possibility. However, performance of ICA in this demanding environment must be investigated.
Isotropic Conductive Adhesive

- ICA has been used for electronic packaging and interconnect for several decades.

- Composite material
  - Adhesive resin
  - Conductive material

- Silver particles are commonly used as conductive material.

- Common problem is brittleness due to CTE mismatch between filler and metal particles.
ICA based on metallized polymer spheres

• Replace e.g. silver flakes with highly uniform metallized polymer spheres.

• Size of the polymer spheres can be custom tailored.

• Different core material can be used:
  - Optimization of Tg.
  - Match the CTE to the adhesive matrix.
  - Mechanical energy absorption.

• Noble metals may be used for metallization at relatively low cost.
Test structures and test boards

- MEMS test structures for interconnect testing were designed and fabricated on the same SOI wafers as the real MEMS devices.
- Board used for temperature cycling test. Contains daisy-chain structures and structures for Kelvin measurement of contact resistances.
- Board used for firing tests contains 2 test structures and 4 pcs of 0402 resistances on each side. Kelvin measurement of contact resistances before and after firing test.

Size: 9X16 mm²
Stencile printing of ICA

- Used ICA with different sized polymer spheres.
  - 30 µm : silver coated (ICA-A).
  - 4 µm : gold coated (ICA-B).

- ~50% volume fraction of spheres is used.

- Printing results dependent upon many factors such as:
  - Viscosity
  - Shear thinning
  - Stencil +++
Experiments

• Temperature test between -46°C and +70°C. Compare performance of ICA-A adhesive vs. H20, a commercially available isotropic conductive adhesive.

• Temperature cycling test according to MIL-STD-883 G method 1010.8 test condition B (-55°C - 125°C).
  – 10 cycles
  – 100 cycles

• Vibration tests.

• Recovery firing tests. Temperature cycled samples were used in this experiment.
Comparison: ICA-A vs H20

• H20 is a silver epoxy based adhesive. The test structures were mounted by a commercial supplier.

• ICA-A adhesive consists of 30 µm silver coated polymer spheres and EPO_TEK®353ND.

• Initial values for contact resistances:

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>R average (Ω)</th>
<th>Rmax (Ω)</th>
<th>Rmin (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-20</td>
<td>0.061</td>
<td>0.098</td>
<td>0.048</td>
</tr>
<tr>
<td>ICA-A</td>
<td>0.549</td>
<td>1.394</td>
<td>0.182</td>
</tr>
</tbody>
</table>
Temperature performance: ICA-A vs H20

- H20: 14 of 23 CR passed 100 temperature cycles (60%).
Temperature tests

- Temperature cycling test according to MIL-STD-883 G method 1010.8 test condition B (-55°C - 125°C).
- No underfill on the test structures
- No resistances failed for the I-100 test structures.

<table>
<thead>
<tr>
<th>ICA with</th>
<th>No of cycles</th>
<th>Ω before</th>
<th>Ω after</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICA-A (30µm silver spheres)</td>
<td>10</td>
<td>0.317</td>
<td>0.366</td>
<td>15.5</td>
</tr>
<tr>
<td>ICA-B (4 µm gold spheres)</td>
<td>10</td>
<td>0.091</td>
<td>0.079</td>
<td>-13.2</td>
</tr>
<tr>
<td>ICA-A</td>
<td>100</td>
<td>0.361</td>
<td>0.675</td>
<td>87</td>
</tr>
<tr>
<td>ICA-B</td>
<td>100</td>
<td>0.112</td>
<td>0.217</td>
<td>93.7</td>
</tr>
</tbody>
</table>
Vibration test

- Simulated transport vibration on tracked vehicle. Used acceleration spectral density from CV90 armoured combat vehicle.
- 1 hour test in each direction.
- Test structure mounted with ICA-A performed well.
Firing test
Firing test results

- All fired test structures have been exposed to temperature tests.
- 31 out of 36 contact resistances passed recovery firing test.
- Two test structures without underfill cracked.

<table>
<thead>
<tr>
<th>ICA with</th>
<th>μ before</th>
<th>μ after</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICA-A</td>
<td>0.224</td>
<td>0.205</td>
<td>-8.5</td>
</tr>
<tr>
<td>ICA-B</td>
<td>0.082</td>
<td>0.097</td>
<td>18.3</td>
</tr>
<tr>
<td>ICA-A</td>
<td>0.675</td>
<td>0.733</td>
<td>8.6</td>
</tr>
<tr>
<td>ICA-B</td>
<td>0.217</td>
<td>0.257</td>
<td>18.4</td>
</tr>
</tbody>
</table>
Cross sections
Conclusion

• ICA based on highly uniform metal coated polymer spheres seems to be a viable technology for mounting MEMS devices directly to PCB.

• Using this ICA technology may give higher packaging densities and reduced cost in future fuze applications. However, the stencil printing process must be improved.
Acknowledgement

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About the partners

- More information about the Norwegian Defence Research Establishment (FFI), Conpart and Sintef ICT can be found here:

  - FFI: [www.ffi.no](http://www.ffi.no)
  - Conpart: [www.conpart.no](http://www.conpart.no)
  - Sintef ICT: [www.sintef.no](http://www.sintef.no)