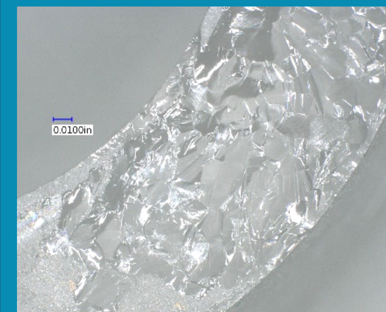
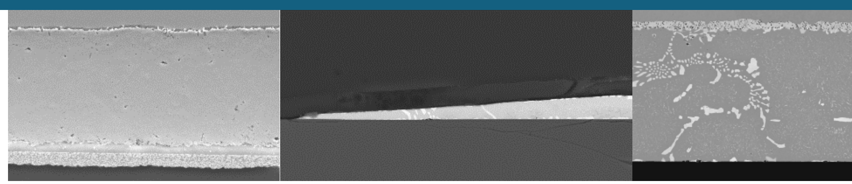
SAND2021-11249C

Active brazing Aluminum Oxynitride (ALON) to Kovar and Niobium





E Arata, C Walker, L Johnson, D De Smet

Sandia National Laboratories

Albuquerque NM 87185, USA company

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Motivation

Niobium (Nb) to alumina ceramic brazing, Kovar added here for comparison

Sealed hermetic vacuum assembly out of braze

Inspection of internal braze joints for excess flow to meet electrical requirements

	Obsolete	Current	Proposed
Year	<2010	2010-2021	2021+
Material	Sapphire	94% Alumina	ALON
Braze	Direct	Active	Active
Alloy	Cu-Au-Ni	Cu-Au-Ni-Ti	Cu-Au-Ni-Ti
Advantage	Optically clear	No cracks	Optically clear
Disadvantage ???	Cracks		X-ray inspection
Strength	8-10 Ksi (55-68 MPa)	11-17 Ksi (75-117 MPa)	???

Materials and thermal profiles

Aluminum Oxynitride (ALON)

- Optically transparent polycrystalline ceramic spinel
- Composition $Al_{23-1/3X}O_{27+X}N_{5-X}$ where $0.429 < X < 2$
- Mainly used for impact resistance and optical transparency
- Produced by Surmet Corporation, Burlington, MA

Nb and Kovar - COTS

Braze alloys produced by Wesgo Metals, Hayward, CA. - 0.002” thick foil

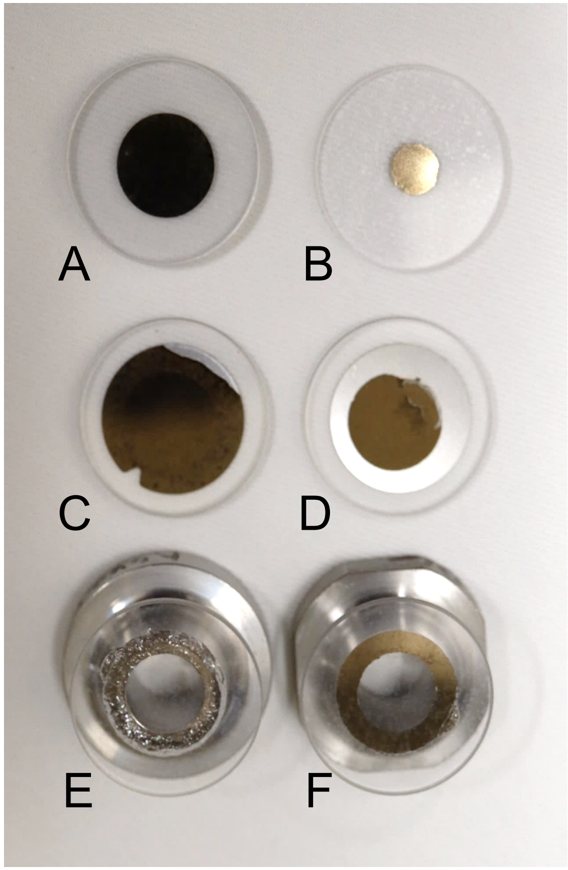
62Cu – 35Au – 1Ni – 2Ti

- High vacuum (<1 x 10^{-5} Torr)
- Heat to 980C at 15C/min, hold 15 min
- Heat to 1030C at 10C/min, hold 5 min
- Cool to room temperature

97Ag – 1Cu – 2Zr

- High vacuum (<1 x 10^{-5} Torr)
- Heat to 900C at 15C/min, hold 15 min
- Heat to 985C at 10C/min, hold 5 min
- Cool to room temperature

Produced samples



A) 1x ALON sandwich (2-sided)

B) 1x wetting drop on ALON (1-sided)

C) 1x Niobium (Nb) to ALON

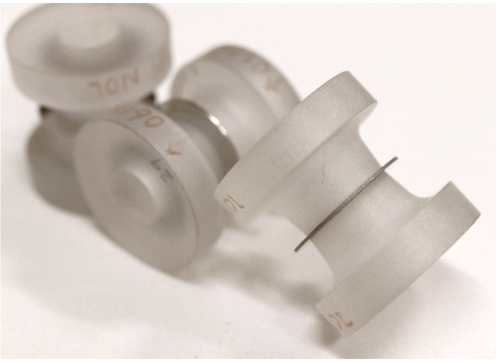
D) 1x Kovar to ALON

E) 2x ALON flat to Kovar Tensile Button (TB)

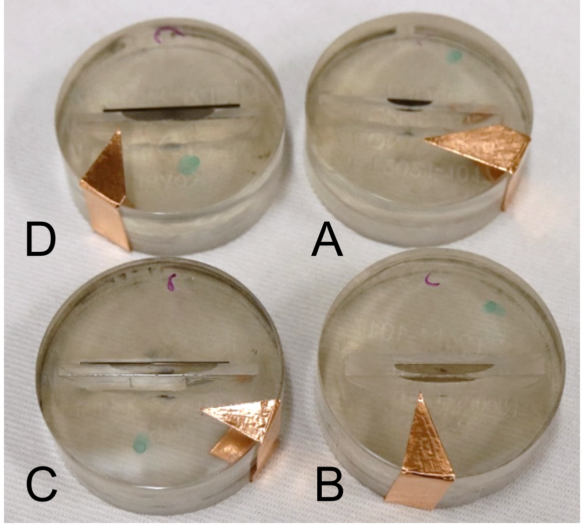
F) 2x ALON flat to Nb TB

2x ALON TB with Nb interlayer

2x ALON TB with Kovar interlayer



Experimental methods



Cross section and mount:

1x wetting drop on ALON (1-sided) – A

1x ALON sandwich (2-sided) – B

1x Niobium (Nb) to ALON – C

1x Kovar to ALON – D

SEM: Zeiss Supra 55VP

EDX: Oxford's Aztec software, X-Max 80mm^2 detector

Tensile testing (ASTM F-19):

Instron 5969, 50kN load cell, Bluehill Universal software suite.

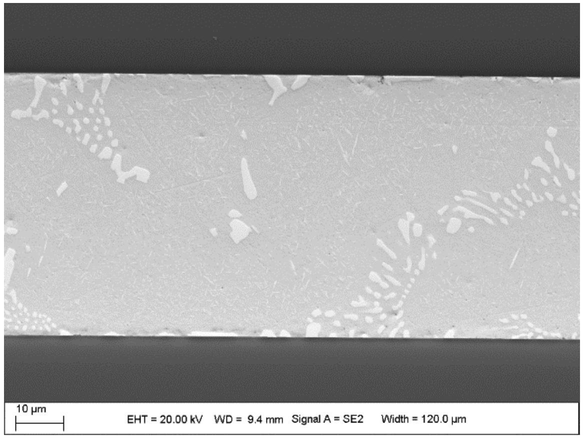
- Rate: 3 x 10^{-4} inch per second

SEM – Au-Cu-Ni-Ti – 2 sided

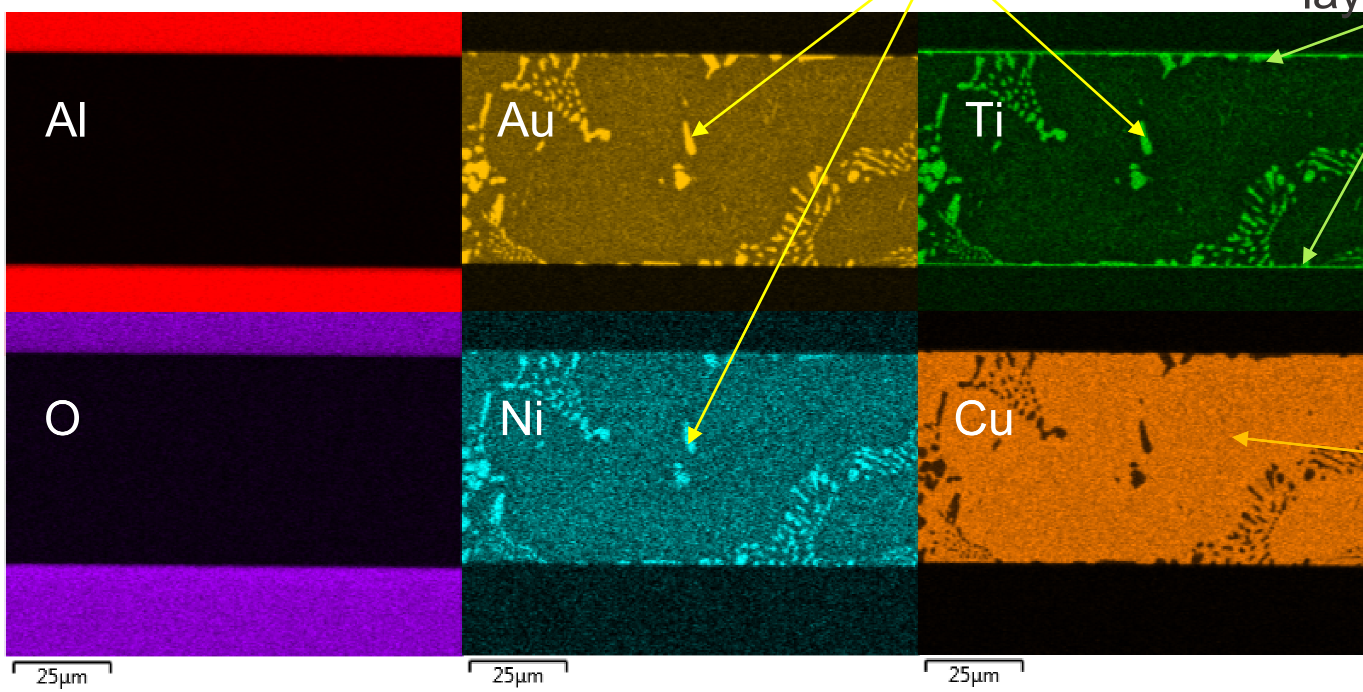
ALON

Alloy

ALON



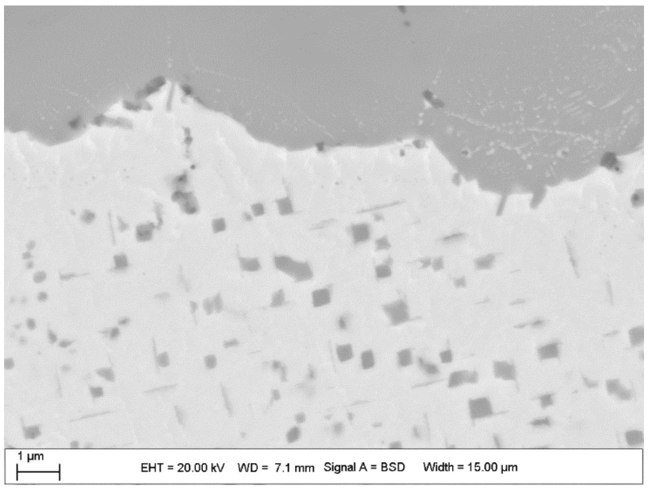
Ti active braze wets well to ALON showing typical reaction layer of minimal thickness

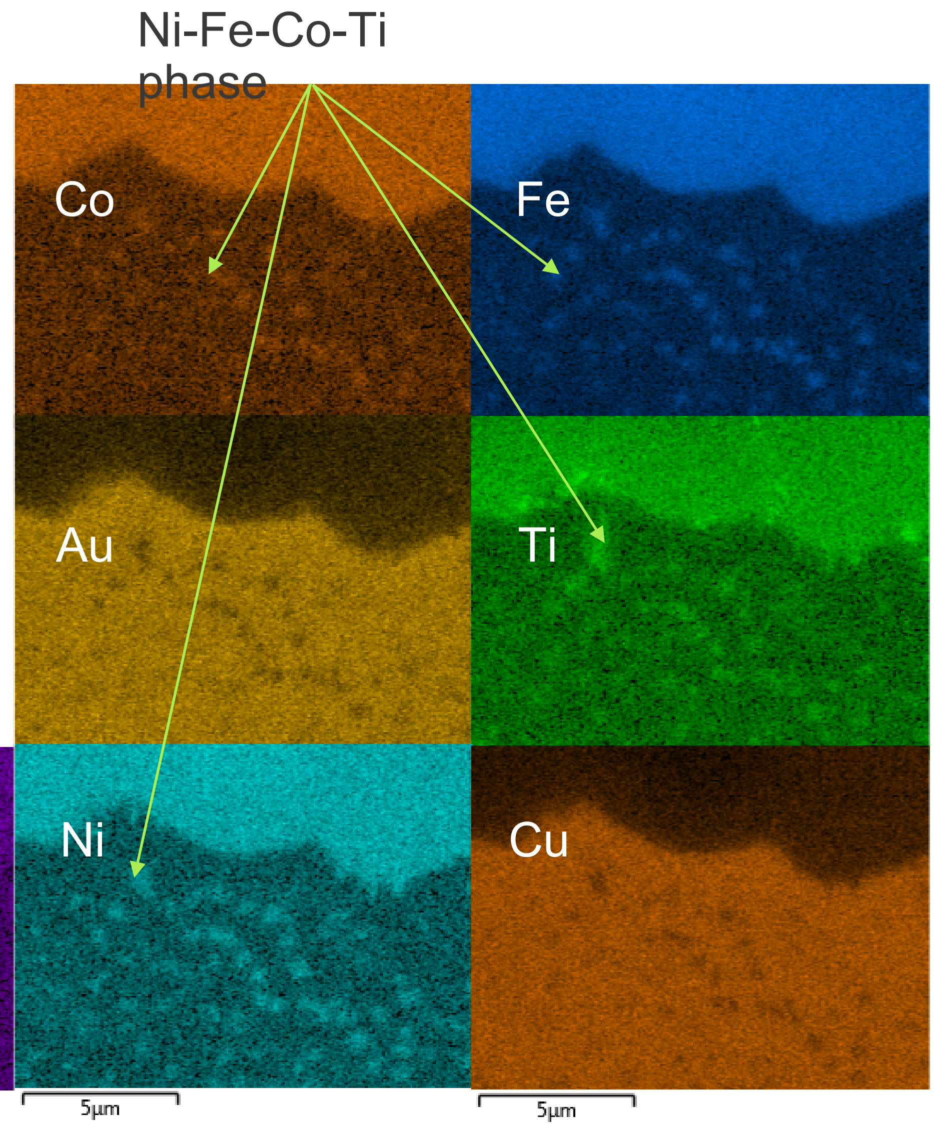


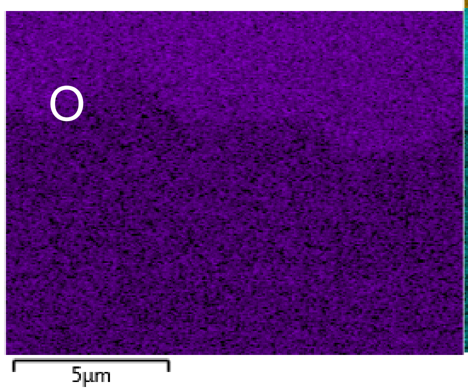
SEM – Au-Cu-Ni-Ti – Kovar/ALON (Kovar side of braze)

Kovar

Alloy

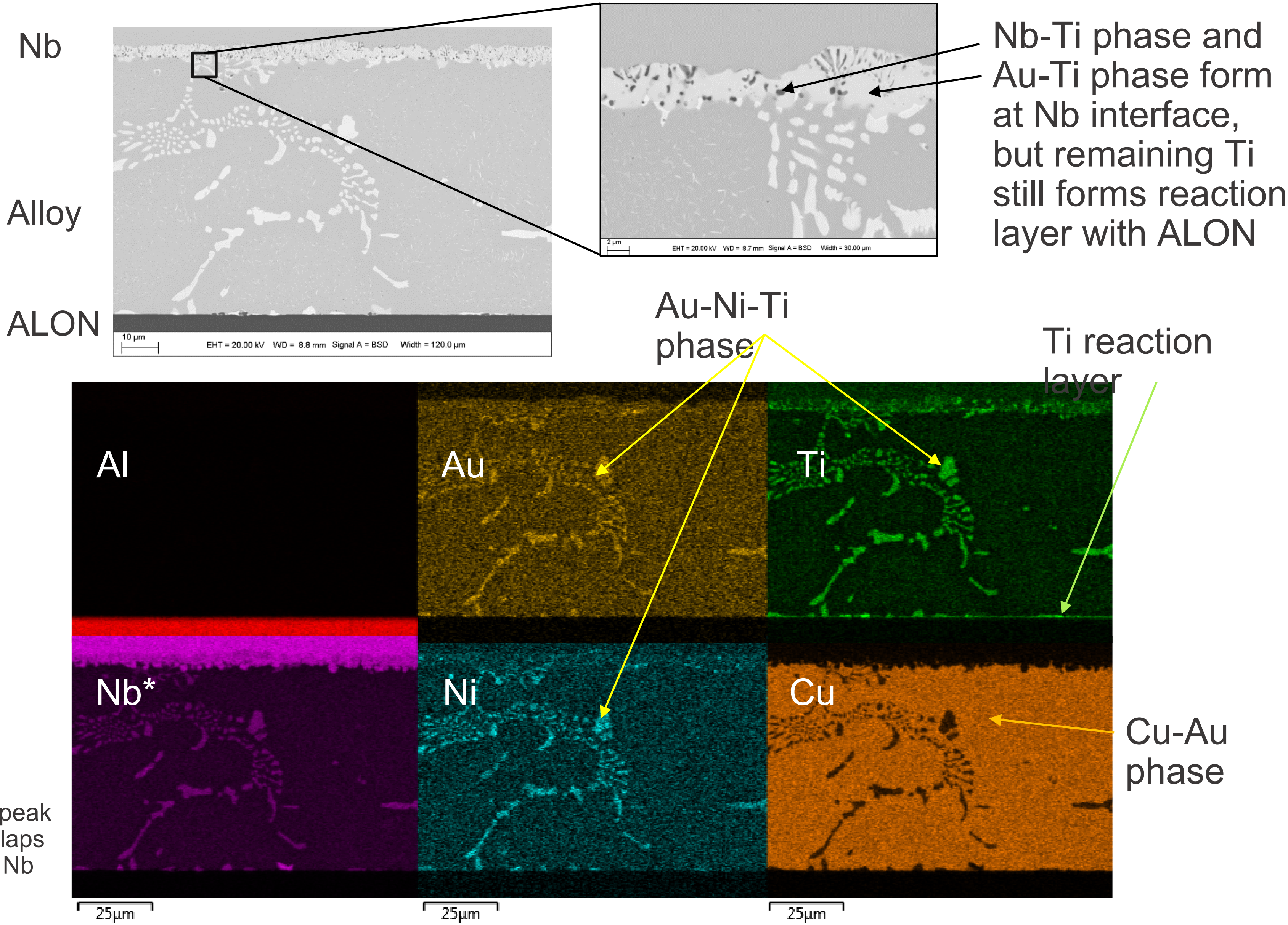






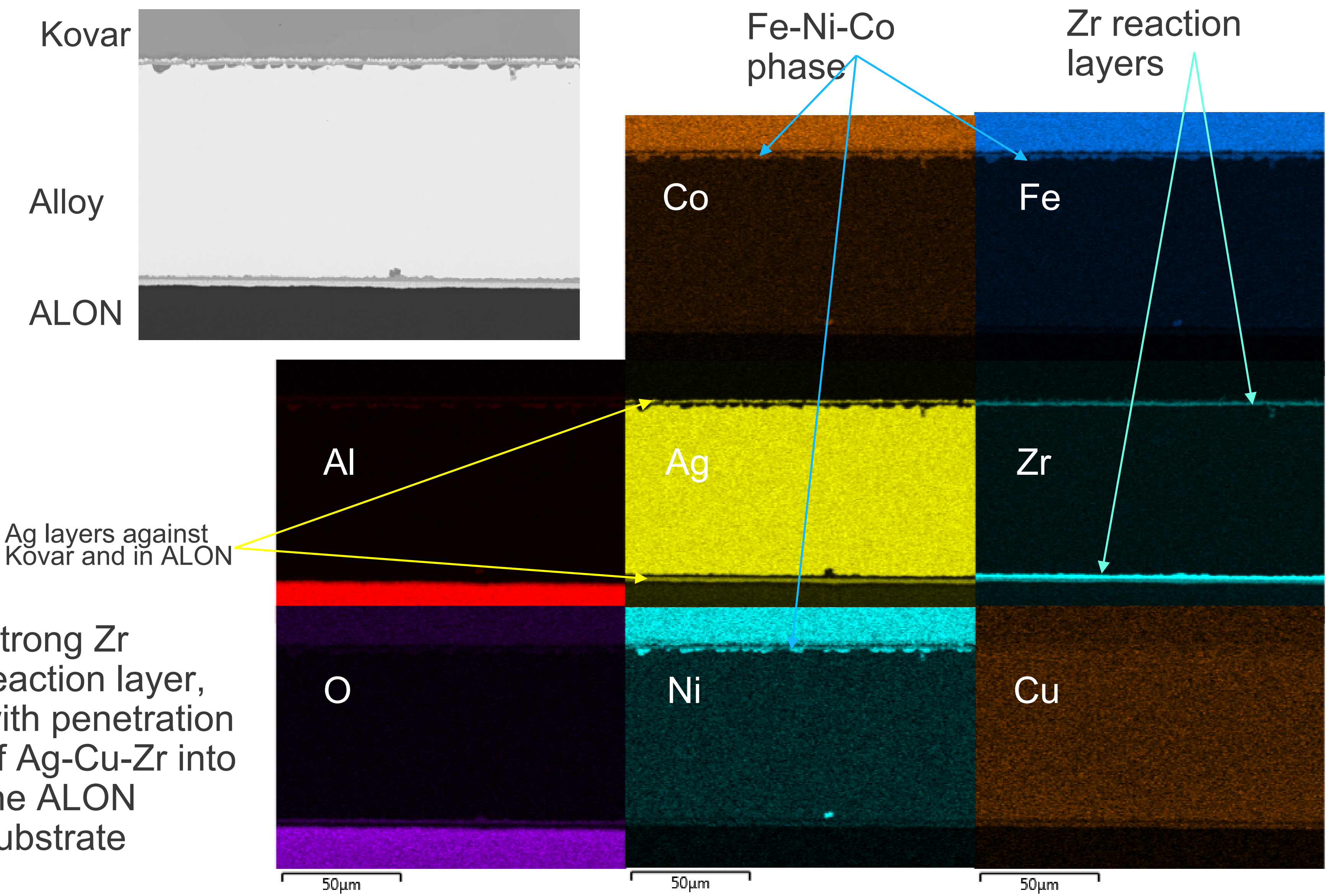
Typical dissolution of Kovar into braze material, forms Ni-Fe-Co-Ti phase

SEM – Au-Cu-Ni-Ti – Niobium/ALON



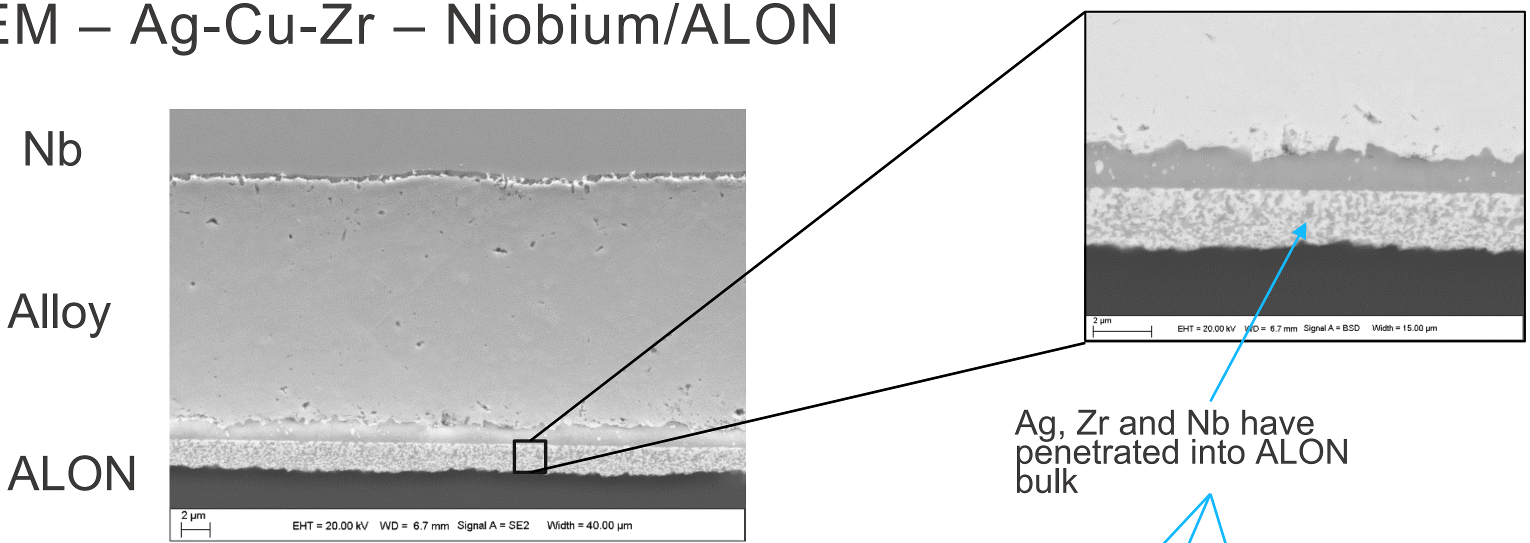
*Au peak overlaps with Nb

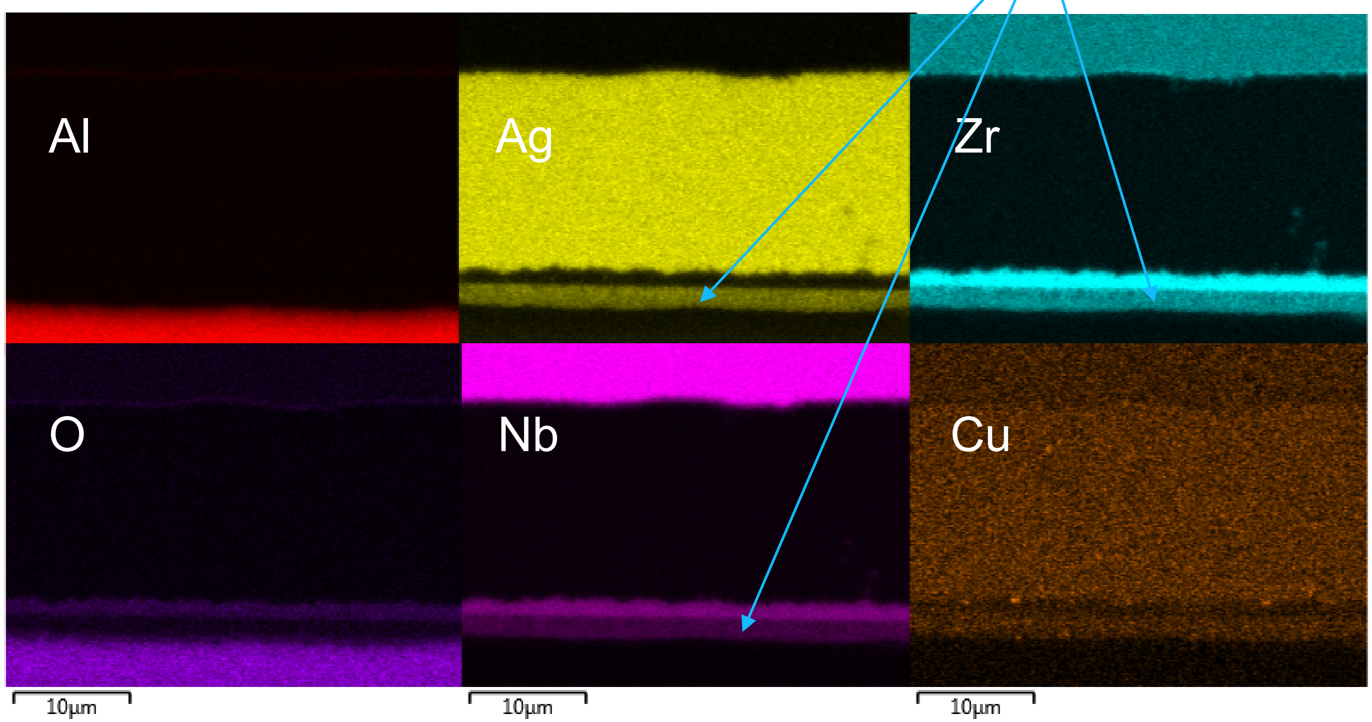
SEM – Ag-Cu-Zr – Kovar/ALON



Strong Zr reaction layer, with penetration of Ag-Cu-Zr into the ALON substrate

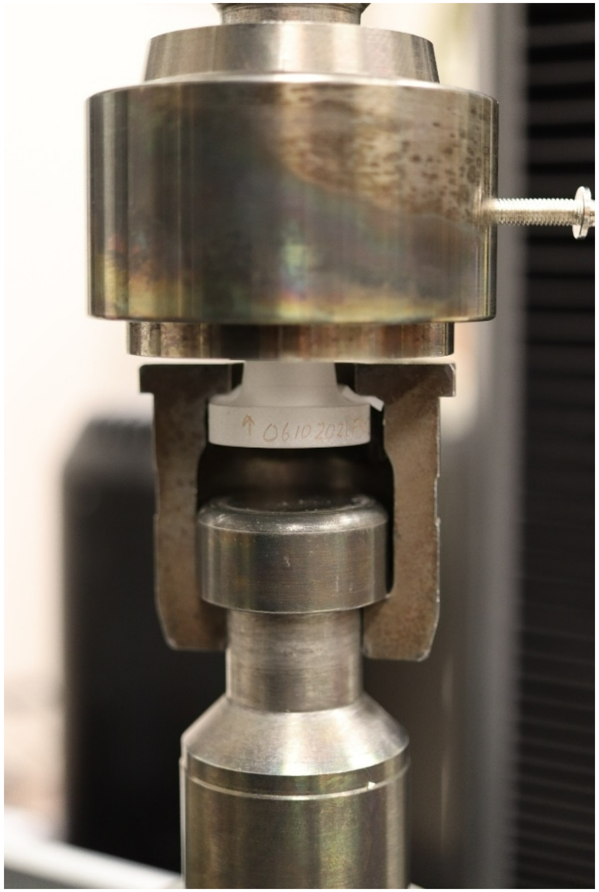
SEM – Ag-Cu-Zr – Niobium/ALON



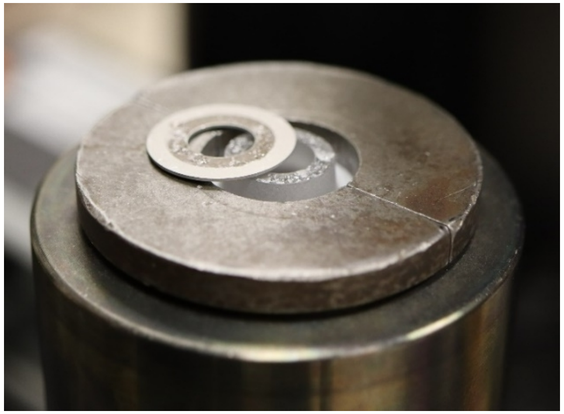


Strong Zr reaction layer deficient in Ag and Cu, penetration of Ag-Cu-Zr into the ALON substrate shown

Tensile testing



Tensile grips for ASTM F-19 samples.
Lower grip open to show sample.



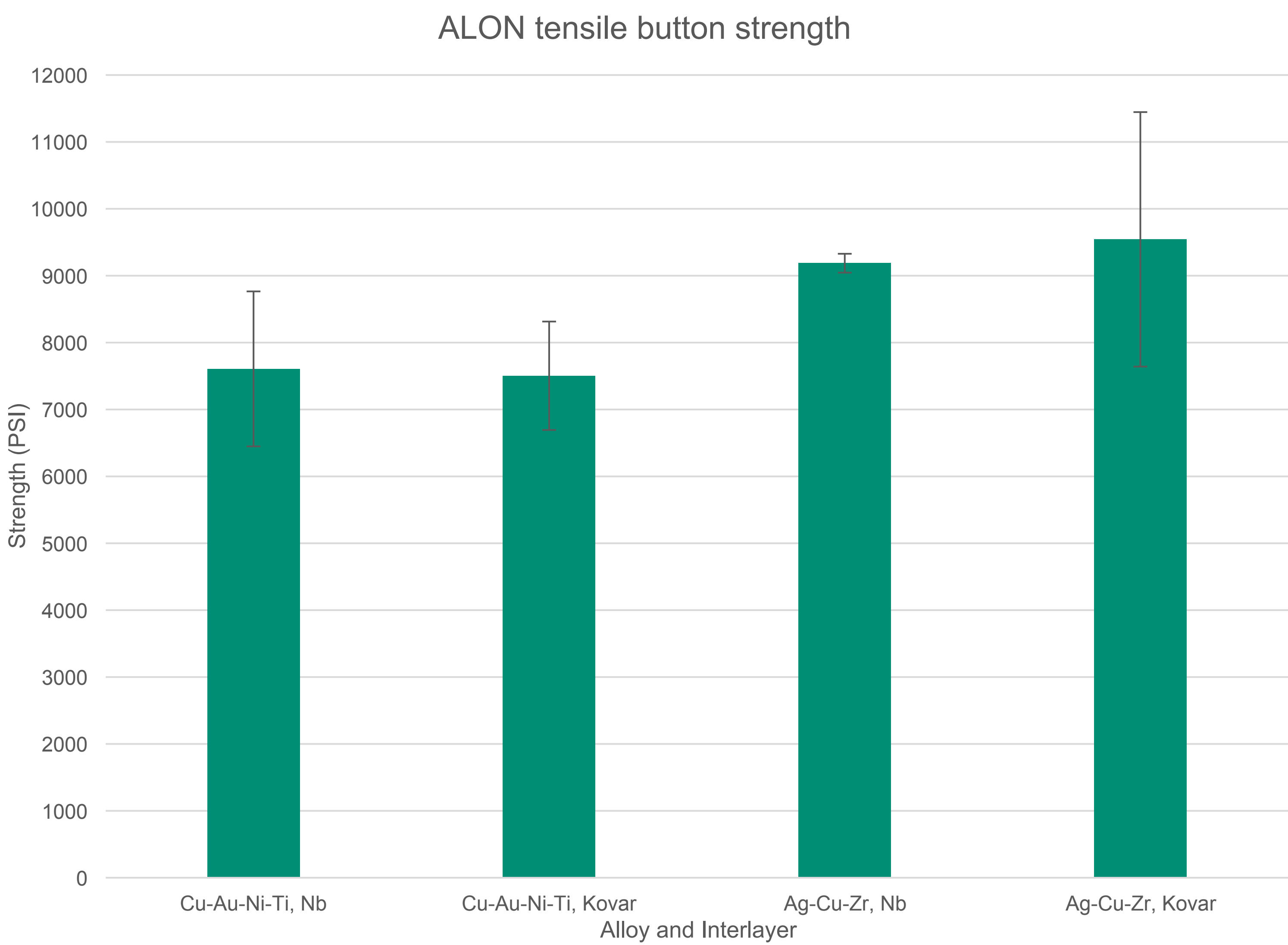
Fractured sample, still in tensile grips.

Two failure modes seen;

Left – fracture in bulk ceramic far from braze,

Right – fracture close to braze with ceramic pull out.

Tensile results



Error bars are standard deviation of data (2 samples each)

Conclusions

Successfully brazed ALON to Niobium and Kovar using Au-Cu-Ni-Ti and Ag-Cu-Zr

- Strength Nb ~ Kovar, slight Ag-Cu-Zr > Au-Cu-Ni-Ti

All samples were hermetic

Strengths comparable to direct braze sapphire

- Mainly showed failure in the ceramic

Further development needed to verify if ceramic strength is acceptable in application

	Obsolete	Current	Proposed
Material	Sapphire	94% Alumina	ALON
Braze	Direct	Active	Active
Advantage	Optically clear	No cracks	**Optically clear**
Disadvantage	Cracks	X-ray inspection	???
Strength	8-10 Ksi (55-68 MPa)	11-17 Ksi (75-117 MPa)	**7-8 Ksi**