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Microstructural characterization of Ti6Al4V/Al_2O_3 joints produced using Ag-Cu sputtered coated Ti foil

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Motivation

Increasing the applications of advanced ceramics for functional structures for:

- Having high thermal stability, stiffness and wear resistance
- Overcoming shortcomings related with high production costs of large or complex components used in
  - Aerospace, automotive, and chemical industries

Joining ceramic materials to metallic parts is a strategy

- However, it is not an easy task because metals & ceramics have different properties, e.g.:
  - Coefficient of thermal expansion
  - Wettability with liquid metal

Brazing technique is a method

- It requires lower temperature, pressure and holding time that it is required for diffusion bonding process
- Brazing has a merit of joining irregular dimensions
- Generally, it leads to the development lower residual stresses than other joining processes

Motivation

Brazing involves

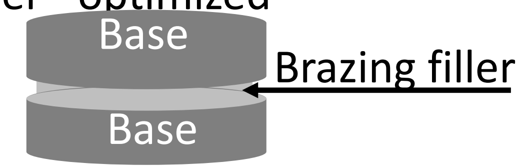
- Joining two components by melting a brazing filler (> 450 °C) that wets and reacts with both base materials, it is traditionally carried out by a torch and the brazing filler

Shortcomings

- Reaction products formed at the interface may limit the operating temperature of joints to 300/350 °C, e.g. the extensive formation of (Ag), when Ag-based brazing fillers are used

Diffusion brazing involves

- Placing a brazing filler between two bases under optimized conditions:
  - Adequate heating apparatus
  - Proper heating temperature
  - Proper brazing filler



- During the heating period, the brazing filler material reacts with the components resulting in
  - the formation of phases with higher melting temperatures

Motivation

Brazing fillers

- Titatium base compositions like
  - Ti-Cu-Ni system
- Silver base compositions like
  - Ag-Cu system

A comparison

- Ti base brazing fillers require higher brazing temperatures (~1000 °C) than Ag base brazing fillers (~800 °C)
- Ag base brazing fillers induce the formation of (Ag) that can buffer residual stresses developed throughout the interface

Shortcomings

- Ag base brazing fillers leave (Ag) in the interface leading to a softening effect
- Therefore, ***for this study***, some Ag content of the brazing filler was replaced by Ti expecting to the elimination of (Ag)

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Objectives

This study involves

- Diffusion brazing of Al_2O_3 to Ti6Al4V by the use of a Ti(Ag/Cu) brazing filler

- Microstructural characterization of the brazed interface by scanning electron microscopy technique (SEM/BES/EDS)
  - Understanding the microstructure evolved at the joint interface
    - Evaluation of the formation of unwanted phases at the joint interface
  - Microstructure influences the mechanical properties of the joints and service life of the joined components

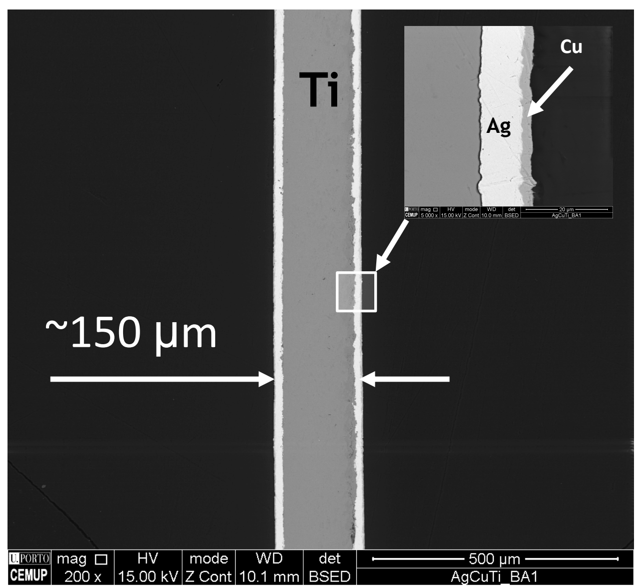
Materials

Bases have disk shape of ~5 mm height

- Ti6Al4V (ϕ 7.0 Mm)
- Al_2O_3 (ϕ 6.0 mm)

brazing filler

- Ag-Cu sputtered coated Ti foil (Ti/Ag-Cu)
  - 82.8Ti-12.4Ag-4.8Cu in wt.% (produced at CF-UM-UP)



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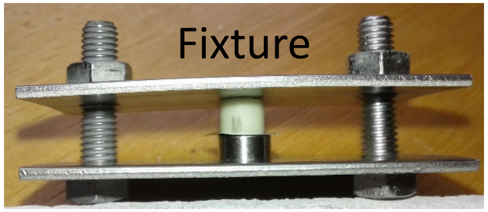
Processing

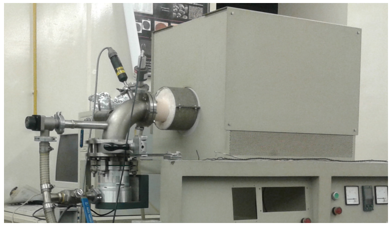
Cutting disks and grinding

- Ti base was ground by silicon carbide emery papers until 1000 mesh
- Alumina base was ground by the Aka disks until 6 µm diamond suspension

Brazing

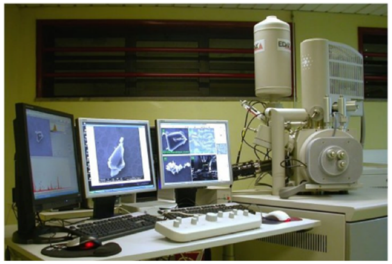


- Pieces were washed with alcohol, and dried
- Arranged in a metallic fixture which is fixed manually
- Heated in a resistance furnace assembled with a high vacuum pump at
  - 980 °C for 10 min at ~8×10^{-4} Pa



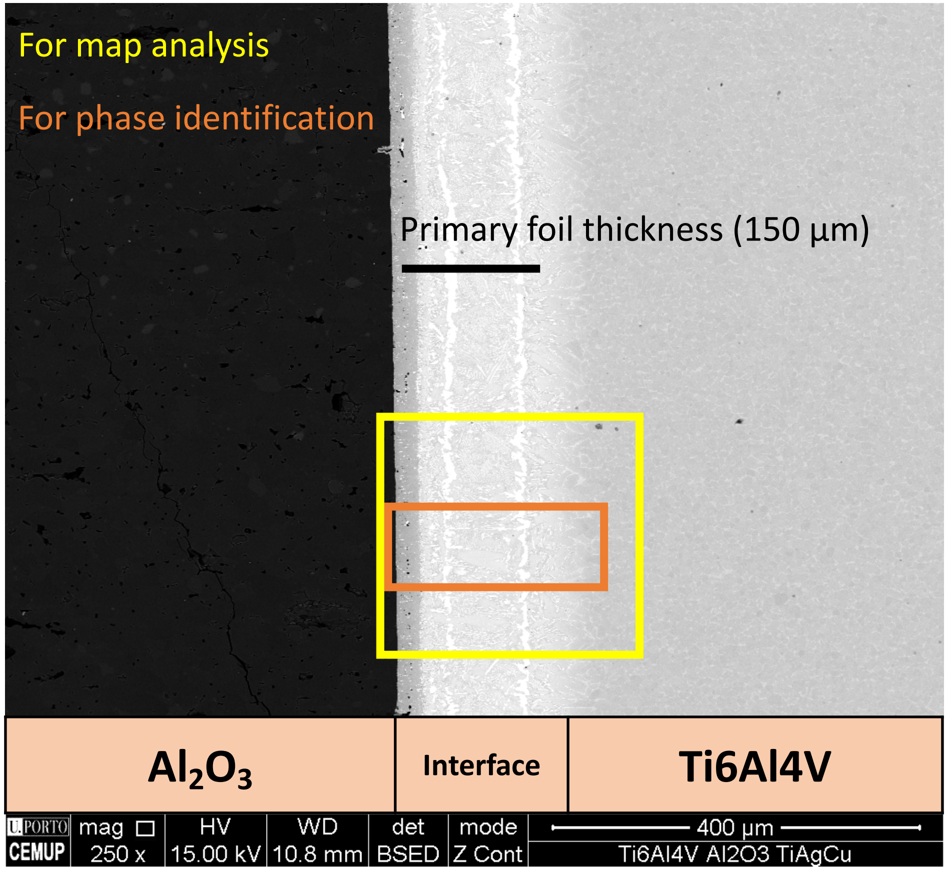
Evaluations

- Visual observation of the joints
- Grinding and polishing for microscopic observations by
  - Optical Microscope
  - SEM/BSE/EDS technique for phase identifications
- Providing a microhardness map of the interface



Microstructural characterization

- A sound joint with a very complex microstructure was obtained by diffusion brazing at 980 °C for 10 min at ~8×10^{-4} Pa



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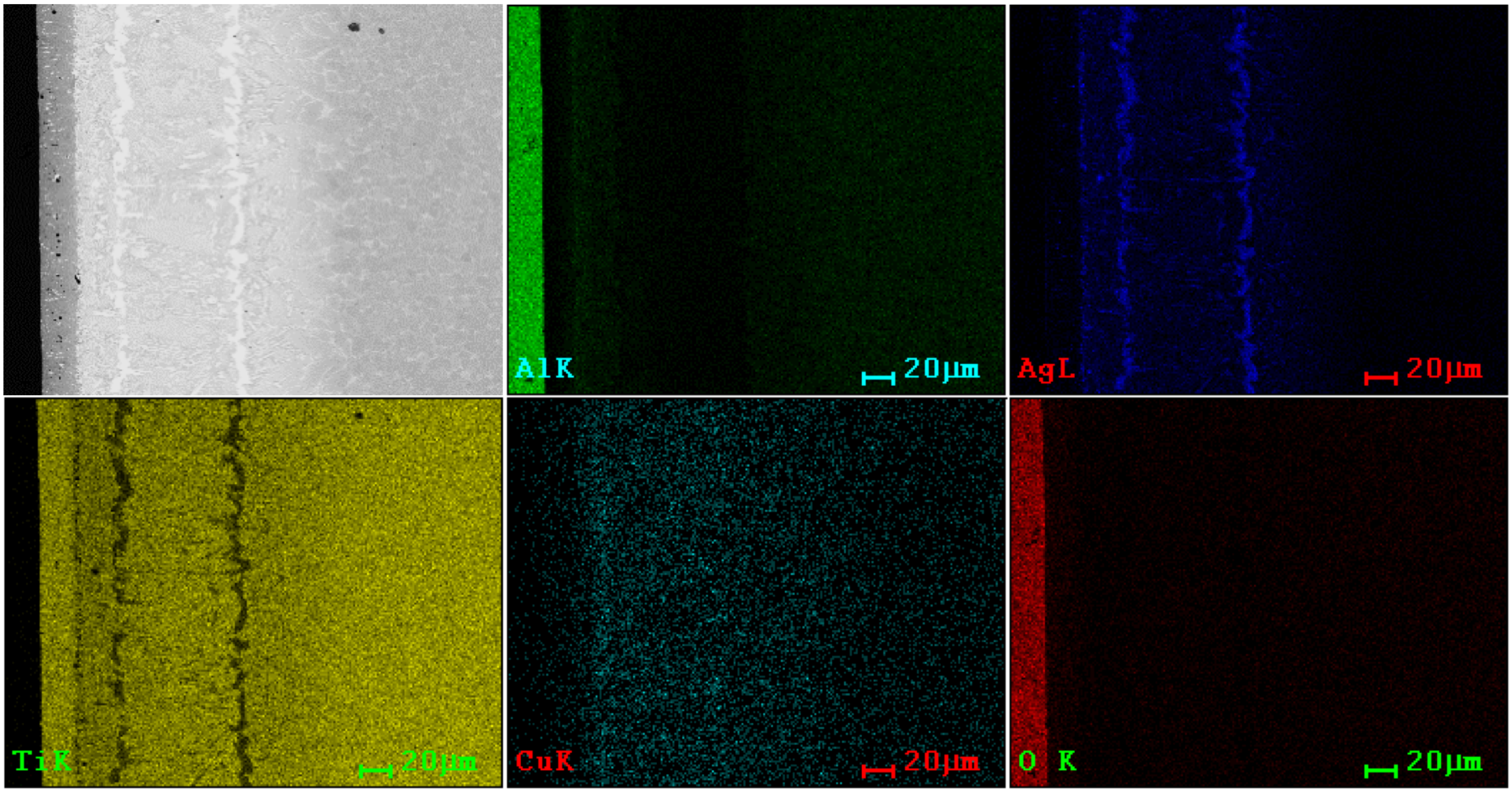
Microstructural characterization

- SEM/EDS map of a selected zone of the Al_2O_3 - Ti(Ag/Cu) - Ti6Al4V interface



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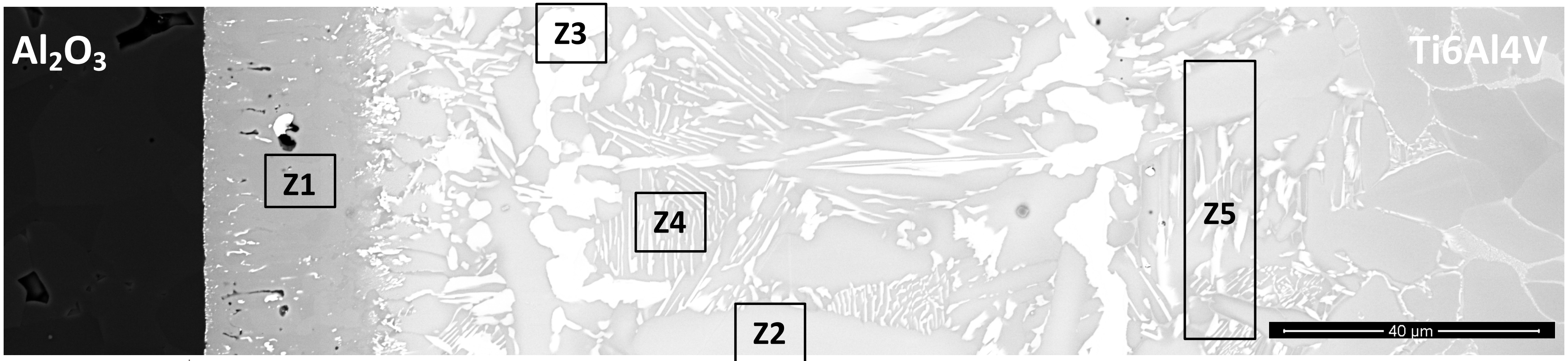
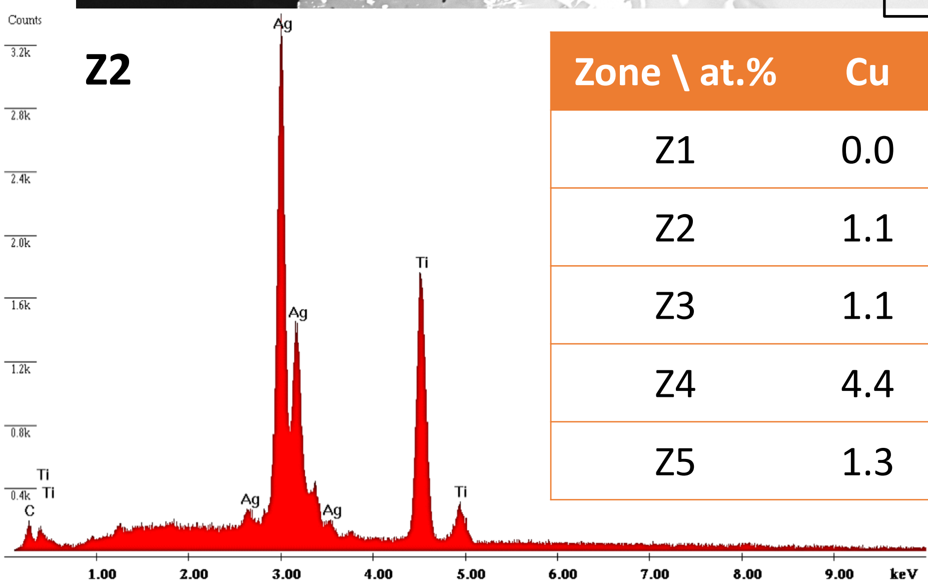
Microstructural characterization

- The pores are most probably inherited from the ceramic base





Zone \ at.%	Cu	Al	Ag	Ti	V	Possible phases
Z1	0.0	3.8	0.0	96.2	0.0	Ti(α)
Z2	1.1	1.9	6.0	91.0	0.0	Ti(α)
Z3	1.1	0.7	47.4	50.8	0.0	TiAg
Z4	4.4	2.1	8.2	85.3	0.0	Ti(α) + $Ti_2(Ag,Cu)$
Z5	1.3	6.7	6.9	83.0	2.1	Ti(α) + Ti_3Al + TiAg

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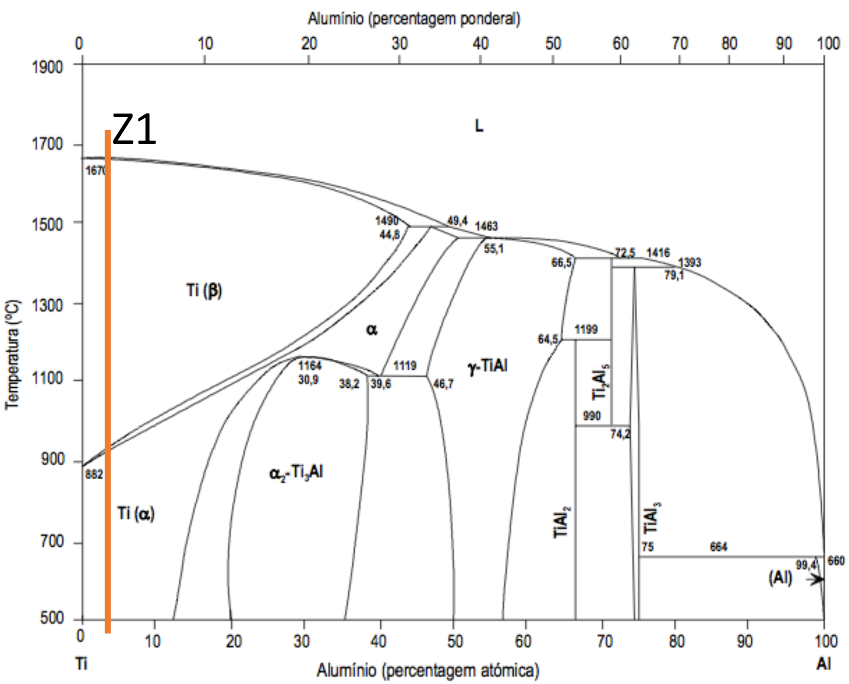
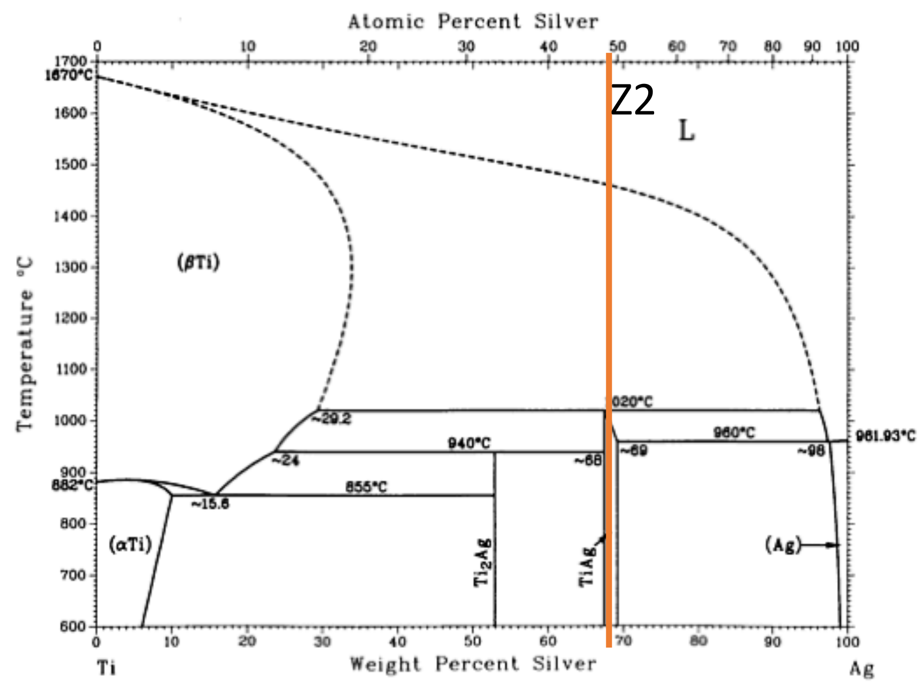
Microstructural characterization

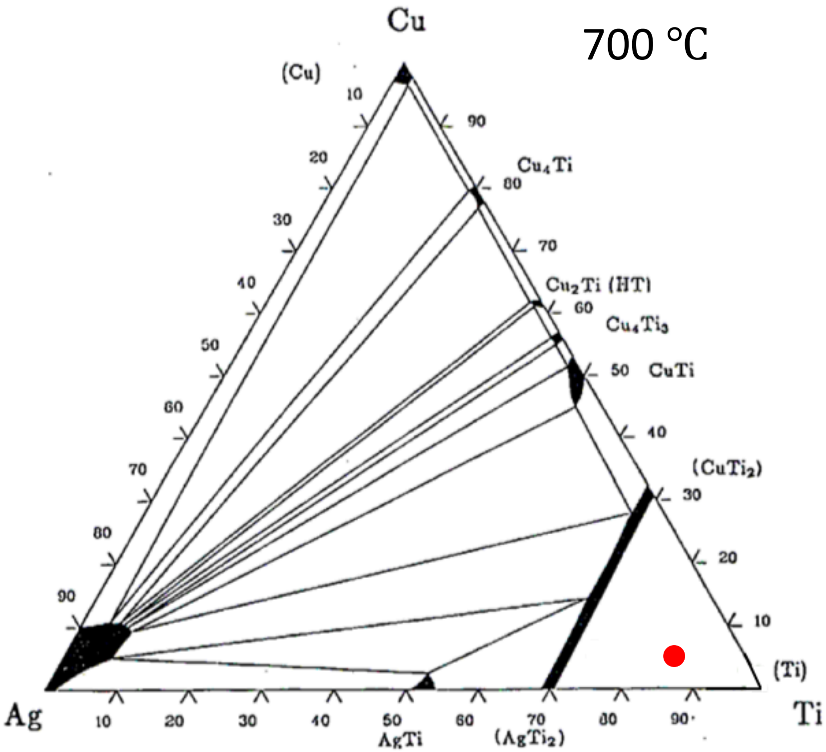
- Phase identification of interested zones



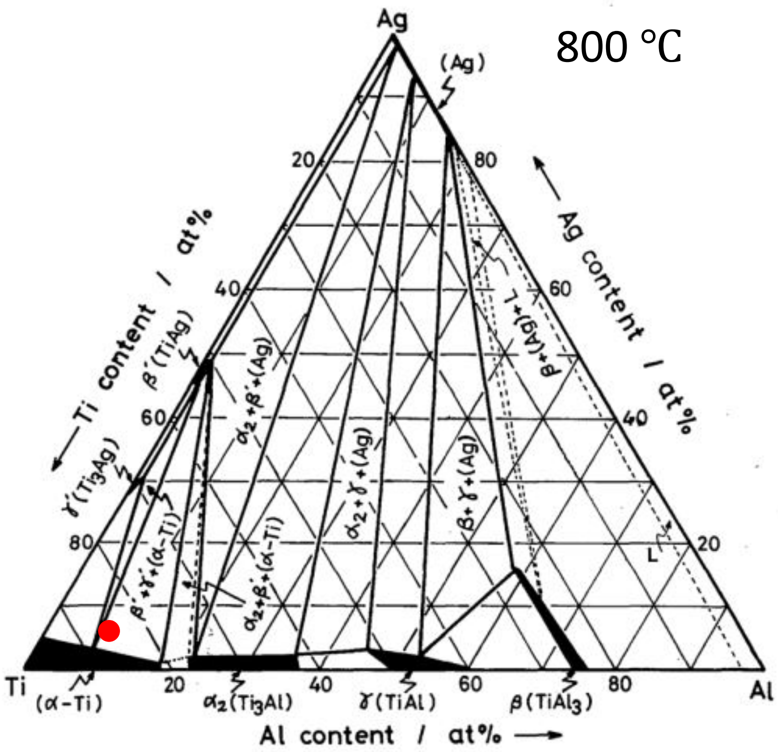


Microstructural characterization

- Phase identification of interested zones



700 °C



800 °C

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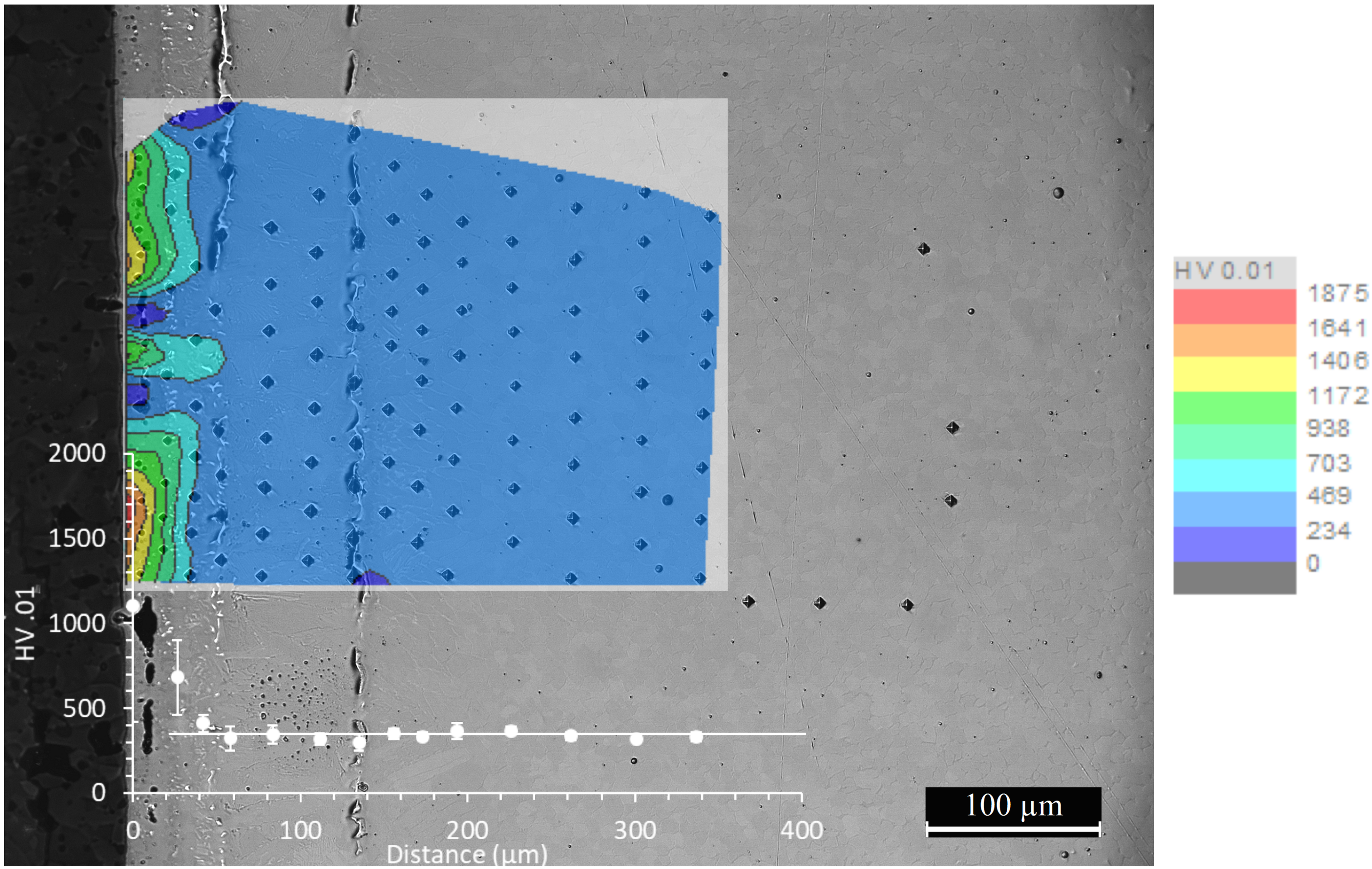
Microhardness map

- Al_2O_3 - Ti(Ag/Cu) - Ti6Al4V interface



Conclusions

- The diffusion brazing process was successfully performed for joining Al_2O_3 to Ti6Al4V by using a Ti(Ag/Cu) brazing filler at 980 °C at high vacuum

- The brazing process did not cause any defect (such as crack or porosity) at the joint interface

- Diffusion at the joint interface resulted in the formation of several intermetallic phases (TiAg, Ti_3Al, and $Ti_2(Ag,Cu)$)

- The formation of (Ag) was not detected

- The hardness transition from the alumina towards the Ti6Al4V base presents values larger or similar to the titanium base alloy

Future works

- Shear strength test
- SEM from fractured surfaces
- X-ray diffraction
- TEM & Electron diffraction pattern analyses
- Influence of thermal post treatments on the strength and microstructure

Acknowledgments

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Thanks for your attention