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Comparison of Metal-Ceramic Brazing Methods

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Outline

Purpose

Background information

Examples of ceramic-metal brazes

Methods that require surface modification.

– Mo-Mn metallization
– Thin-film metallization

Methods requiring no surface modification.

– Active brazing
– Direct brazing

Purpose

Presentation motivation is twofold:

- Document the of methods currently used to braze metals to non-metals, particularly oxide ceramics, and show some positive and negative attributes of each method.

- Additionally, a goal is to compile the results from many years of brazing to create document that could be used by future designers, showing what tensile strengths can be reasonably expected using these methods and braze filler metal combinations.

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Metal-Ceramic Brazing: Background

Brazing is a method of joining materials.

1) Takes place ≥ 450ºC
2) Parent substrate materials are not melted
3) Braze filler metal is drawn into or held within the braze joint by capillary attraction

Standard brazing practices do not work on non-metallic (oxide, carbide, nitride) surfaces, failing to meet the 3rd requirement shown above.

Brazing to a nonmetallic surface requires 1) surface modification* or 2) the use of non-standard braze filler metals.

*direct brazing methods are an exception

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Some Examples of Metal-Ceramic Brazes

- High-voltage insulators/devices
- Vacuum breaks
- Electronic packages and connectors
- Structural brazing

MDC Vacuum Products, LLC

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Molybdenum-Manganese / Nickel Plate

Procedure:

A coating of molybdenum (or sometimes tungsten) and manganese particles mixed with silicates and glass additives and volatile carriers is applied to the ceramic surface to be brazed.

The coating is fired in a wet hydrogen environment at 1450-1600ºC leaving a “glassy” metallic coating 300-500 micro-inches thick.

The coating is subsequently plated with 0.001-0.003 inch layer or nickel.

The nickel plating is sinter-fired at 850-950ºC in a hydrogen atmosphere leaving a finished metallic surface that can be readily brazed using standard braze filler metals.

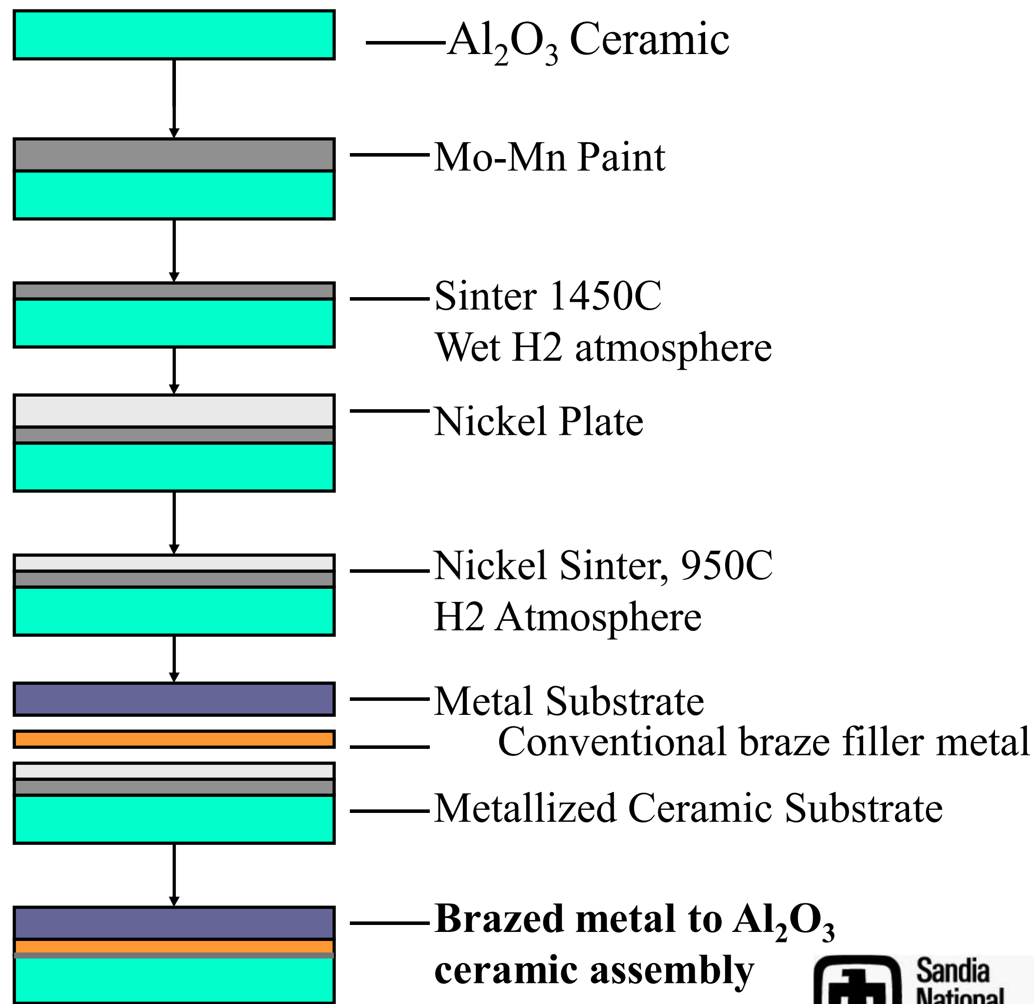
Molybdenum-Manganese / Nickel Plate

Advantages

- Mature technology
- Proven history
- Easily brazed using standard filler metals
- Commercial Suppliers Available

Disadvantages

- Time consuming
- Multiple-step process
- Requires specialized equipment
- Nickel plating depletion
- Expensive



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Molybdenum-Manganese / Nickel Plate
ASTM-F19 Tensile Button Test Results

Filler Metal	Non-metal Substrate	Metal Substrate	Brazing Temperature	Furnace Atmosphere	Tensile Strength
50Au/50Cu	94% Alumina	Fe-29Ni-17Co	1000ºC-3 min	Dry Hydrogen	17.1 ksi ±1.8 ksi
65Cu/35 Au	94% Alumina	Fe-29Ni-17Co	1040ºC/3 minutes	Dry Hydrogen	14.5 ksi
72Ag-28Cu	94% Alumina	Fe-29Ni-17Co	810ºC/3 minutes	Dry Hydrogen	14.3 ksi
77Au-13Ag-10Ge	94% Alumina	Fe-29Ni-17Co	495ºC/3 minutes	Dry Hydrogen	15.6 ksi ±0.2 ksi
77Au-13Ag-10Ge (2x thk)	94% Alumina	Fe-29Ni-17Co	455ºC/5 minutes	Dry Hydrogen	16.1 ksi ±1.0 ksi

Test Samples:
ASTM-F19 Tensile Buttons

(94% alumina with Fe-29Ni-17Co interlayers)

- Tensile strength (crosshead speed = 8.38E-03 mm/sec)
- Hermeticity Data (helium leak rates <2E-09 atm-cc/sec)

Paul Vianco, AWS 2001

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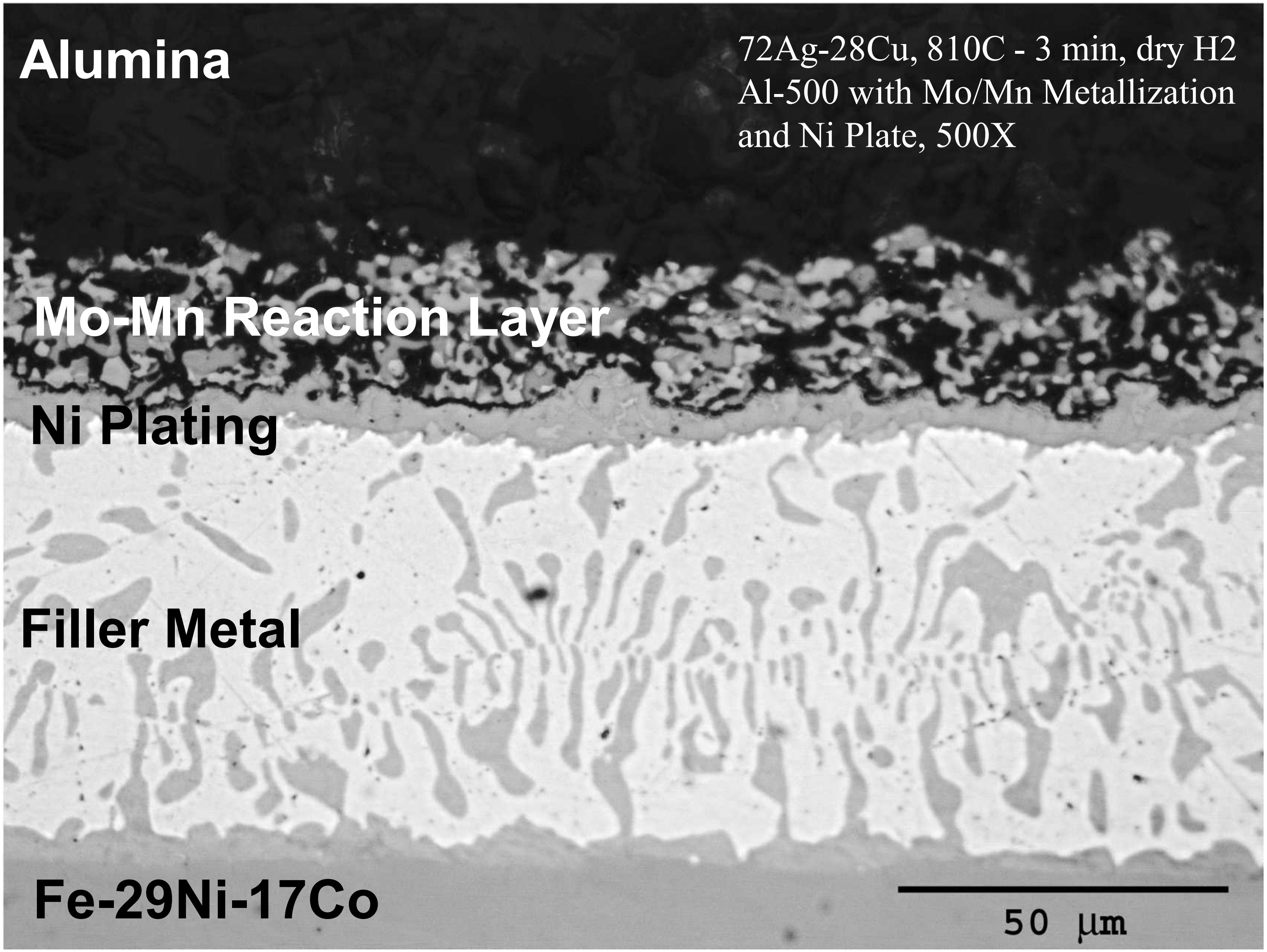
Molybdenum-Manganese / Nickel Plate



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Thin-Film Metallization

Procedure:

A combination of materials, usually 2 or 3, are deposited onto the nonmetallic surface using a physical vapor deposition (PVD) method such as evaporation or sputtering.

The first layer deposited, usually titanium, is typically 0.05-0.25μm thick.

The top layer is a noble metal such as gold, platinum or palladium that is 0.25-1.0μm thick.

Occasionally an additional layer is used as a diffusion barrier layer. When used it is applied prior to the noble metal layer.

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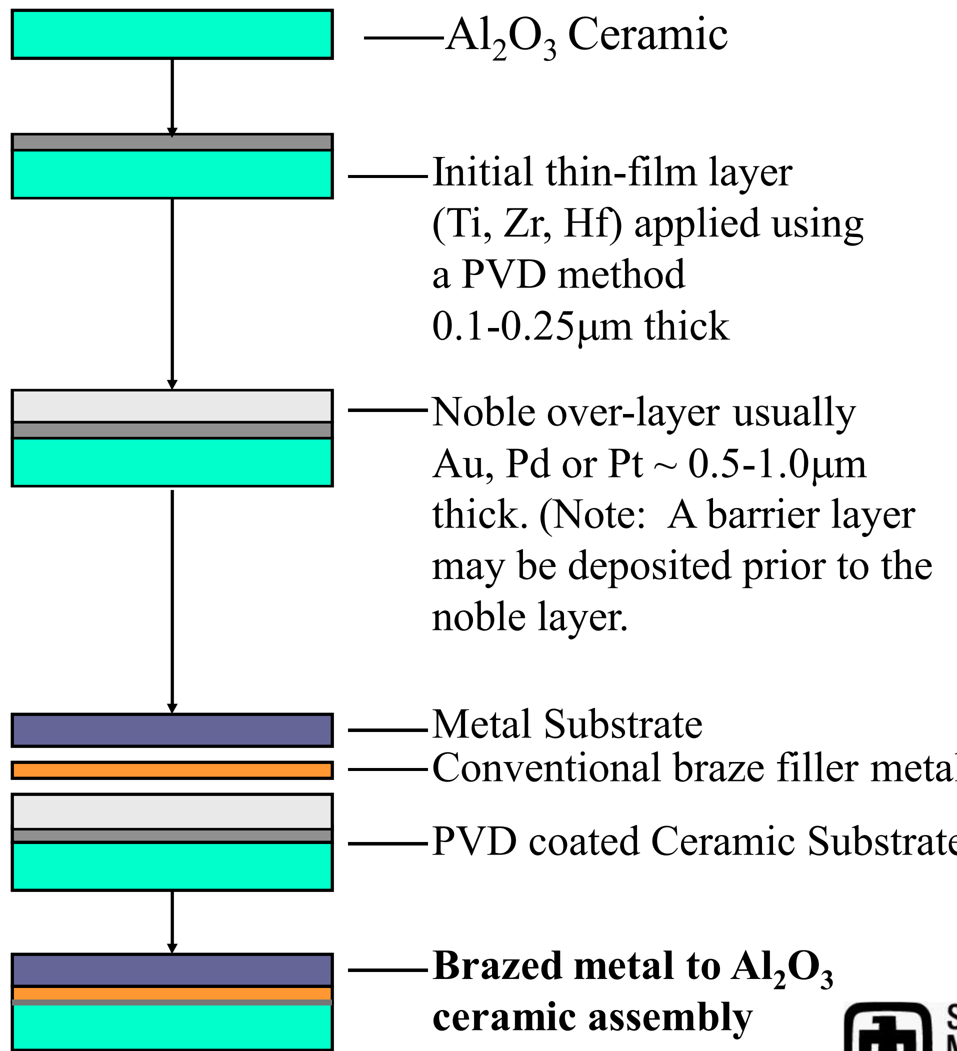
Thin-Film Metallization

Advantages

- Materials Variety
- Proven history
- Easily brazed using standard filler metals

Disadvantages

- Requires specialized equipment
- Masking required
- Size constraints



Thin-Film Metallization

ASTM-F19 Tensile Button Test Results

Filler Metal	Substrates	Thin-Films	Brazing Temperature/Time	Furnace Atmosphere	Tensile Strength
50Au/50Cu	94% Alumina Fe-29Ni-17Co	0.25mmTi/ 0.5mmAu	1000ºC/3 minutes	Dry Hydrogen	14.8 ksi
50Au/50Cu	94% Alumina Fe-29Ni-17Co	0.25mmTi/ 0.5mmAu	1020ºC/10 minutes	Dry Hydrogen	12.9 ksi
72Ag-28Cu	94% Alumina Fe-29Ni-17Co	0.25mmTi/ 0.5mmAu	810ºC/3 minutes	Dry Hydrogen	13.0 ksi
50Au/50Cu	94% Alumina Fe-29Ni-17Co	0.25mmTi/ 0.02mmPd/ 0.5mmAu	1000ºC/3 minutes	Dry Hydrogen	16.1 ksi
50Au/50Cu	94% Alumina Fe-29Ni-17Co	0.25mmTi/ 0.02mmPd/ 0.5mmAu	1020ºC/10 minutes	Dry Hydrogen	11.8 ksi
63Ag-27Cu-10In	94% Alumina Fe-29Ni-17Co	0.25mmTi/ 0.5mmPt	755ºC/2 minutes	UHP Argon	13.2 ksi
63Ag-27Cu-10In	951 LTCC Fe-29Ni-17Co	0.25mmTi/ 0.5mmPt	755ºC/2 minutes	UHP Argon	8.2 ksi
63Ag-27Cu-10In	951 LTCC Fe-29Ni17Co	0.5mmTi/ 0.5mmAu	755ºC/5 minutes	UHP Argon	6.5 ksi
63Ag-27Cu-10In	951 LTCC Fe-29Ni-17Co	0.5mmTi/ 0.5mmPd	755ºC/5 minutes	UHP Argon	3.8 ksi

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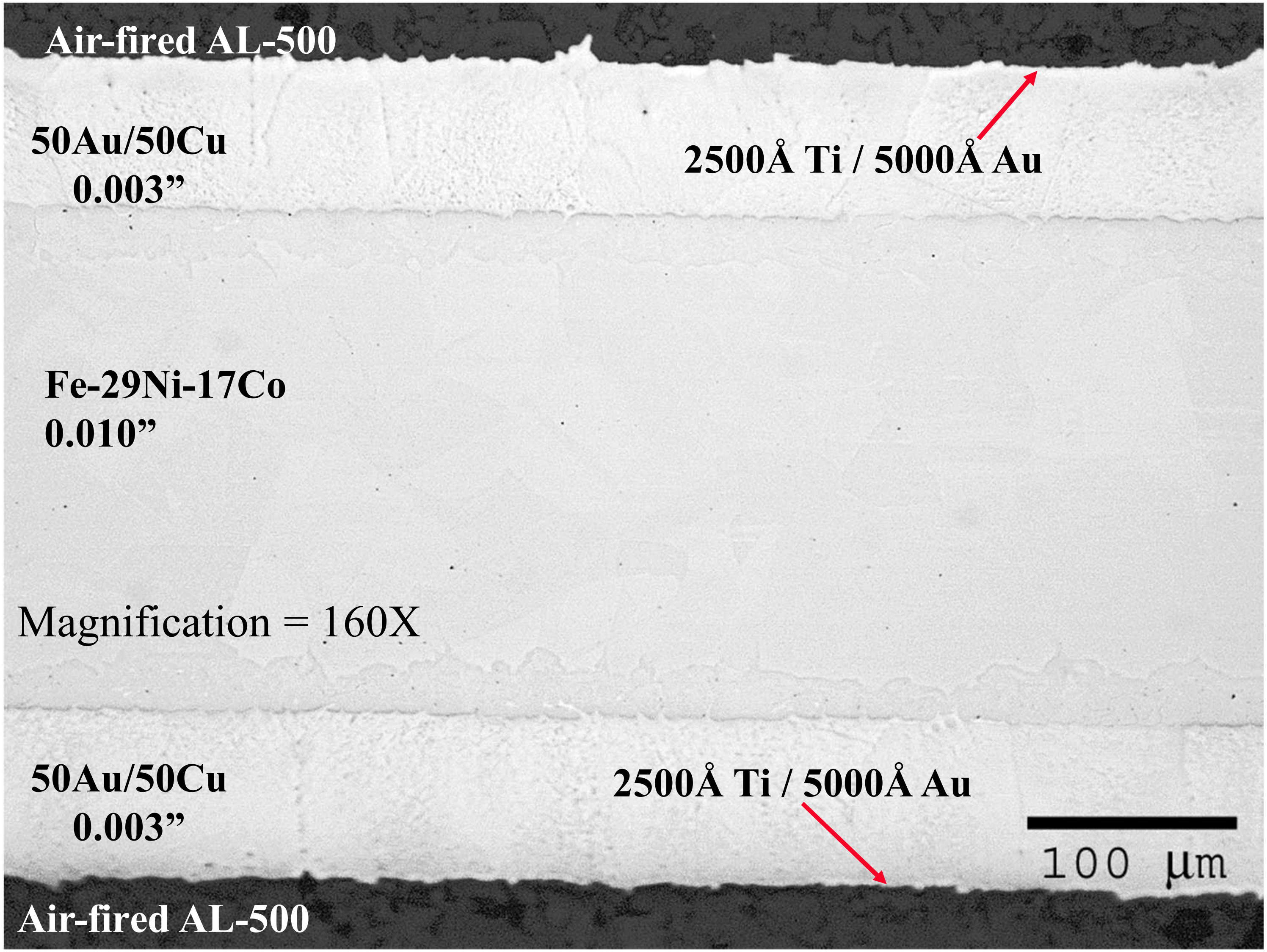
Thin-Film Metallization



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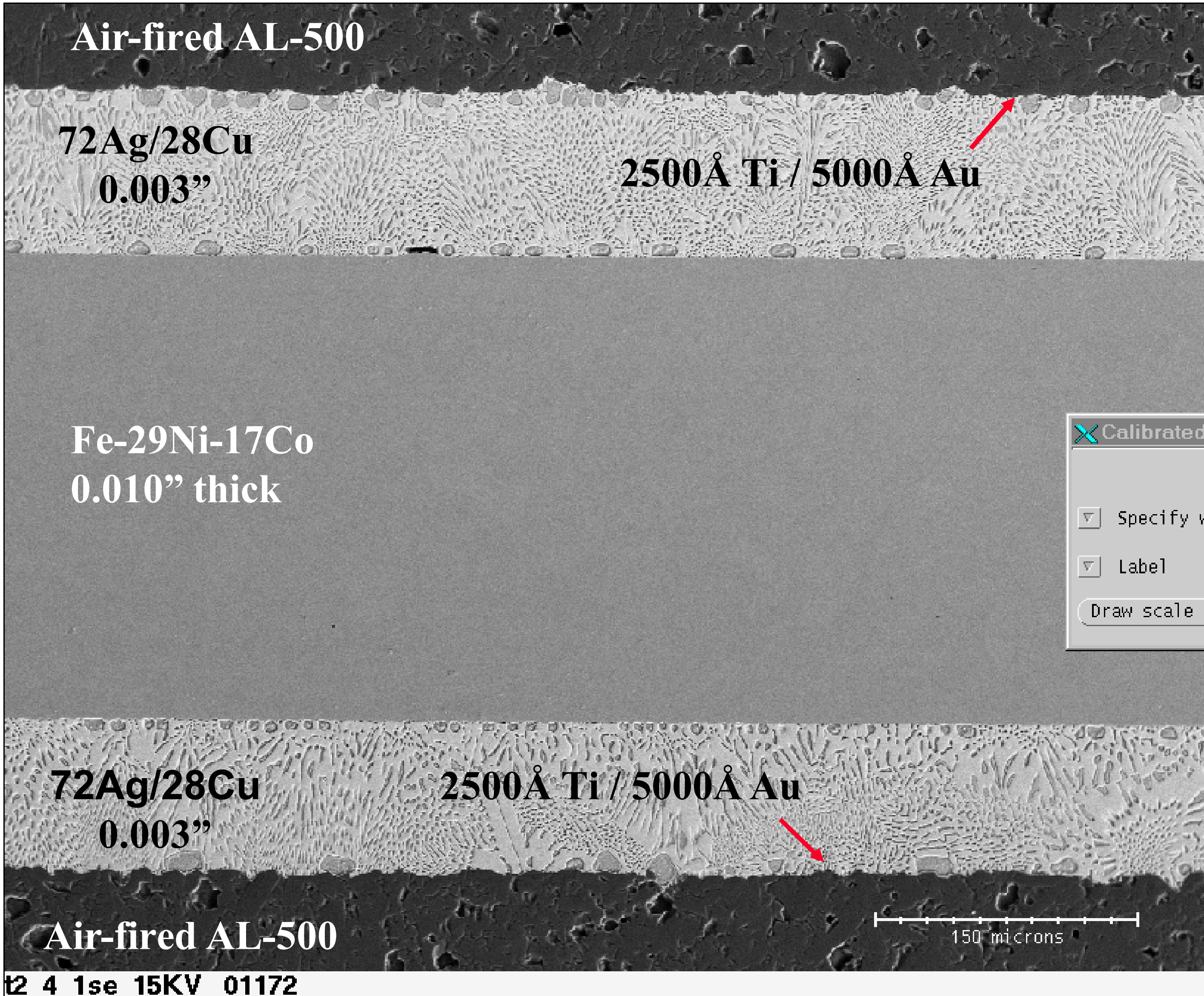
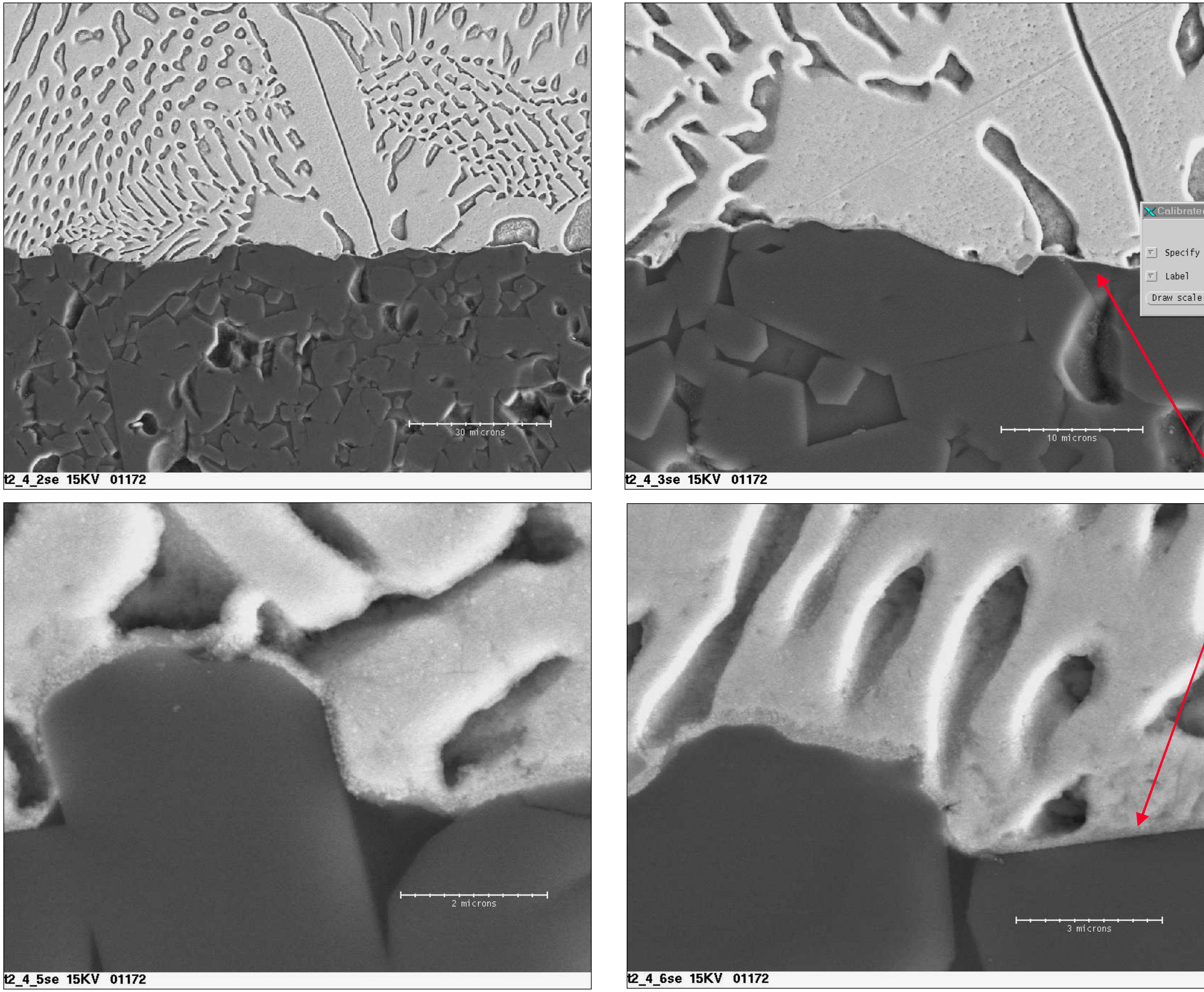
Thin-Film Metallization



Thin-Film Metallization



Sample T-2-4: 810°C-3 min, Dry H2 2500Å Ti/5000Å Au on Air Fired Al-500

Ti/Au Thin-Film Layer

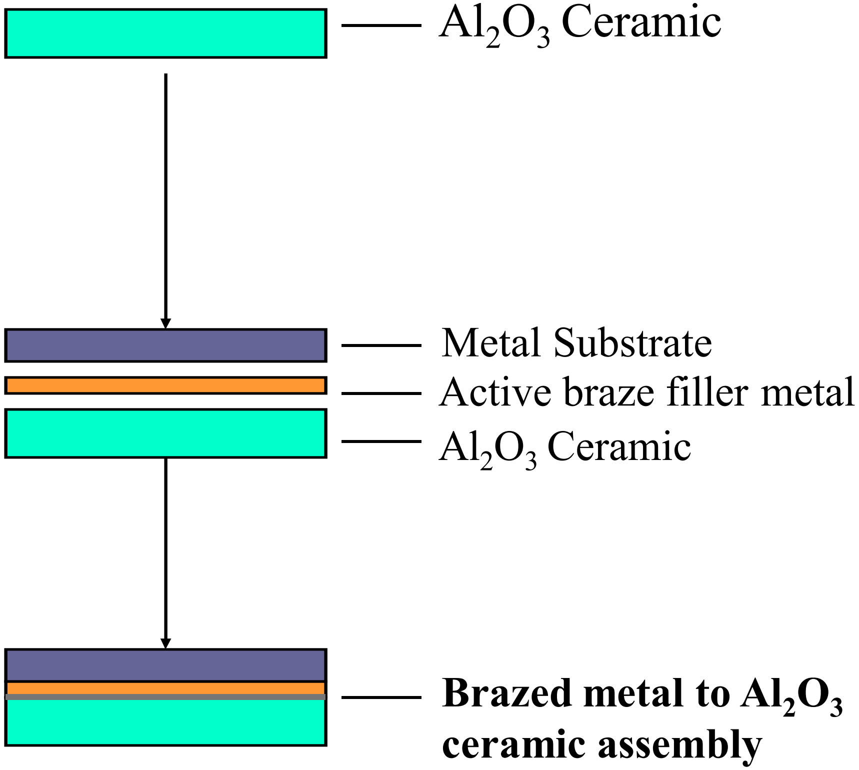
Active Filler Metal Brazing

Procedure

- Active filler metal brazing lets one use standard brazing techniques when making metal to ceramic brazements.
- The metal and nonmetal substrates are cleaned, the active filler metal preform or paste is applied within the braze joint area.
- The braze is performed, usually in an inert or ultra-high vacuum environment.

Active Filler Metal Brazing

Advantages
- Ease of use
- Variety of filler metal schemes & temperature ranges
- No specialized metallization equipment or processes required
- Easily brazed using standard filler metals



Disadvantages
- Requires specialized equipment/atmosphere control
- Not usable with all joint designs
- Size constraints

Active Filler Metal Brazing
ASTM-F19 Tensile Button Test Results

Filler Metal	Non-metal Substrate	Metal Substrate	Brazing Temperature	Furnace Atmosphere	Tensile Strength
59.00Ag-27.25Cu-12.5In-1.25Ti	94% Alumina	Fe-29Ni-17Co	998-1028ºC/2-3 min 1000ºC suggested	Vacuum	14.5ksi ±1.8ksi
59.00Ag-27.25Cu-12.5In-1.25Ti	DuPont 951 LTCC	Fe-29Ni-17Co	755ºC/5 min	Vacuum	8 ksi ±1.8ksi
63.00Ag-35.25Cu-1.75Ti	94% Alumina	Fe-29Ni-17Co	825-1040ºC/2-10 minutes	Vacuum	11-16 ksi
63.00Ag-35.25Cu-1.75Ti	94% Alumina	Fe-29Ni-17Co	1040ºC/2 minutes	Dry Hydrogen	14.5ksi
63.00Ag-35.25Cu-1.75Ti	94% Alumina	Fe-29Ni-17Co	825-1040ºC/2-10 minutes	Partial pressure argon	11-14 ksi
62Cu-35Au-2Ti-1Ni	94% Alumina	Fe-29Ni-17Co	1006-1026ºC 6-8 minutes	Vacuum	11-14 ksi
97Ag-1Cu-2Zr	94% Alumina	Fe-29Ni-17Co	963ºC, 3 minutes above liquidus	Partial pressure argon, 2 torr	21.3ksi ±0.2ksi
97Ag-1Cu-2Zr	94% Alumina	Fe-29Ni-17Co	990ºC/5 minutes	Dry Hydrogen	15.4ksi ±3.2ksi
62Cu-35Au-2Ti-1Ni	94% Alumina	Fe-29Ni-17Co	810ºC/3 minutes	Vacuum	14.3ksi

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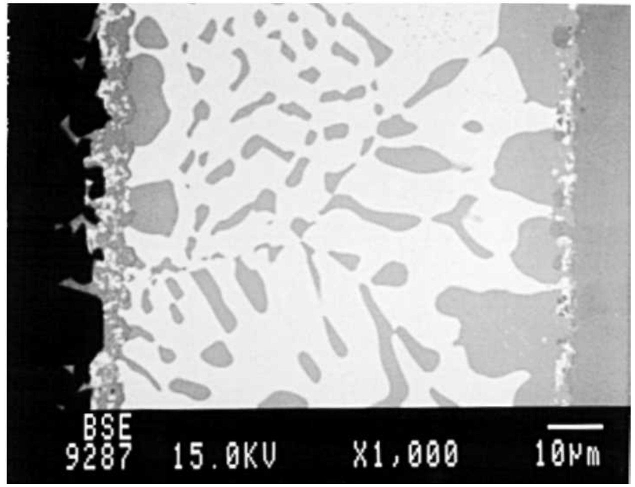
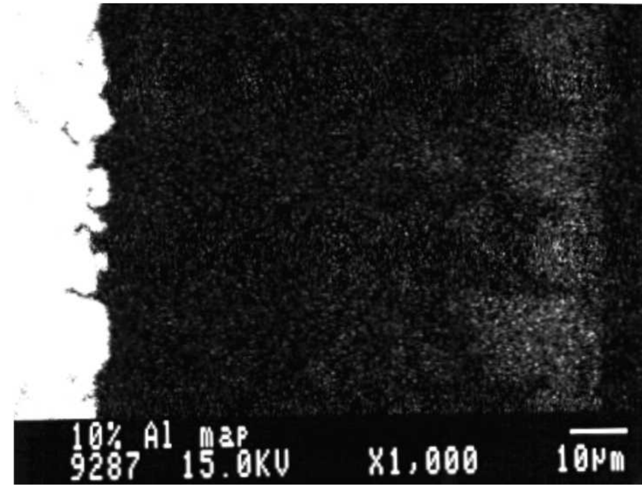
Active Filler Metal Brazing
97Ag-1Cu-2Zr

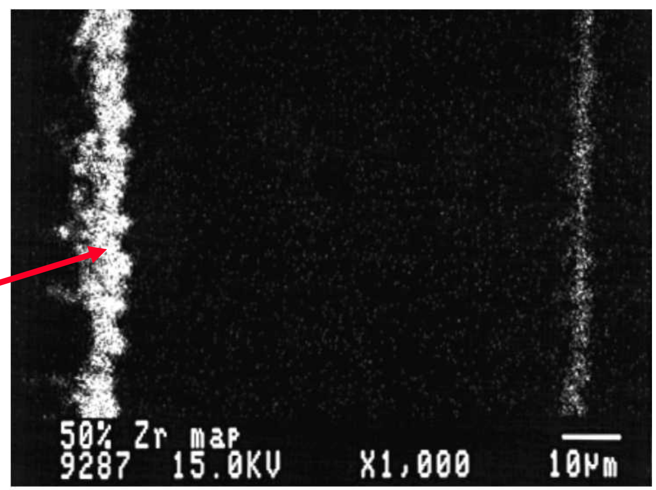
BSE and Probe Maps for a sample brazed with 97Ag-1Cu-2Zr at 950°C, 5 min in a 12 torr argon partial pressure atmosphere

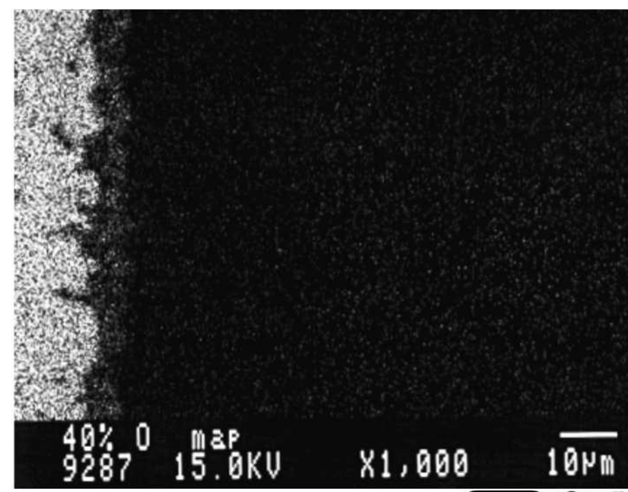




Alumina Braze Fe-29Ni-17Co **Alumina Braze Fe-29Ni-17Co**

Note that the Zr has successfully migrated to the oxide ceramic surface to allow the filler metal to "wet" properly.





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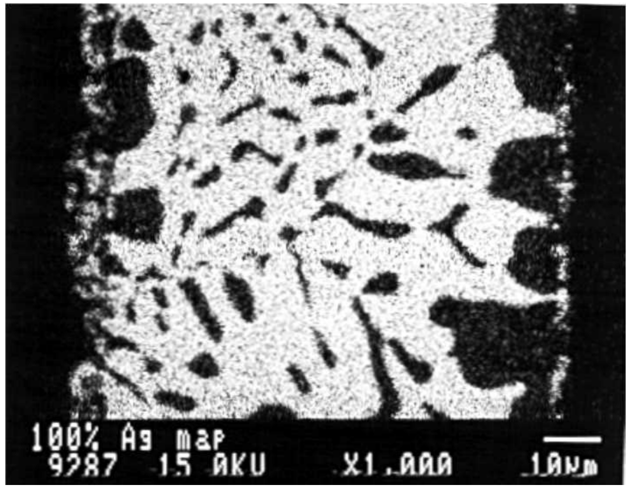
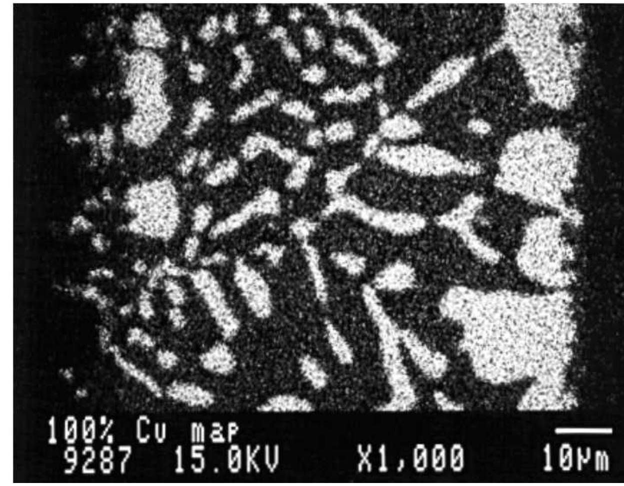
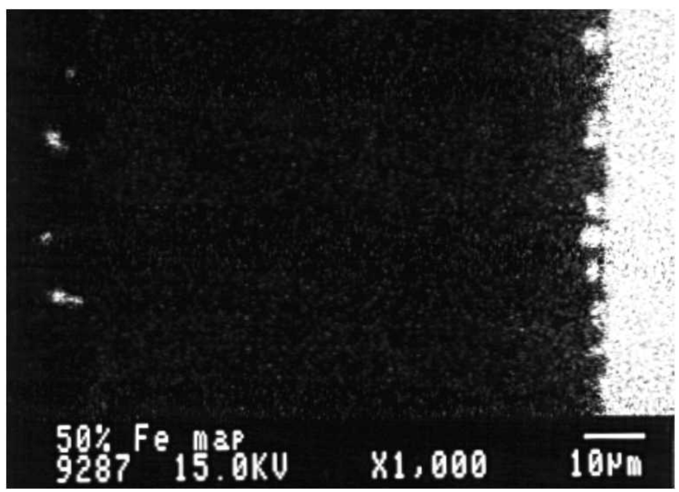
Active Filler Metal Brazing
97Ag-1Cu-2Zr

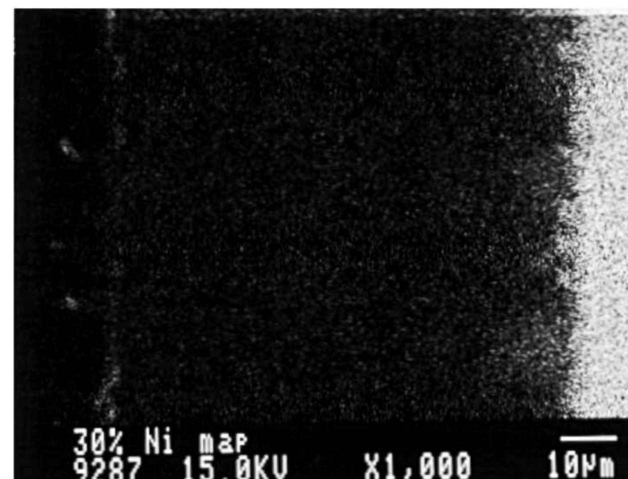
BSE and Probe Maps for a sample brazed with 97Ag-1Cu-2Zr at 950°C-5 minutes in a partial pressure atmosphere of 12 torr argon



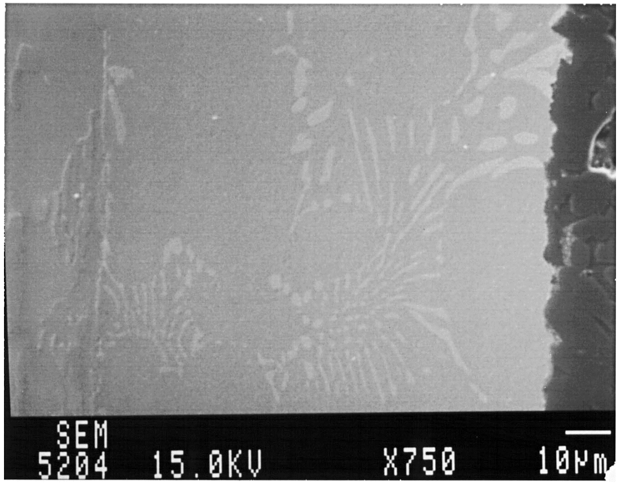


Alumina **Braze** **Fe-29Ni-17Co** **Alumina** **Braze** **Fe-29Ni-17Co**

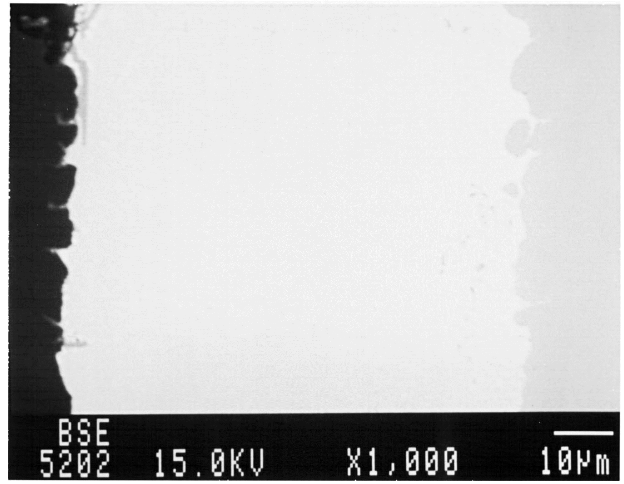




Active Filler Metal Brazing 62Cu-35Ag-2Ti-1Ni

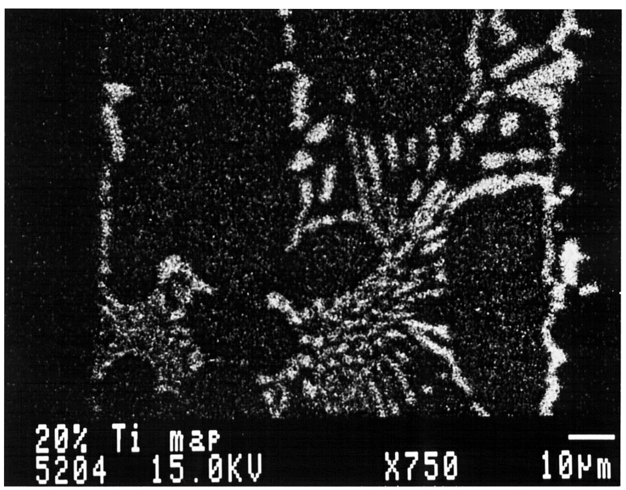


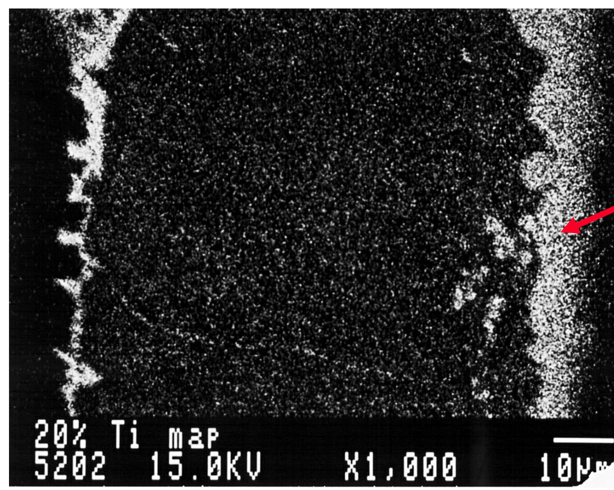
Moly Braze Alumina



Alumina Braze Fe-29Ni-17Co

Comparison of molybdenum vs. Fe-29Ni-17Co metal members.





Note titanium penetration into Fe-29Ni-17Co

Reference: J. J Stephens et all - *Elevated Temperature Mechanical Properties of the 62Cu-35Au-2Ti-1Ni Braze Alloy*, 2004 AWS

Direct Brazing

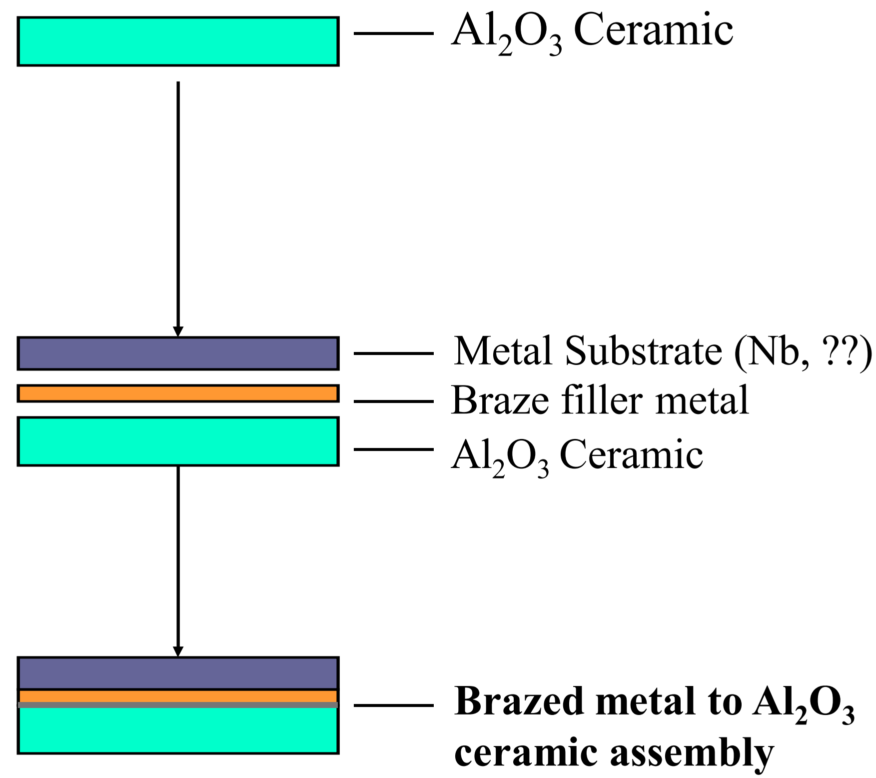
Procedure

- Direct brazing lets one use conventional braze filler metals and standard brazing techniques when making metal to ceramic brazements.
- Specific metal substrate and braze filler metals interact to form an adherent metallic oxide layer on an oxide ceramic material.
- The metal and nonmetal substrates are cleaned, the braze filler metal is applied within the braze joint area.
- The braze is performed, usually in an inert or ultra-high vacuum environment.

Direct Brazing

Advantages

- Ease of use
- Inexpensive
- Variety of filler metal schemes & temperature ranges
- No specialized metallization equipment or processes required
- Easily brazed using standard filler metals



Disadvantages

- Requires specialized equipment/atmosphere control
- Not usable with all joint designs

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Direct Brazing

ASTM-F19 Tensile Button Test Results

Filler Metal	Non-metal Substrate	Metal Substrate	Brazing Temperature	Furnace Atmosphere	Tensile Strength
62Cu-35Au-3Ni	94% Alumina	Niobium	1058ºC/3 min	Vacuum	8.8ksi ±1.0ksi
92Au-8Pd	94% Alumina	Niobium	1270ºC/4 min	Vacuum	12.8ksi ±1.8ksi
50Au-50Cu	94% Alumina	Niobium	1000ºC/3 min	Vacuum	8.8ksi ±0.8ksi

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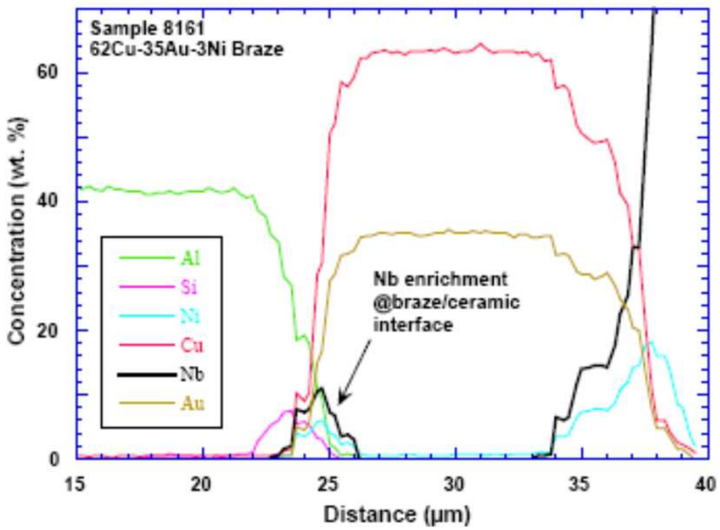
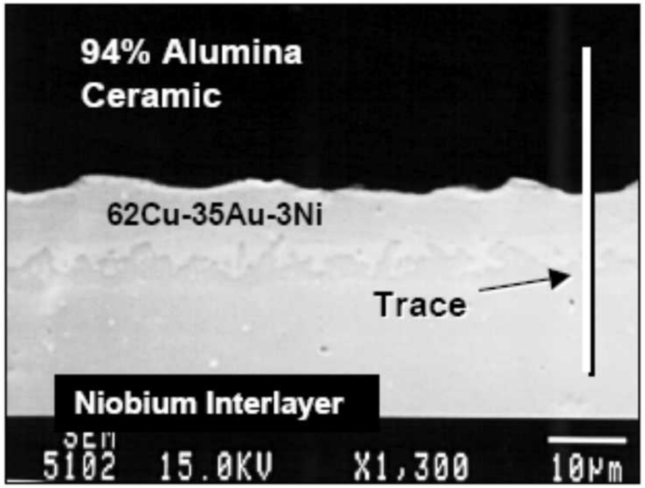
Direct Brazing

Requirement for successful braze joints:

1) Sufficient solubility of the metal member within the liquid braze alloy.
2) An "active" element within the metal member of the brazement.

This example shows how Niobium provides the "active" element to react with alumina ceramic.





Reference: J. J Stephens - *Metal-Ceramic Brazing for Hermetic Components, AWE Aldermasten, May 2001*

Summary

- Variety of methods can be used to make hermetic, strong metal to ceramic brazed assemblies.
- The use of conventional filler metals may be used when the ceramic surface is pre-metallized.
- A limited set of conventional filler metals form sufficient bond strength when used in conjunction with specific base metal combinations such as niobium and titanium.
- Active braze filler metals can be used as a replacement system for most metal to ceramic brazed assemblies with no loss of mechanical properties.
- Active and direct brazing techniques work best with butt or lap-style braze joint geometries.

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