The Effect of Plating, Surface Finish, and Bond Line Thickness on AuSn Solder Joints

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Spectra-Mat, Inc
A Member of
SAES® Getters Group
Agenda

- About Spectra-Mat
- Rationale
- AuSn Methods and Applications
- Experimental Matrix
- Procedures
- Results
- Discussion
- Plans
Spectra-Mat (SMI) History

- SMI, spun off from Varian in 1963, is a wholly owned subsidiary of SAES Getters USA (2008)
- 2 facilities totaling 26,000 square foot facility in Watsonville, CA, 40 miles south of San Jose (Monterey Bay area)
- For nearly 50 years our material technology solutions have been contributing to innovation in:
  - Microwave Power tubes
  - Flash/Arc Lamps and Ion Lasers
  - Medical/Oncology Therapy
  - Thermal Management in microelectronics
  - Wafer Ion Implantation
SMI offers solutions to thermal management

For the device packaging business:

- Mo/Cu and W/Cu are used for CTE-matched heat spreading substrates with good TC for power semiconductor devices
- We make to order custom designs, but we also have a few simple standard designs available.
  - We can provide various compositions to match different CTE, but 90% of our market specifies W/Cu 90/10 weight %
- We plate Au over Ni and also vacuum coat AuSn to order
SMI Material advantage: microstructure comparison

*SEM top, optical bottom. Polished, etched surfaces.*

SMI’s microstructure is more consistent.

SMI W/Cu  

Comparison W/Cu
Typical thermal management components
AuSn Solder for CTE-matched assemblies

Gold-Tin solder is used on W/Cu and Mo/Cu by many high power laser and rf device manufacturers.
Some use preforms (foils) and others, vacuum deposited thin films of the solder.
Spectra-Mat has developed high performance thin film AuSn products, in collaboration with our parent company's central R&D laboratory near Milan, Italy and with key service suppliers.
We can provide almost any heatsink configuration with AuSn applied, either eutectic or tin-rich formulation.

(..........but we don’t do die attach)
Rationale for this work

- SMI receives RFQ’s for many different parts, with different surface finish and plating requirements.
  - High purity, solderable Au, (specifications MIL-C-45204D or ASTM B 488)
  - Thickness requested varies from 0.25 micron to 3+ micron.
  - About half request electroless Ni (NiP) per MIL-C-26074 or ASTM B 733
  - The rest request “pure” Ni, electrolytically applied (QQ-N-290 or ASTM B 689) (1-10 microns)

- Some fraction of these require vacuum-deposited thin film AuSn.
  - Almost every customer has a different “metallization stack”, with adhesion and barrier layers, different AuSn thickness, and different AuSn compositions specified.

Two questions became important to us:

1. Can we help give design guidelines for better soldering?
2. Can our processes affect the AuSn joint quality?
Experimental Matrix Plan 1

- **Inputs:** things SMI could control:
  - Au thickness
  - Ni type
  - AuSn thickness and composition
  - Surface finish
  - Thermal history
  - Load

- **Outputs:** things SMI could measure:
  - Bond strength
  - Electrical resistance
  - AuSn interface
  - NOT very easily:
    - Reliability
    - Thermal resistance
    - Residual stress
    - Device function
## Experimental Matrix Plan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au</td>
<td>0.15</td>
<td>0.5</td>
<td>1</td>
<td>microns</td>
</tr>
<tr>
<td>Ni</td>
<td>electroless</td>
<td>electrolytic</td>
<td>category</td>
<td></td>
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<tr>
<td>AuSn Comp</td>
<td>75/25</td>
<td></td>
<td>80/20</td>
<td>Wt% ratio</td>
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<tr>
<td>AuSn Thick</td>
<td>2</td>
<td>5</td>
<td>&gt;10</td>
<td>microns</td>
</tr>
<tr>
<td>Surface Roughness</td>
<td>0.2</td>
<td>0.4</td>
<td>0.8</td>
<td>Ra, microns</td>
</tr>
<tr>
<td>Post Thermal Treat</td>
<td>None</td>
<td>120C/2hr</td>
<td>200C/12hr</td>
<td>time/temp</td>
</tr>
<tr>
<td>Load (applied pressure)</td>
<td>0.01 (15)</td>
<td>0.03 (40)</td>
<td>Kg/mm² (PSI)</td>
<td></td>
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Actual Experiments, this phase

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This phase of work was primarily intended as method validation.
Experimental Outline

Sample Preparation
- Manufacture and lap Mo/Cu and W/Cu to desired finish
- Cut to dimensions
- Electroplate Ni, then Au
- Special cleaning/surface prep
- Sputter coat AuSn over desired stack
- Bond lap joints under forming gas
  - target ~2mm²
- Clean samples acetone, nitric acid
- Place AuSn to Au
  - (add 25 micron preform)
- Apply pressure w/deadweight
- Ramp ~3 °C/sec to 310 °C
- Hold 45 seconds
- Cool ~ 1°C/sec

Sample Testing- Resistance
- 5 samples at each experiment
- Clamp sample in four point probe 2mm length (very close to joint)
- Test resistance at 10 A driven
- Test controls (same material, same sampling length)
- Repeat each sample 5 times (refixture)

Sample Testing- Bond Strength
- Miniature lap joint shear
- Clamp carefully in custom jaws
- Manual tension by lever
- Readout force max at break

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RaMP San Diego April 9, 2014
Typical bond lines from this process

5 micron thin film AuSn high applied pressure (0.03 kg/mm²)

25 micron AuSn preform high applied pressure (0.03 kg/mm²)

Bond line ~ 4 microns

Bond line ~ 7 microns
Example of a test part melting (no load)

An AuSn preform is also in place
Joint strength, Kgf to fail in lap shear test. The low applied pressure bonded joints had several fails at ~0. 3 to 5 parts each.
Electrical resistance across the joint. Controls are parts from same batch not bonded. 5 measurements each on 5 parts. The difference between the control and the samples can be considered the joint resistance.
Bond Area Issues Revealed

Breakage is ~all cohesive on higher pressure joins. On lower applied pressure, pull-away occurs and actual bond area is not close to the nominal contact area.

High P thin film

High P thick preform

Low P thin film

Low P thick preform
Conclusions

- The methods appear promising to evaluate AuSn joints both destructively and non-destructively.
- Joints do have measurable resistance when bulk material subtracted.
  - Value is about 12 micro-ohms/mm² for high pressure bonding and 24 micro-ohms/mm² for low pressure bonding. (based on nominal area)
- A sympathetic eye would be persuaded that we were able to show that joint resistance was lowest at higher applied pressure
  - 50/50 chance a statistician would be persuaded.
  - More precise fixturing during bonding would probably help.
  - Simply, we need to use higher pressure to eliminate that variable
- Thin or thick bond line (thin film vs. preform) gave ~ same resistance.
- Break force for the low pressure joining case was much lower (more than half the parts broke in set up). Higher applied pressure was better.
Future Plans

- We will investigate the other parameters as proposed and include Mo/Cu in the evaluation.
- Bonding parameters need to be optimized to do the material tests we envision.
- The test parts should be redesigned, one design to minimize bulk contribution and maximize joint contribution for conductivity test, and another for larger contact area for the strength test.
- We will then try to generate more of this type of data to improve internal processes and also materials recommendations we make to our customers.
References


Thank you for your attention

www.saesgroup.com