

Wire Bonding onto Niobium for Superconducting Applications

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Agenda – Wire Bonding onto Niobium

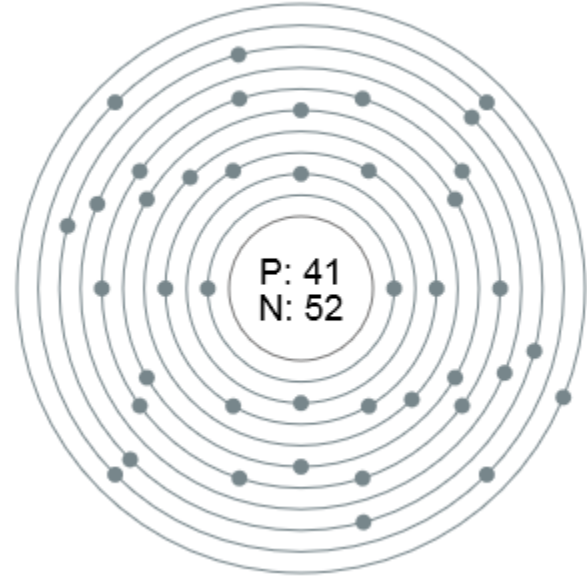
- Reason for this work
- Setup and test conditions
- Bondability and test results
- Conclusions
- Future work

Reason for this work

- Idea started at MTTTS in Tampa FL in 2014.
- This initial work is the first of two-three experiments.
- Initial work was with 20 mil Al.
- Reason to use large diameter wire was to reduce induction to help produce nice, clean signals in the 10GHz range.
- Applications include: superconducting of flex cables, data centers, quantum computing, autonomous vehicles, etc.
- Future work will be for 1 mil Al. Project will start soon.

Why Niobium?

- Nb is great for superconducting applications.
- Nb is a refractory material - one that retains its strength at high temperatures.



Setup and Test Conditions

Bonder	BJ939-0123		
Bondhead	HBK07-0087		
Bonding temperature	Ambient		
Workholder type	Vacuum clamping		
Software	3.81.13		
Wire	Heraeus 20 mil ALW-59P BL=500-800 EL=12-18%		
Wedge	DeWeyl MISIVG-20-1/8-2.733-70MP		

Nb Samples

- Sputter the Nb in a high vacuum.
- Expect that the sputtered films have a columnar growth mode (still needs more characterization).
- Nb seems to be porous – reacts with oxygen.
- Nb
- AlNb
- AuNb
- All samples were prepared on wafers.
- Thickness layers for Al and the Au were in the 50nm range.
- Nb thickness was in the 250nm range.

Test Conditions - Touchdown Parameters

Action Settings
Edit Bond Parameters
3.81.12

Bondjet BJ939

Production

File: 500UM_FC

Source

Destination

Activate write protection

Touchdown

Touchdown:	52911	µm	52914	µm
Starting height:	<input type="text" value="5000"/>	µm		
Touchdown area:	<input type="text" value="200"/>	µm	<input type="text" value="200"/>	µm
Lower tolerance:	<input type="text" value="500"/>	µm	<input type="text" value="500"/>	µm
Touchdown velocity:	<input type="text" value="10000"/>	µm/s	<input type="text" value="10000"/>	µm/s
Touchdown force:	<input type="text" value="525.00"/>	cN	<input type="text" value="525.00"/>	cN

Bonding

Shape angle: °

Overtravel: µm

Pad Locator

Delay: ns

Turning height: µm

Angle offset: deg

TH Overtravel: µm

Loop

Welding

Quality check

Tear off

Inline Pull Test

OK
Text Export
Cancel

H&K

Settings

ce height

e to Pos.

ce

ination

aters

500UM_FC

Load

Edit

1

by step

e Wire

start


Service

11 47


Test Setup – Looping

Action Settings
Edit Bond Parameters
3.81.12



Bondjet BJ939



Production

File: 500UM_FC 

Activate write protection

Source  Destination 

+ Touchdown

+ Bonding

- Loop

Starting angle: °

Intermediate height: μm

Intermediate radius: μm

Horizontal distance: μm

Vertical distance: μm

Loop angle: °

Loop shape source: %

Close clamp

Method:

Loop height source

Loop height destin.

Apex height

Wire length

Loop height: μm

Height correction: %

Loop shape dest.: %

Close clamp

Intermediate height: Vertical

Direct

Arc

Horizontal distance: μm

H&K

Settings

Wire height

to Pos.

ce

ination

eters

500UM_FC

Load


Edit

1

by step

Wire

start




Service

11:46

Test Setup – Bonding Parameters




Action Settings
3.81.12

Bondjet BJ939



Production

Edit Bond Parameters

File: 500UM_FC  Source  Destination 

Activate write protection

- Touchdown
- Bonding
- Loop
- Welding

Process control: Const. voltage
 Const. current

Stop after deformation: %

Max. welding time: ms

No. of intervals:

Interval:

 Ultrasonic: U

 Bond force: cN

 Duration: ms

 Ramp: ms

Interval:

 Ultrasonic: U

 Bond force: cN

 Duration: ms

 Ramp: ms

Process control: Const. voltage
 Const. current

Stop after deformation: %

Max. welding time: ms

No. of intervals:

Interval:

 Ultrasonic: U

 Bond force: cN

 Duration: ms

 Ramp: ms

Interval:

 Ultrasonic: U

 Bond force: cN

 Duration: ms

 Ramp: ms

Quality check

Tear off

Inline Pull Test

OK
Text Export
Cancel

H&K

Settings

Pre height

to Pos.

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ination

eters

500UM_FC

Load


Edit

1

by step

e Wire

start



Service

11:47

Test Setup – Bond Head Alignment

Calibration Mode Action Settings Extras 3.81.12

Bondjet BJ939 Calibrate ultrasonic generator X: 325.858 mm Y: 5.367 mm Z: 43.546 mm P: 90.000 deg H&K

Frontcut 500 AL

Calibrations

E-Box

1000

Cutter dist.: 273 µm

Side R 1
Front 3
Side L 5
Clamp 6
Cutter 7

Bottom 2
Back 4
Quit

PiQC

Settings

Calibration

Characteristic

ues

onance Frequency

0.8 kHz

Save

Back

Production

Manual bonding

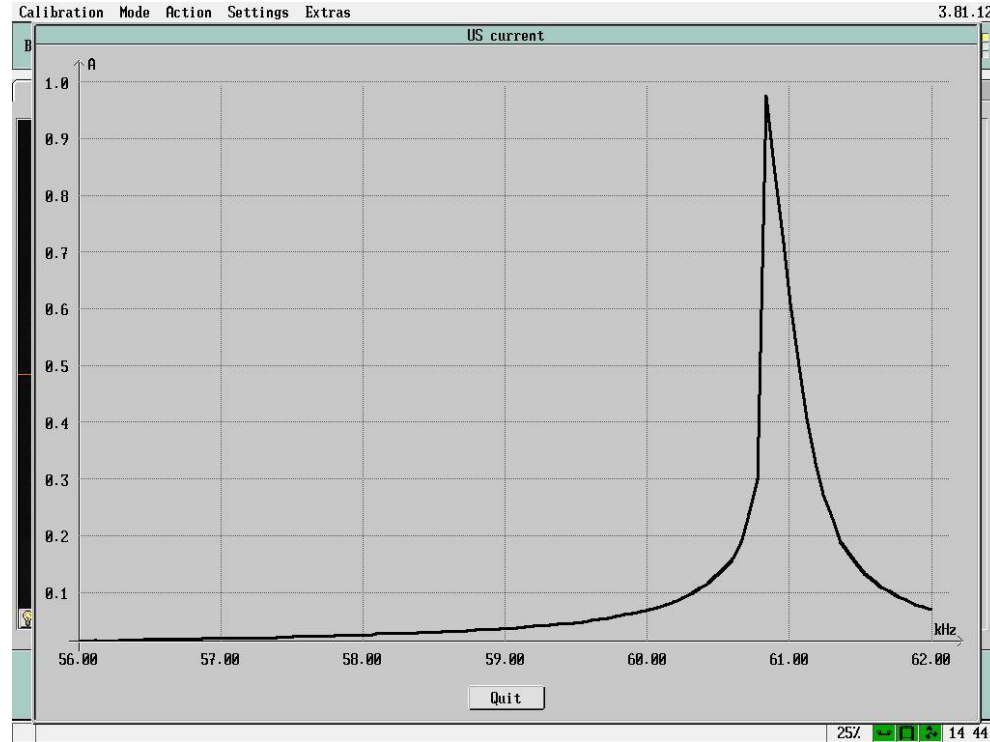
Setup

Programming

Administration

Service

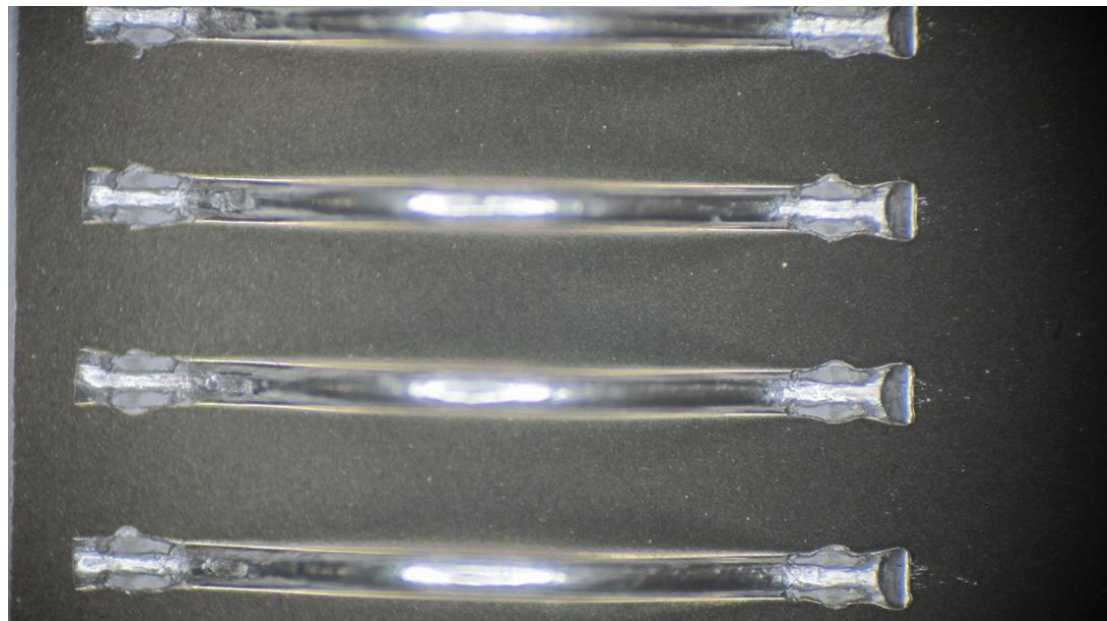
Ultrasonic Tuning



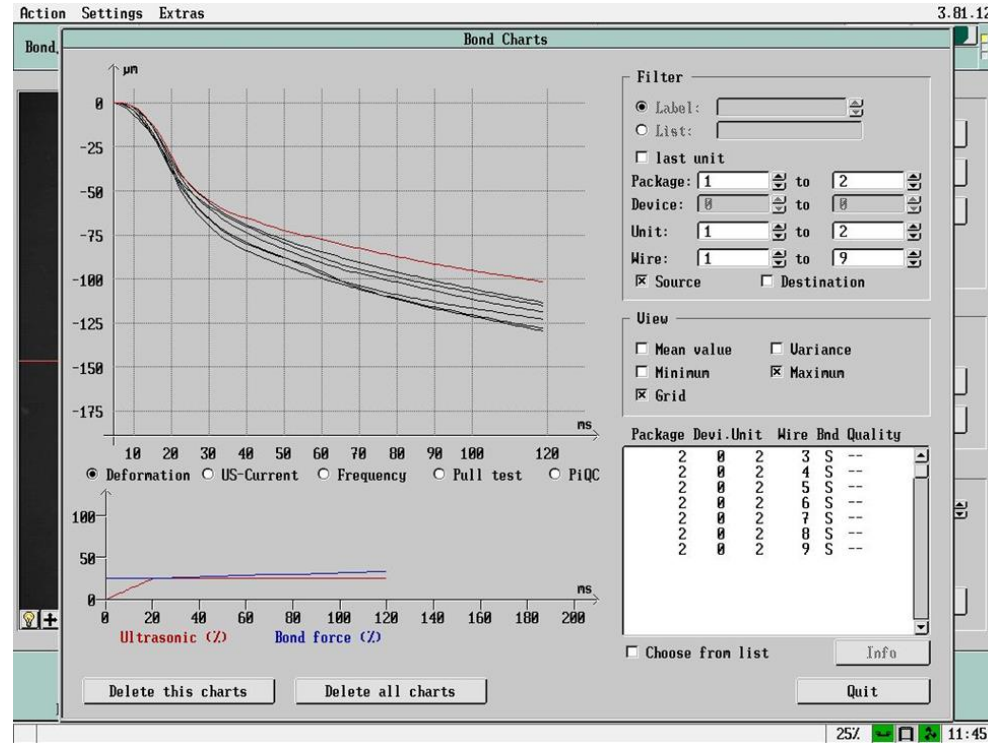
Top View of 20 mil Al wires on AlNb



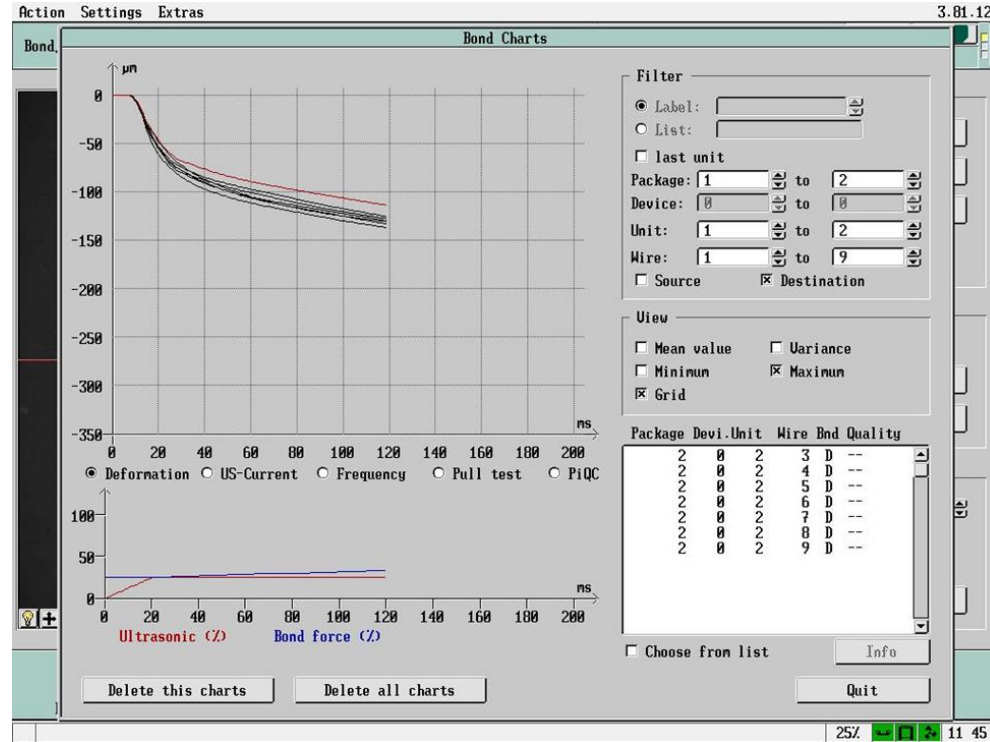
Top View Photo of Al wires on Au-Nb



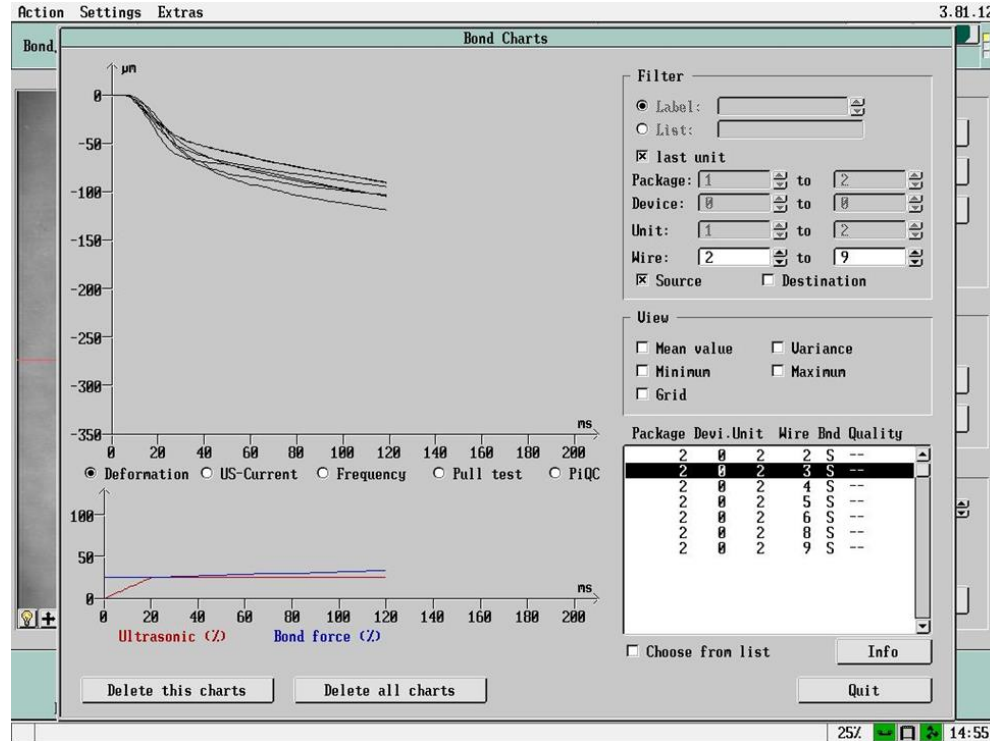
Bond Deformation Trace on Au-Nb on 1st bond



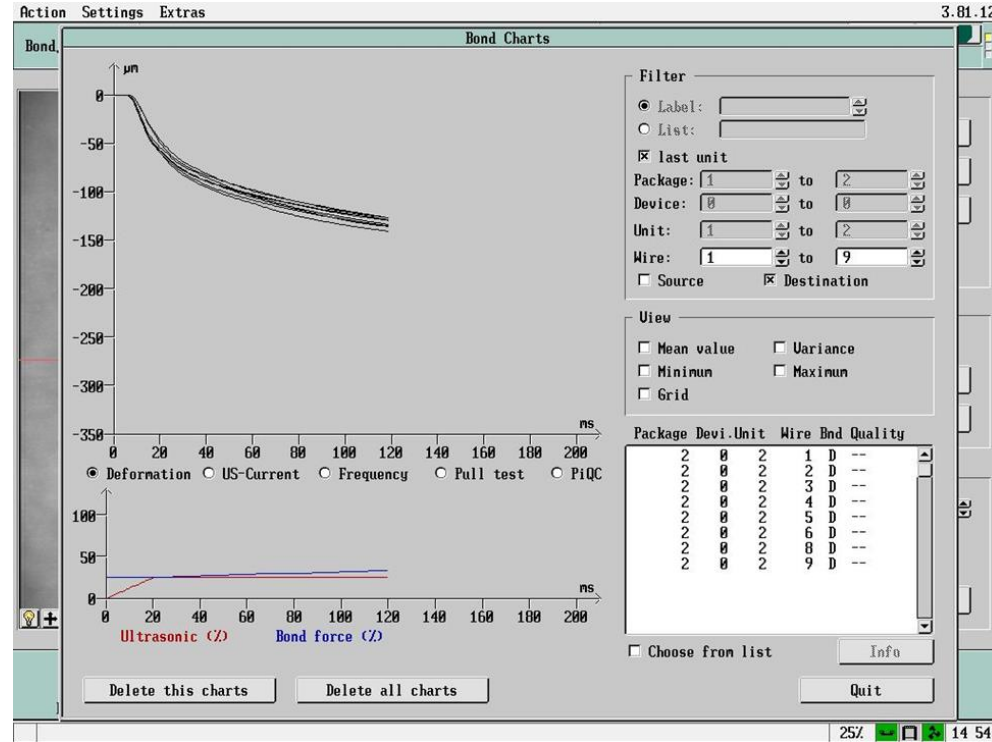
Bond Deformation Trace for Au-Nb on 2nd bond



Bond Deformation on AlNb – 1st bond



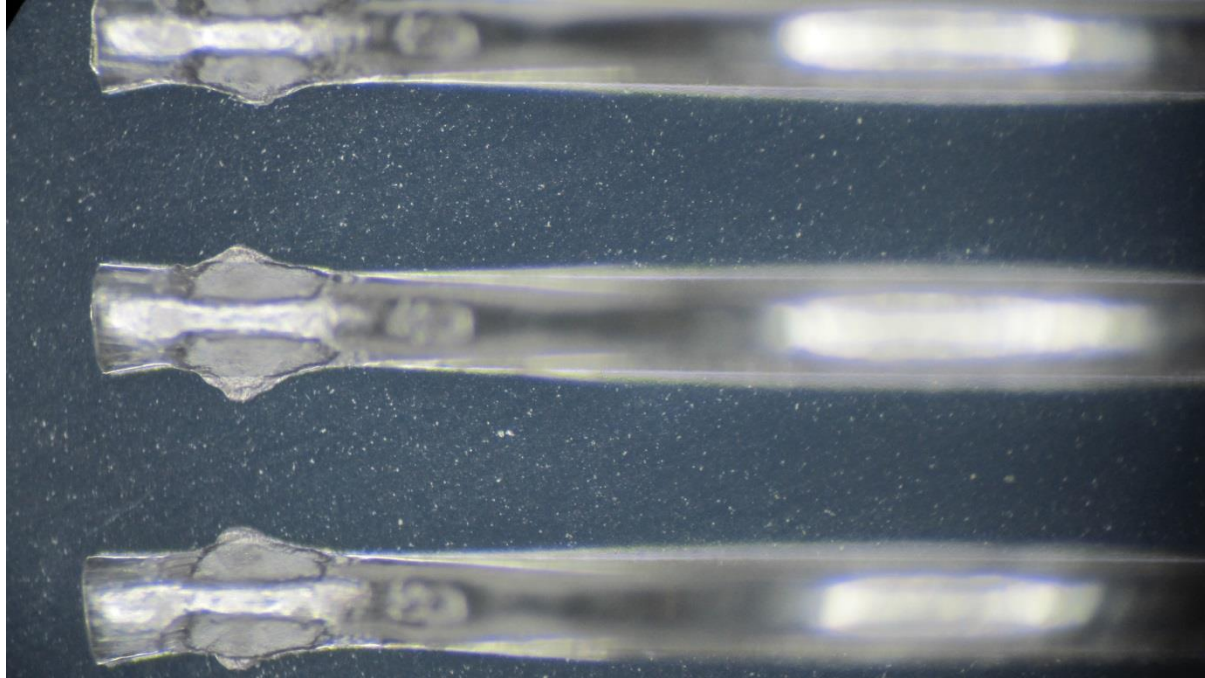
Bond Deformation Trace on AlNb – 2nd bond



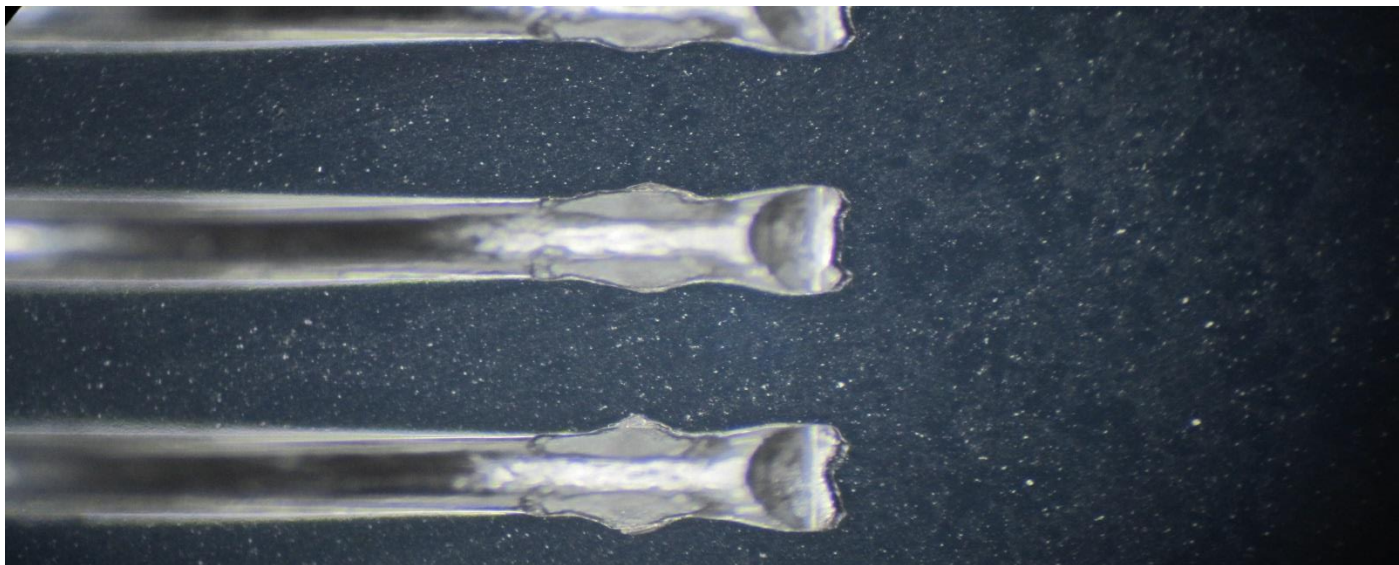
Al wire on AlNb



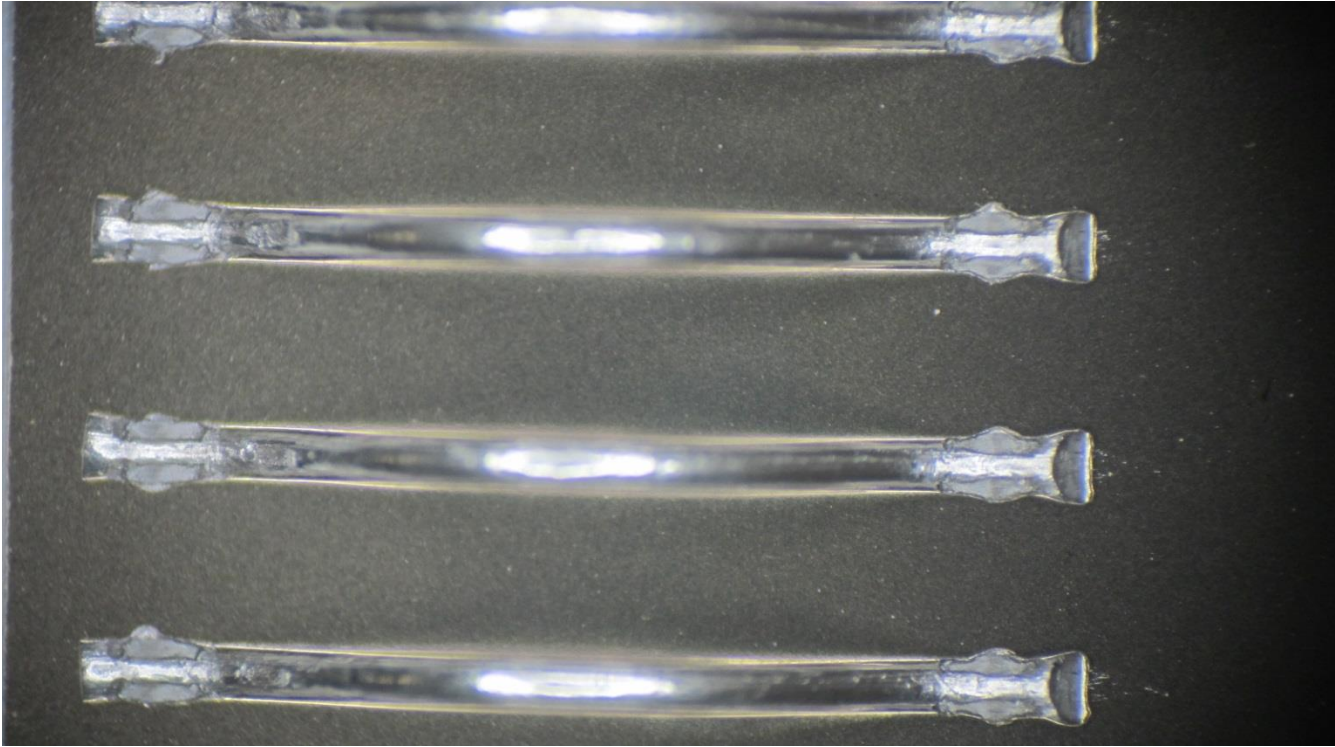
Close up of 1st bonds on AlNb



Close-up 2nd bonds of Al wire on AlNb



Close up of Al wires on AuNb



Bonding onto Nb

- Many instances of non-sticks.
- Need to investigate as to why the high number of non-sticks.
- No instances of contamination.
- Frequency?
- Grain structure?
- Do cross-sectional analysis of parts.

Problem – Non-stick of Al wire on Nb



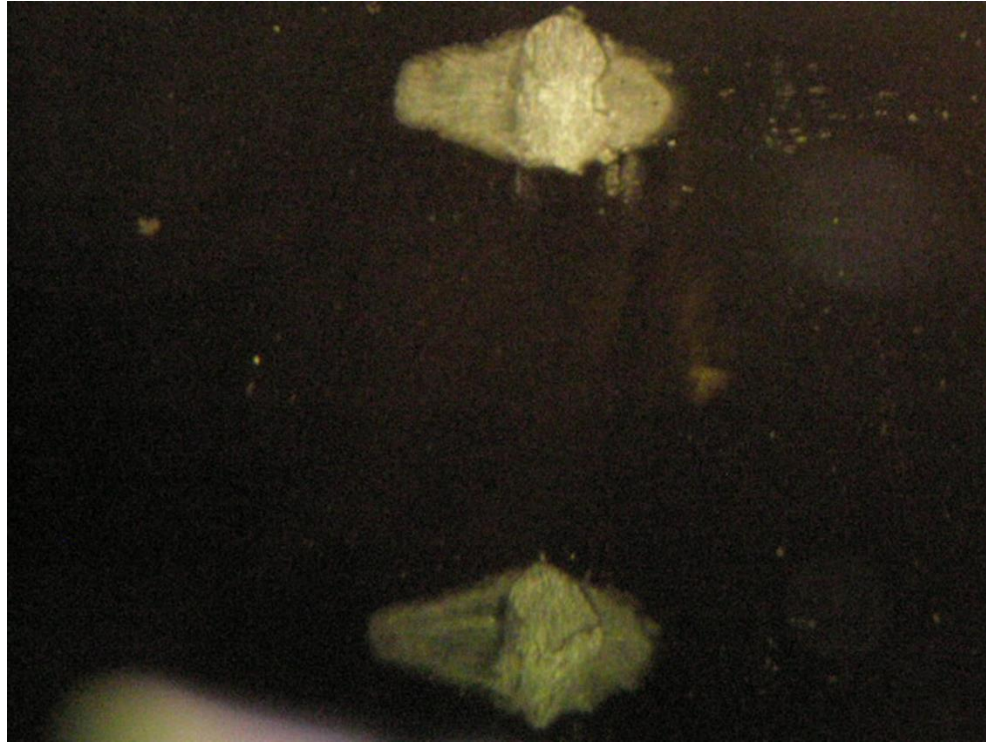
Wire Pull Test Data - AlNb

- 20 mil Al wire
- Breaking load of wire was 500 to 800 grams tensile.
- Minimum pull strength is half the tensile - 250 grams.
- Mean: 1.2183 kg
- Standard Deviation: 70.284 g

Shear Test Results for AuNb

- Average Shear was 1,566 grams with standard deviation of 161.
- Minimum expected shear is 500 grams.
- Decent nuggets post-shear.

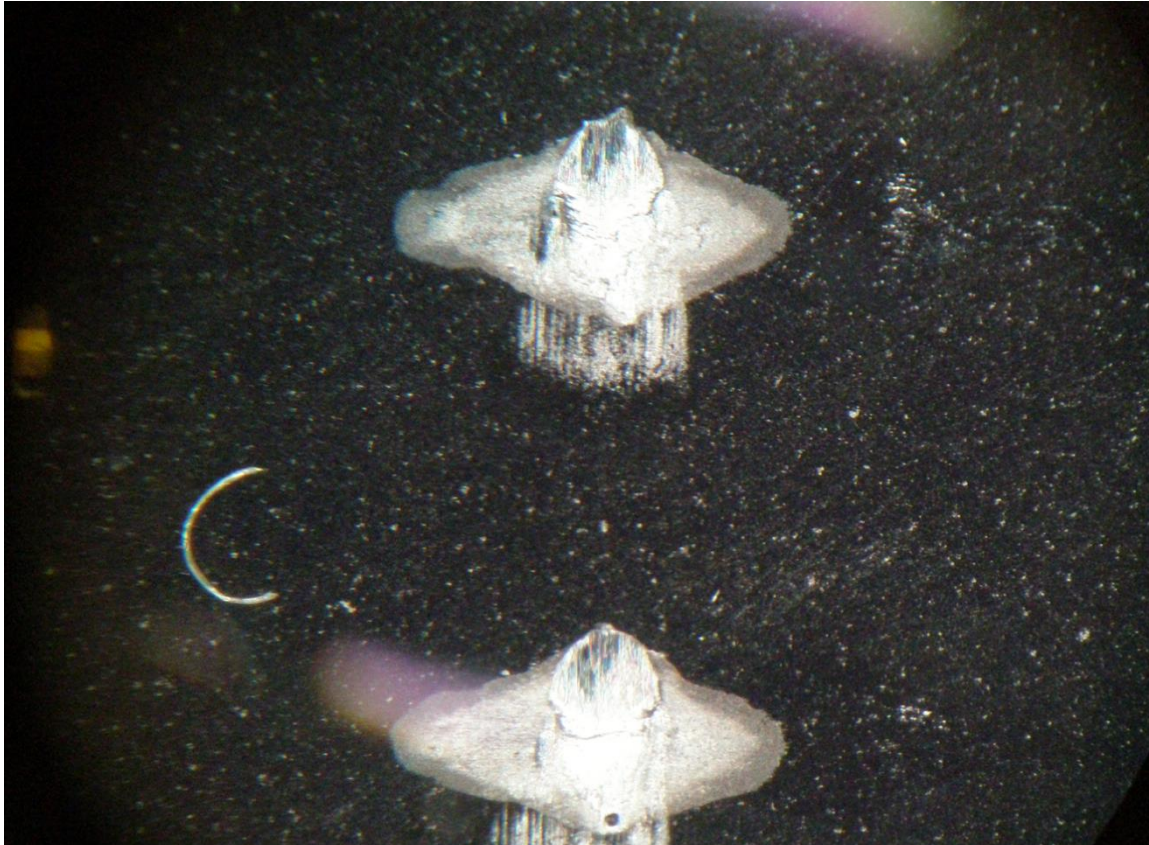
Shear Results - AuNb



Shear Results for AlNb

- Average shear was 1,746 grams with a standard deviation of 88.
- Minimum shear value is 500 grams.
- Acceptable nugget post-shear.

Shear Results – AlNb Nuggets



Conclusions

- Bonding onto AlNb had the best bondability and test results.
- Bonding onto AuNb was 2nd best.
- Bonding onto Nb was not good. Investigating reasons why and will setup a DOE to determine bond parameters.

Future Work

- Auburn University, Hesse Mechatronics & Fermilab have just started a new experiment with wire bonding fine Al wire onto: Nb; AlNb; AuNb.
- NIST in Colorado has been working with Hesse on wire bonding to Nb for quantum computing.
- Applications include microwave amplifiers for the South Pole and Particle Physics (“God-particle”).
- Additional testing of heavy Al wire and ribbon will be used in actual parts.

Thank you for your kind attention!

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Targeting 100%
Wire Bonding Yields

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