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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

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Agenda

- About Spectra-Mat
- Rationale
- AuSn Methods and Applications
- Experimental Matrix
- Procedures
- Results
- Discussion
- Plans

Spectra-Mat (SMI) History

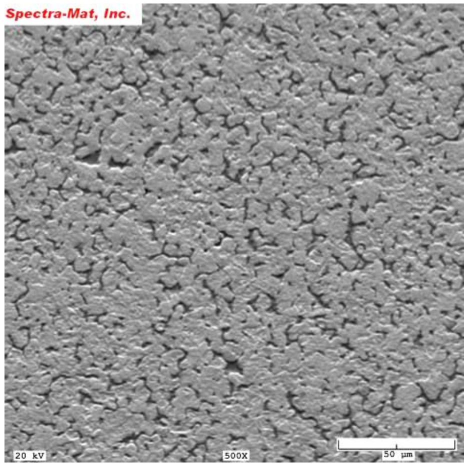
- SMI, spun off from Varian in 1963, is a wholly owned subsidiary of SAES Getters USA (2008)
- 2 facilities totaling 26,000 square foot facility in Watsonville, CA, 40 miles south of San Jose (Monterey Bay area)
- For nearly 50 years our material technology solutions have been contributing to innovation 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:

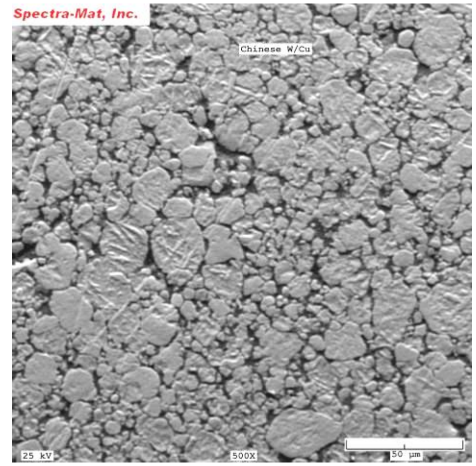
- Mo/Cu and W/Cu are used for CTE-matched heat spreading substrates with good TC for power semiconductor devices
- We make to order custom designs, but we also have a few simple standard designs available.
  - We can provide various compositions to match different CTE, but 90% of our market specifies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

SMI Material advantage: microstructure comparison



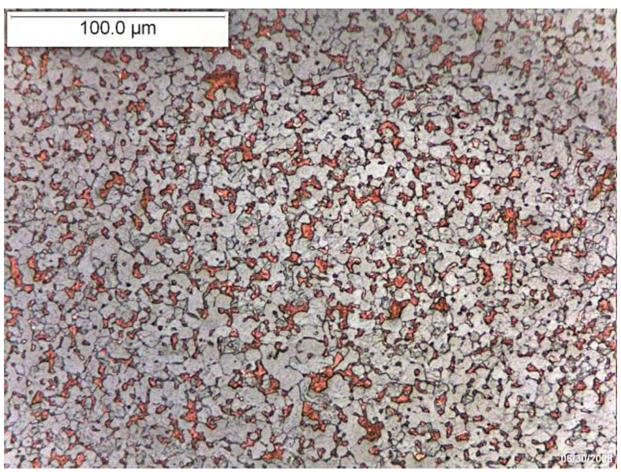
SEM top, optical bottom. Polished, etched surfaces.

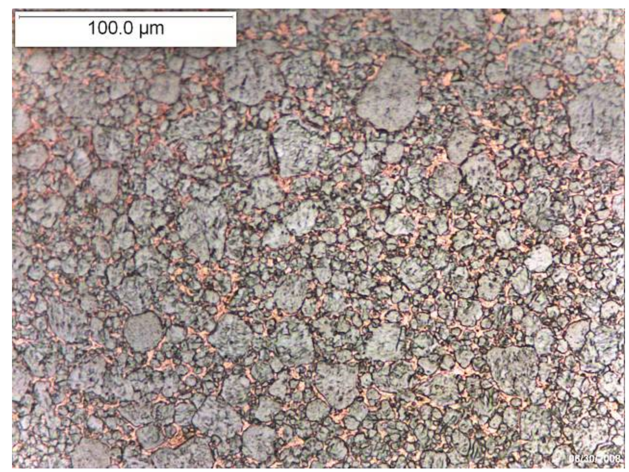
SMI's microstructure is more consistent.



SMI W/Cu

Comparison W/Cu





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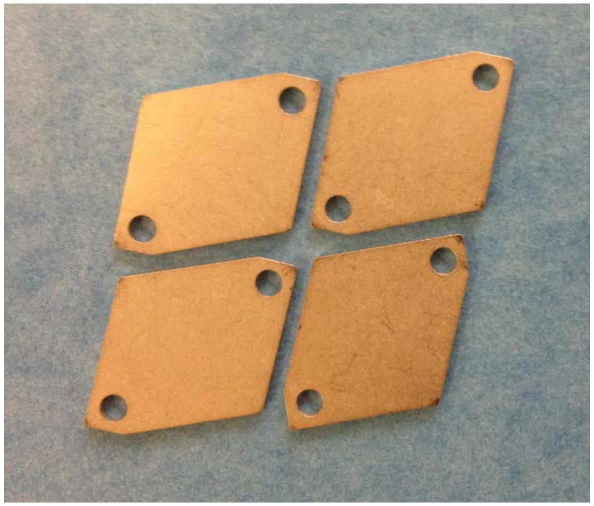
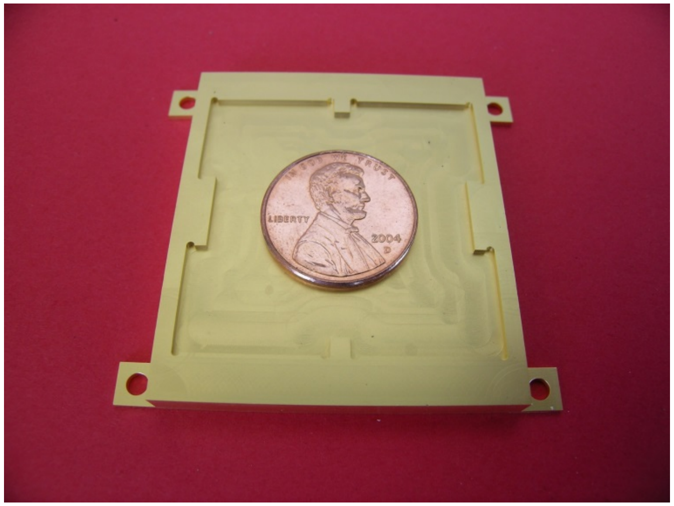
Typical thermal management components





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

Parameter	Low	Mid	High	Units
Au	0.15	0.5	1	microns
Ni	electroless		electrolytic	category
AuSn Comp	75/25		80/20	Wt% ratio
AuSn Thick	2	5	>10	microns
Surface Roughness	0.2	0.4	0.8	Ra, microns
Post Thermal Treat	None	120C/2hr	200C/12hr	time/temp
Load (applied pressure)	0.01 (15)		0.03 (40)	Kg/mm^2 (PSI)

Actual Experiments, this phase

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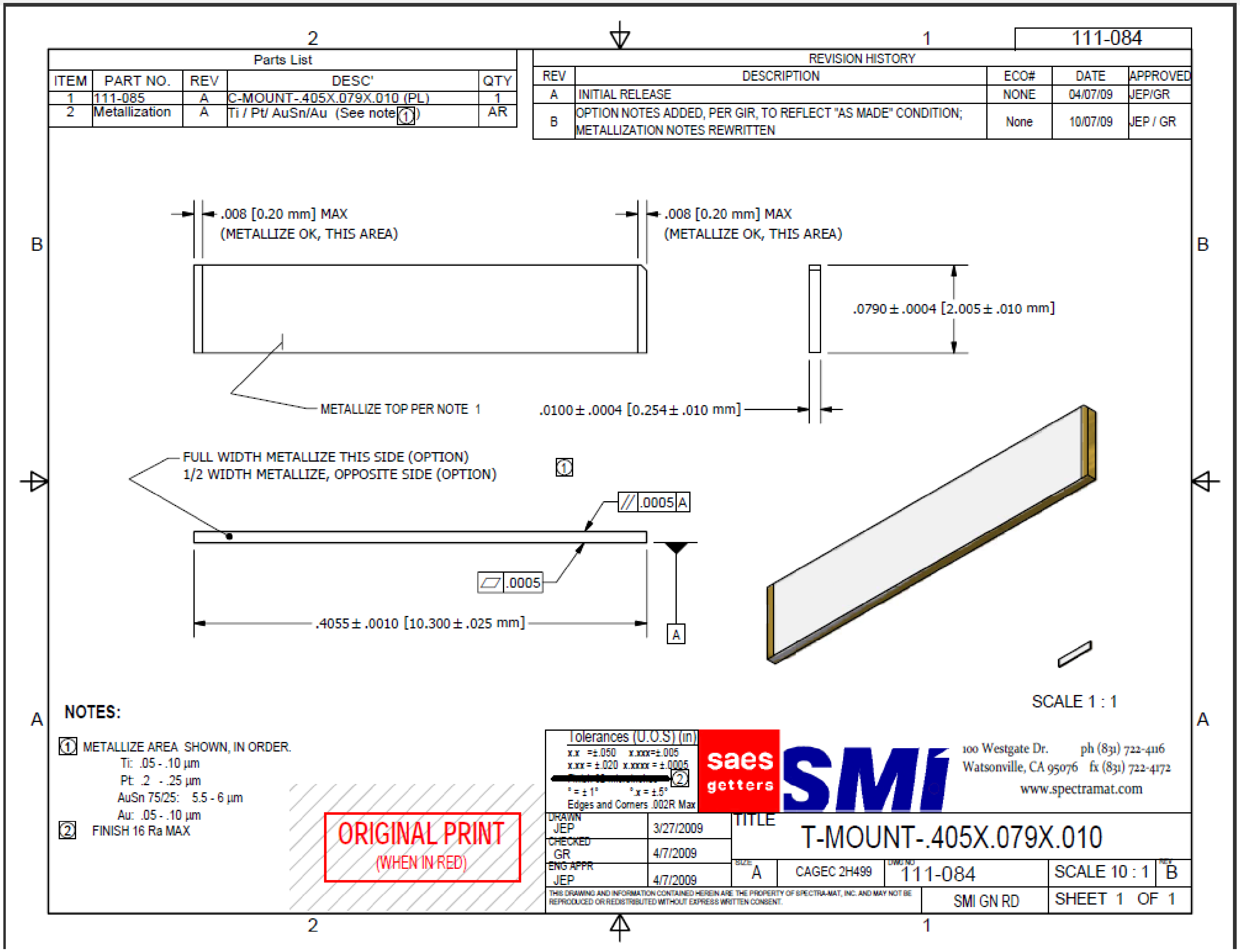
This phase of work was primarily intended as method validation.

Test Pieces Schematic



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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 ~2mm^2
- 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

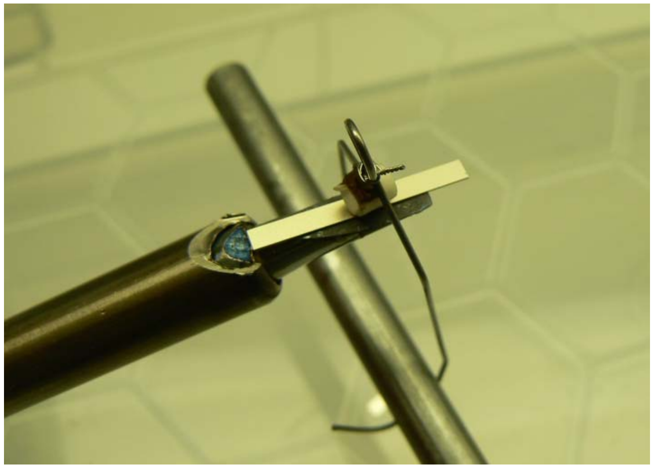
Sample Testing- Resistance

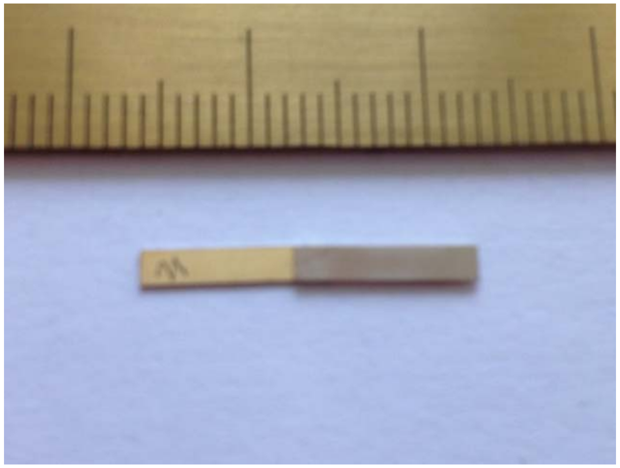
- 5 samples at each experiment
- Clamp sample in four point probe 2mm length (very close to joint)
- Test resistance at 10 A driven
- Test controls (same material, same sampling length)
- Repeat each sample 5 times (re-fixture)

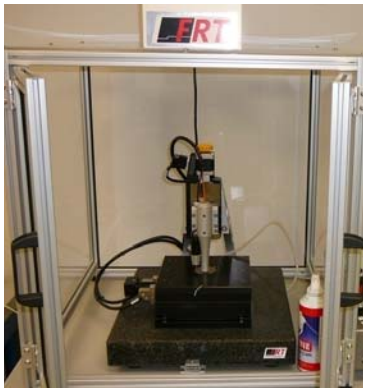
Sample Testing- Bond Strength

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

Experimental setup pictures

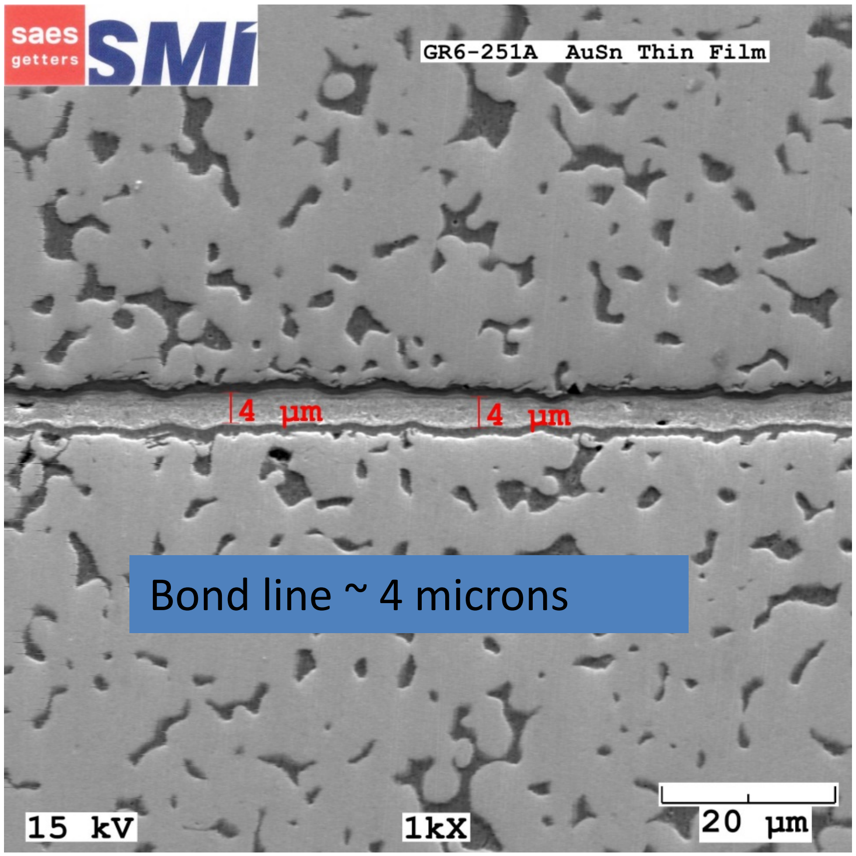




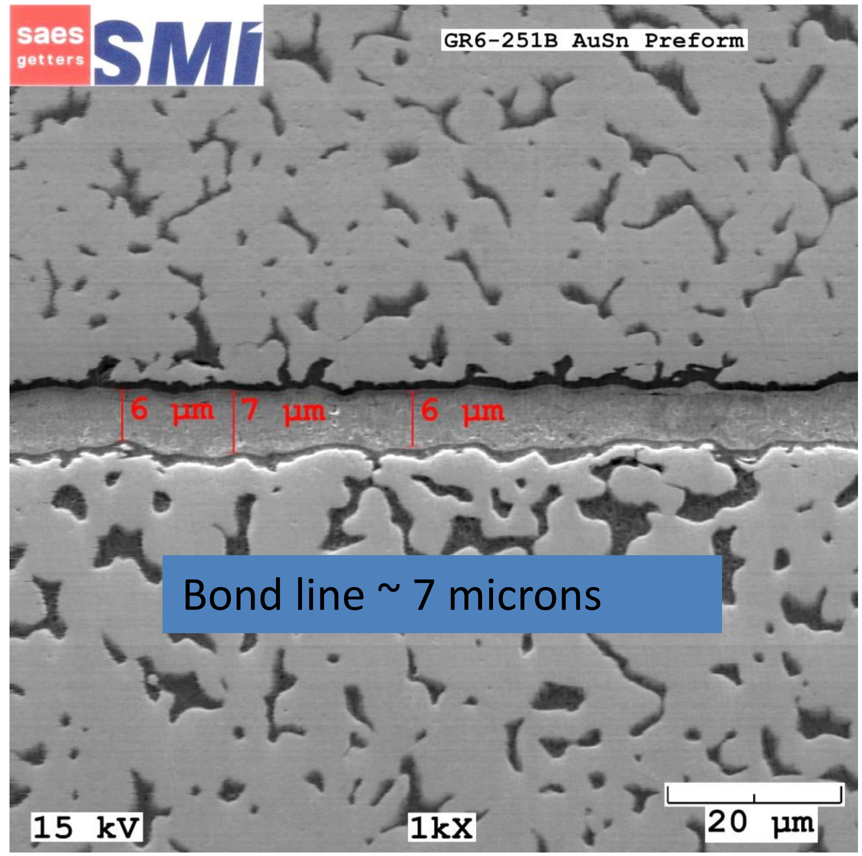


Typical bond lines from this process

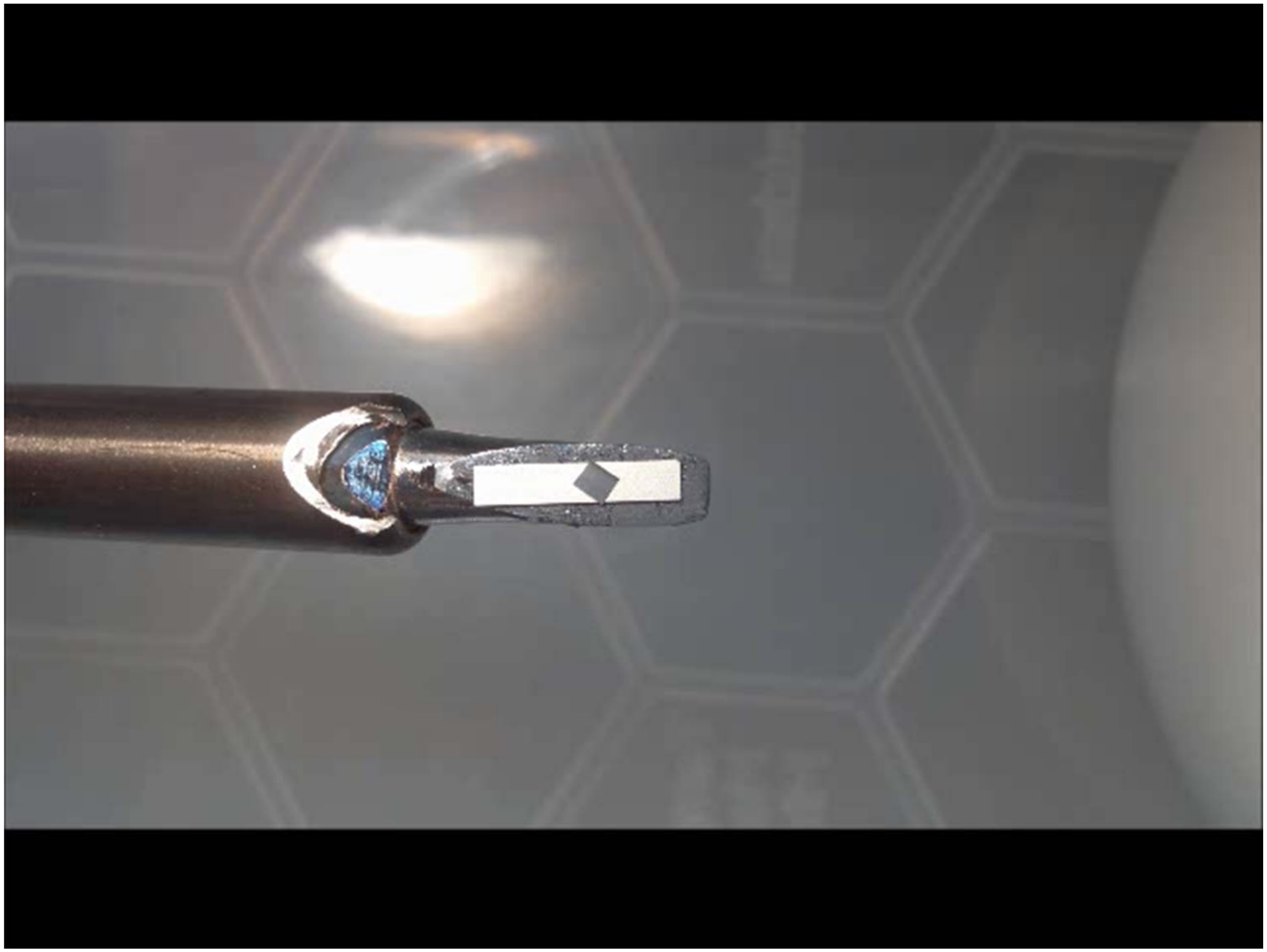
5 micron thin film AuSn high applied pressure (0.03 kg/mm^2)



25 micron AuSn preform high applied pressure (0.03 kg/mm^2)

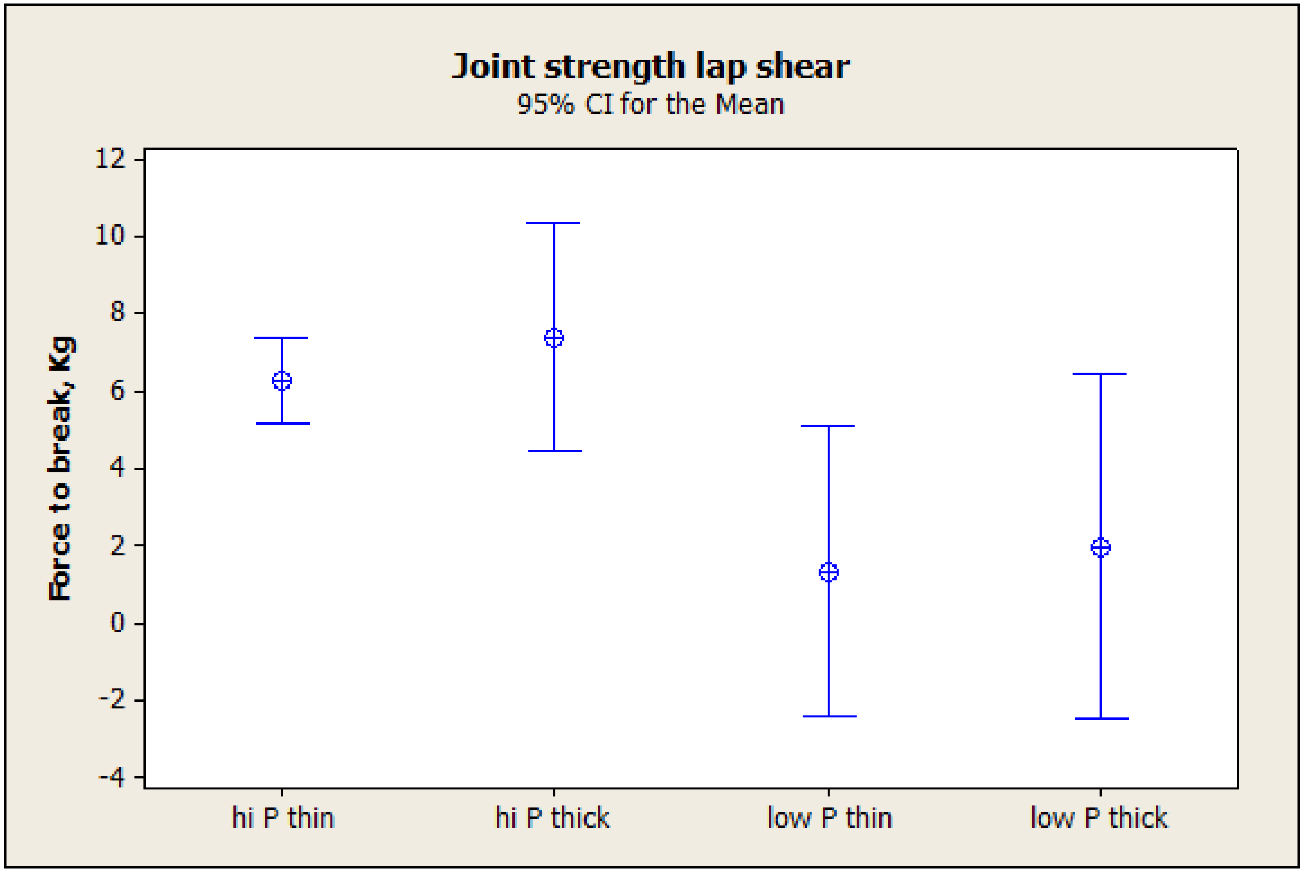


Example of a test part melting (no load)



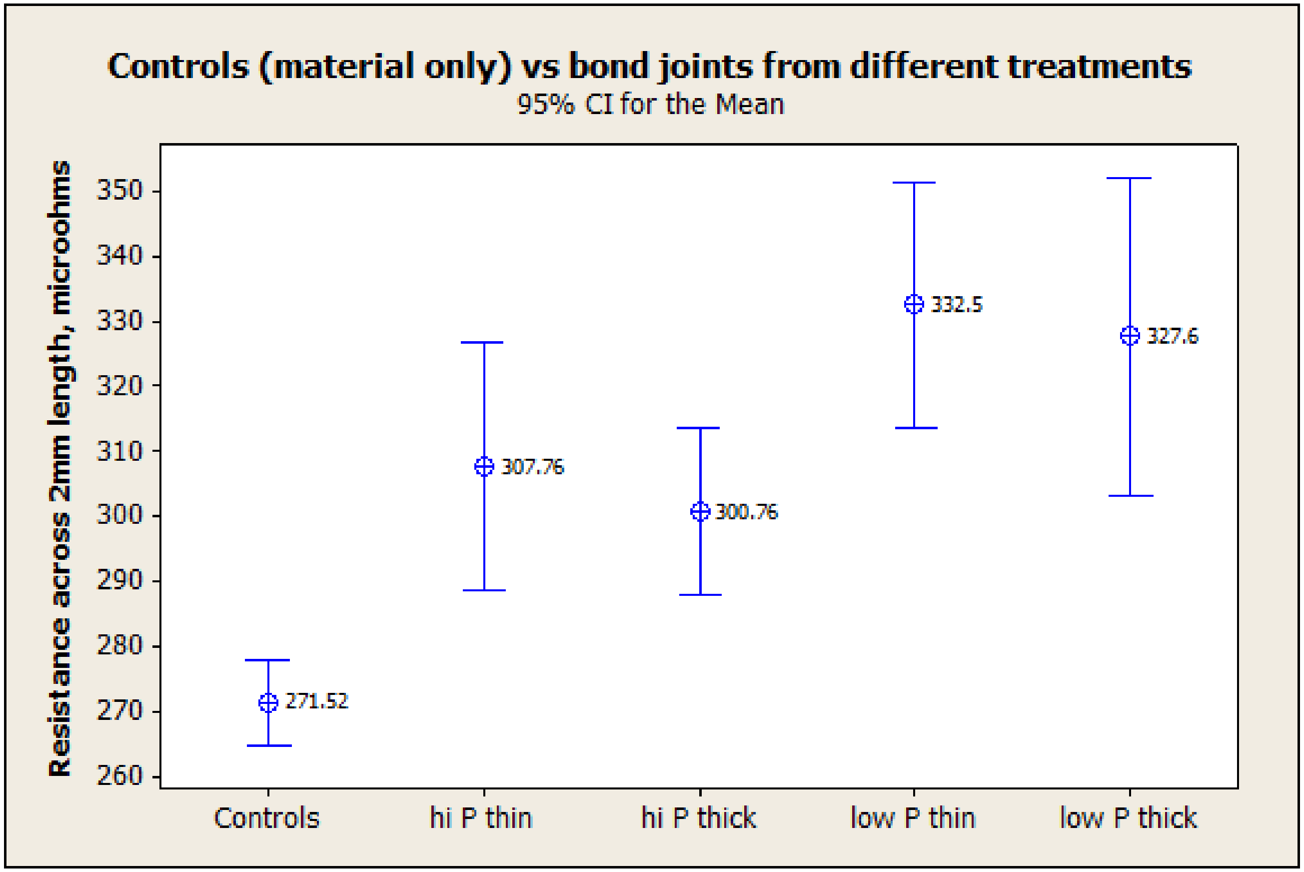
An AuSn preform is also in place

Data Summary Graphics 1



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.

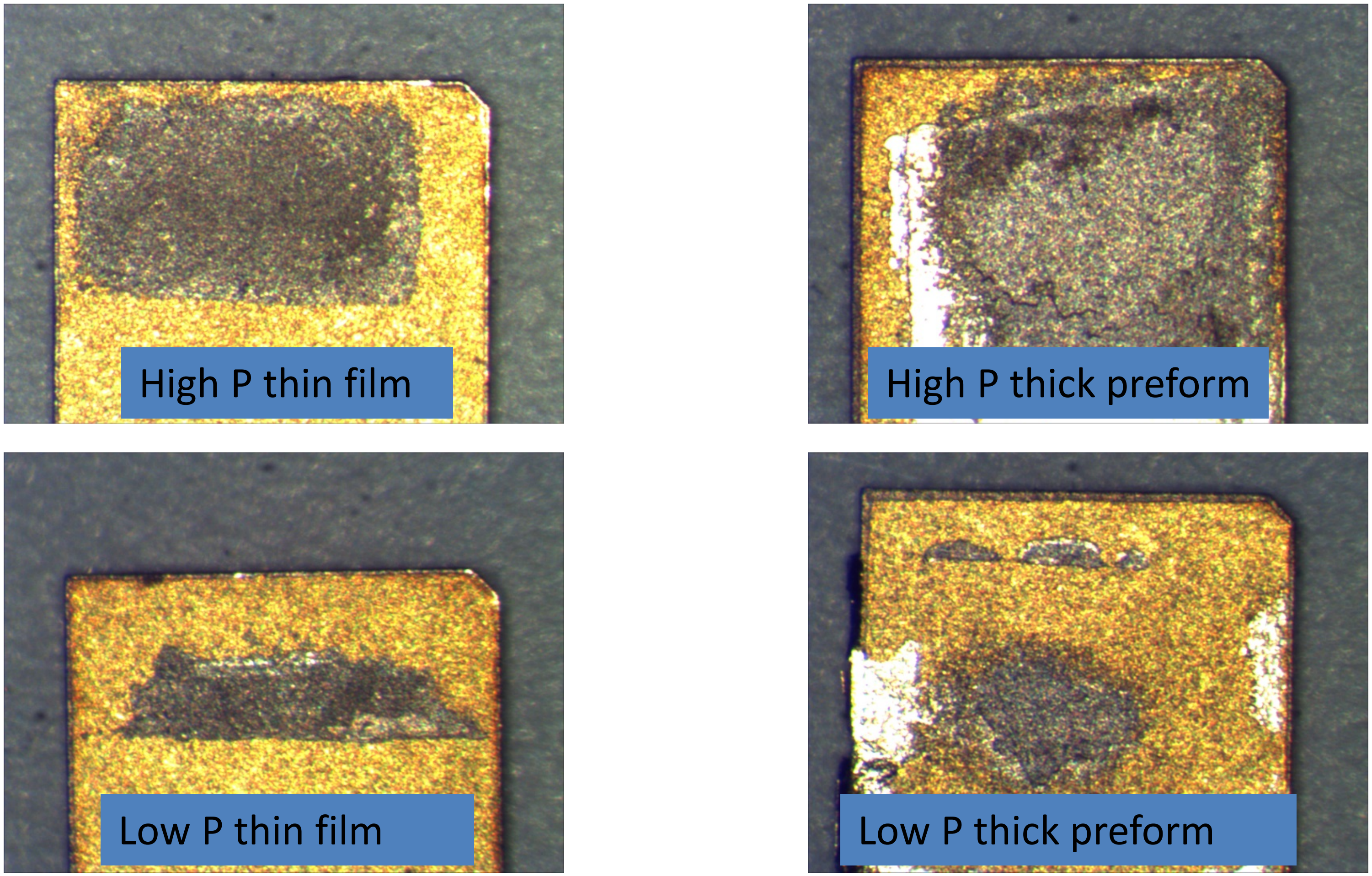
Data Summary Graphics 2



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



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/mm^2 for high pressure bonding and 24 micro-ohms/mm^2 for low pressure bonding. (based on <u>nominal</u> 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.

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Thank you for your attention

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