Joining Ti6Al4V to alumina by diffusion bonding using thin titanium layer

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Motivation

Joining of Ti alloys to ceramic materials can contribute to overcome the limitations that titanium alloys present when the application requires operating temperatures above 550 °C.

However, processing of ***high quality and high strength*** dissimilar joints between Ti alloys and ceramic materials constitutes a ***major challenge***!

- ***Brazing*** and ***diffusion bonding*** are the most reported technologies for metal to ceramic joining.
- ***Thin films*** have been successfully used as filler material for similar and dissimilar joining of metals by diffusion bonding

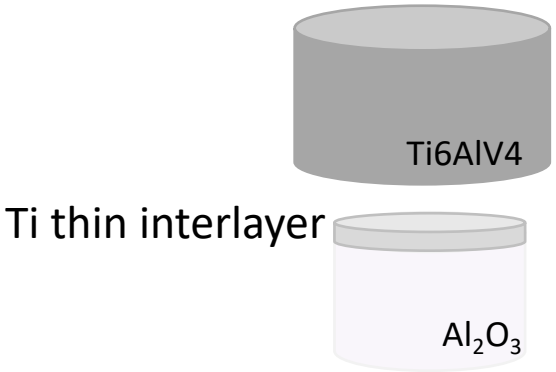
Objectives

- The objective of the present work consists in the study of the feasibility of joining Ti6Al4V to Al_2O_3 by diffusion bonding using titanium interlayer.

- Different titanium interlayer was investigated: thin film coated into base materials by magnetron sputtering and a freestanding thin foil for purposes.

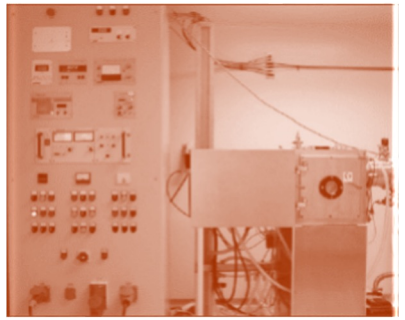
- Microstrutural and mechanical characterizations were performed

Base materials



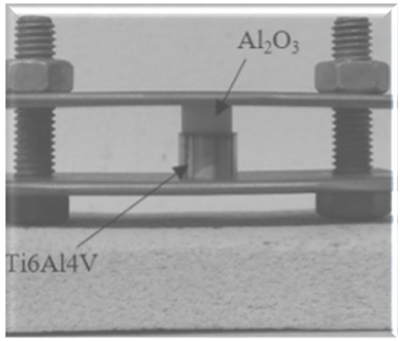
Experimental Procedure

Thin film deposition



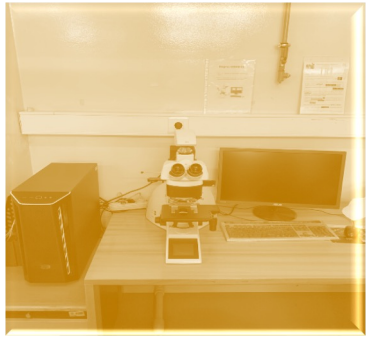
Ti monolithic thin films were deposited onto the polished surfaces of the alumina by direct current magnetron sputtering.

Diffusion bonding



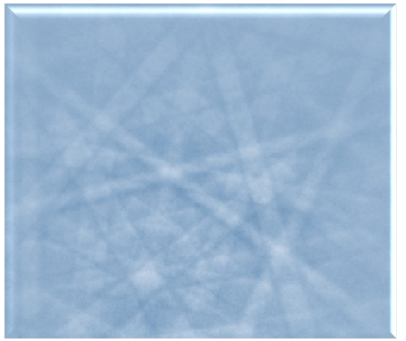
Diffusion joining was performed in the tubular horizontal furnace under vacuum, at 900, 950 and 1000 °C. Ti thin films deposited, and freestanding films were used as interlayers.

OM Characterization



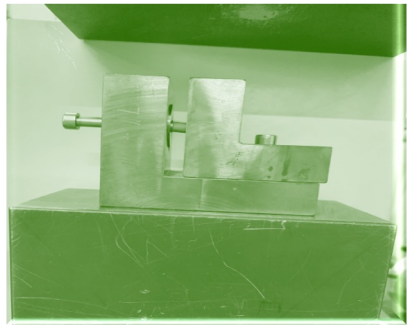
Optical microscopy (OM) was used to overview the soundness of the interface

SEM and EBSD



Microstructural and chemical characterization, cross-sections of interlayer and interface of the joints, were carried analyzed by SEM and EBSD.

Hardness and shear tests



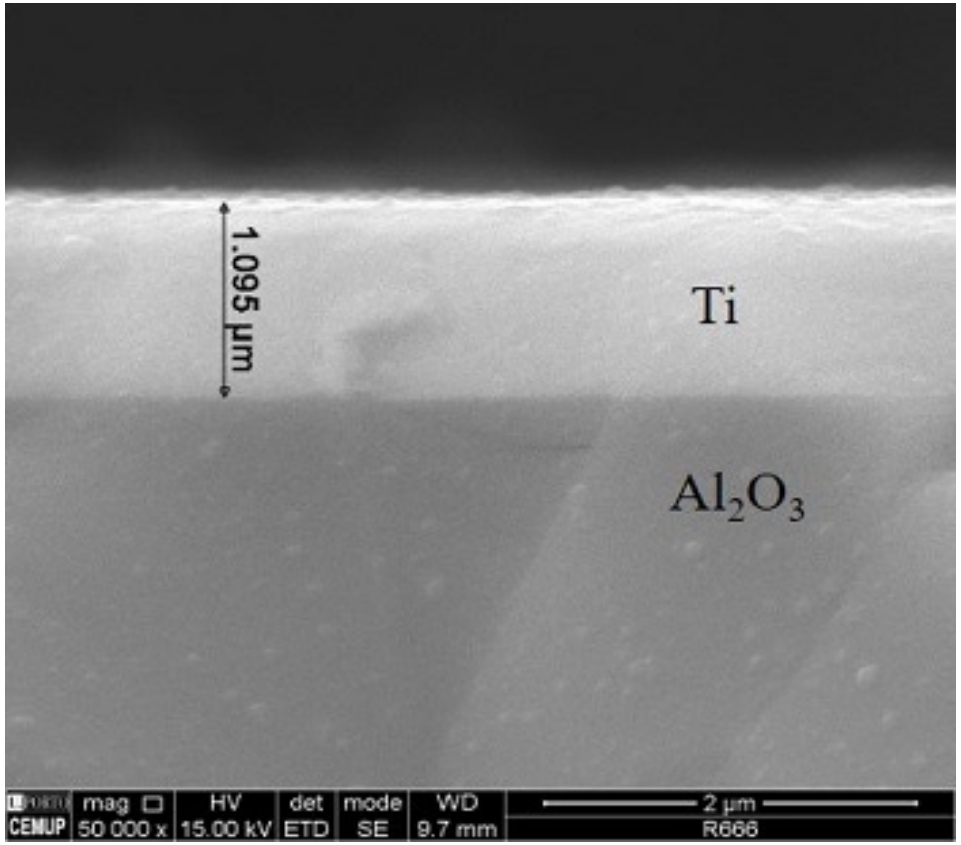
Nanoindentation tests were were performed in load control mode, at a maximum load of 5 mN.

The shear tests were performed at 1 mm/min.

Ti thin film adhesion

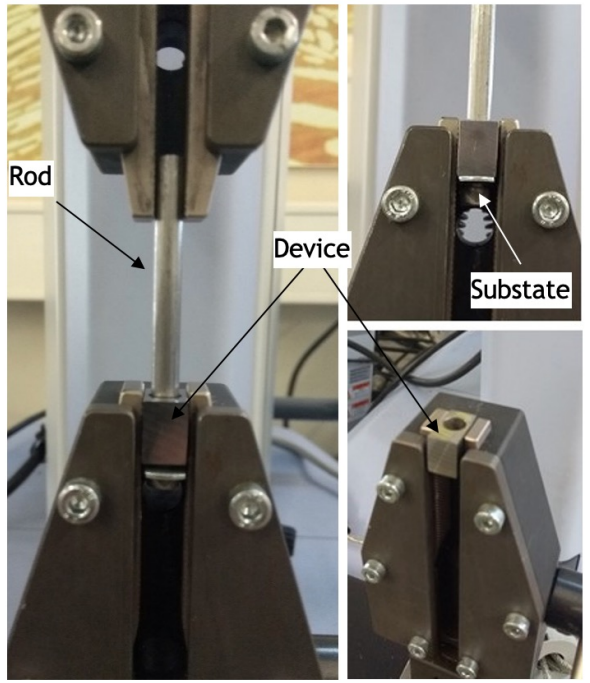
- The adhesion of the Ti films to Al_2O_3 plays an important role in the joints processed by diffusion bonding and is affected by the surface topography of the alumina substrate.

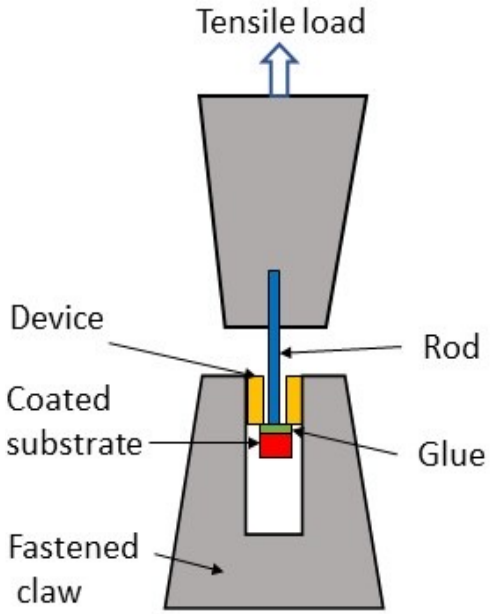
- The substrate's surface roughness was measured by profilometry, and the results show Ra values of 0.10 μm.



Ti thin film adhesion

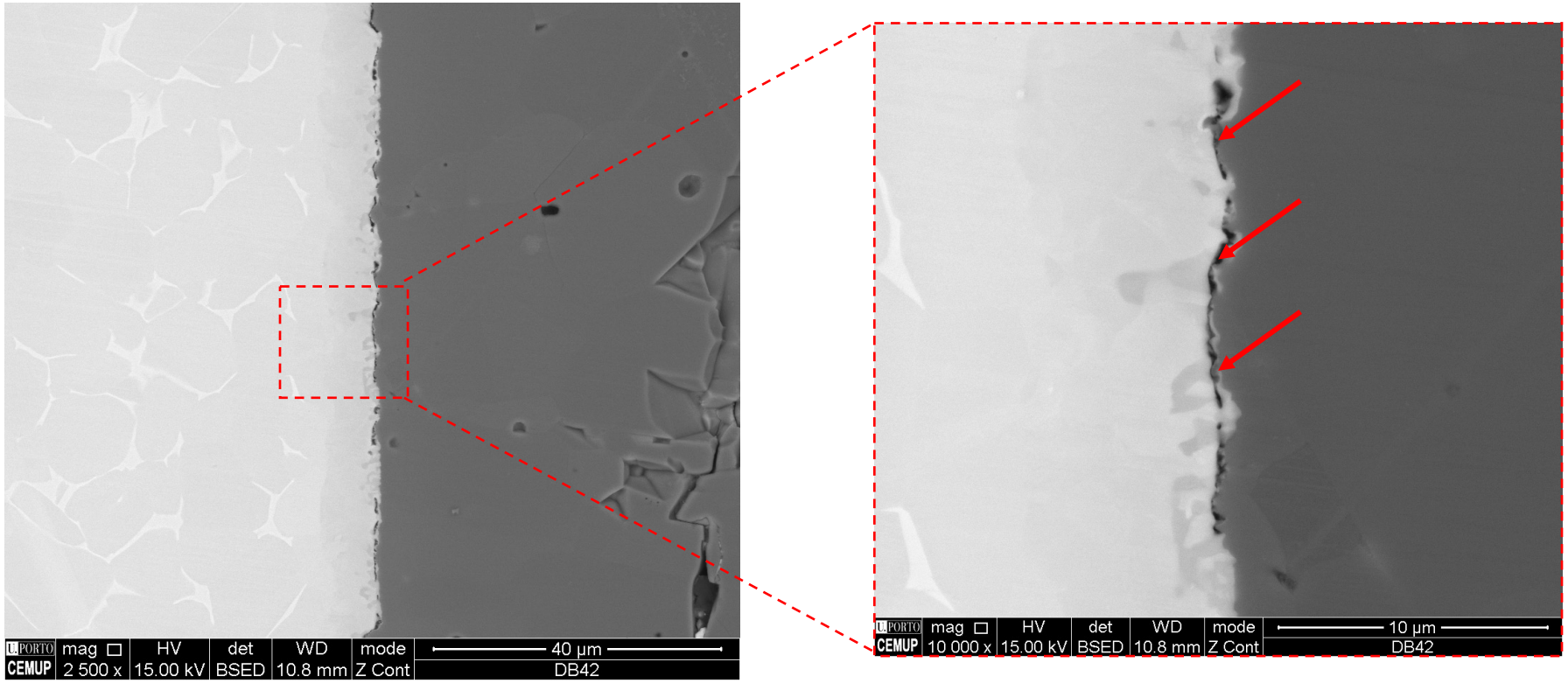
- The adhesion of the Ti films to Al_2O_3 plays an important role in the joints processed by diffusion bonding and is affected by the surface topography of the alumina substrate.
- The substrate's surface roughness was measured by profilometry, and the results show Ra values of 0.10 µm.
- The adhesion pull-off test shows average adhesion strength of 8 MPa, which is slightly below the 10 MPa referred in the literature. Therefore, this value seems enough for the envisaged application





$Ti6Al4V/Al_2O_3$ joints

Without interlayer

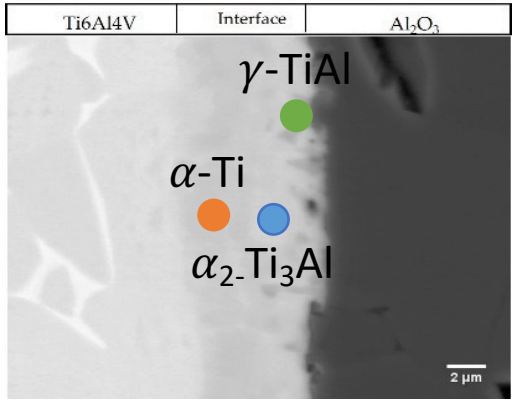


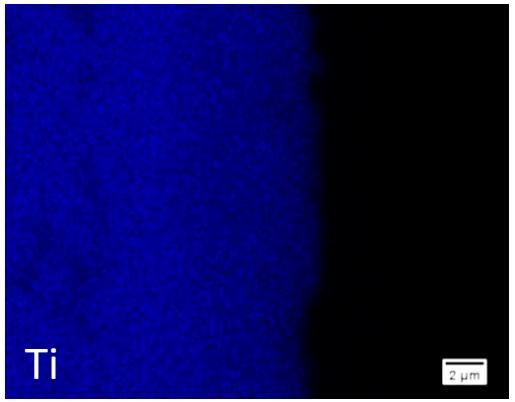
The joining between Ti6Al4V and Al_2O_3 without interlayer was apparently bond at 1000 °C with dwell times of 10 and 60 min with contact pressure.

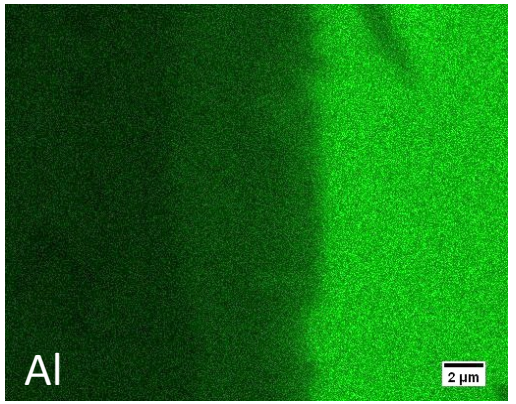
Some defects are observed at zones adjacent to Al_2O_3.

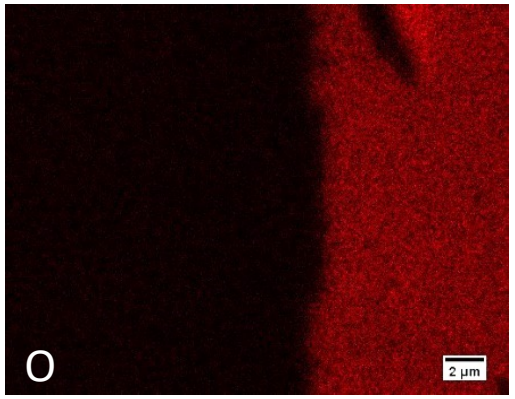
Ti6Al4V/Al_2O_3 joints

Without interlayer

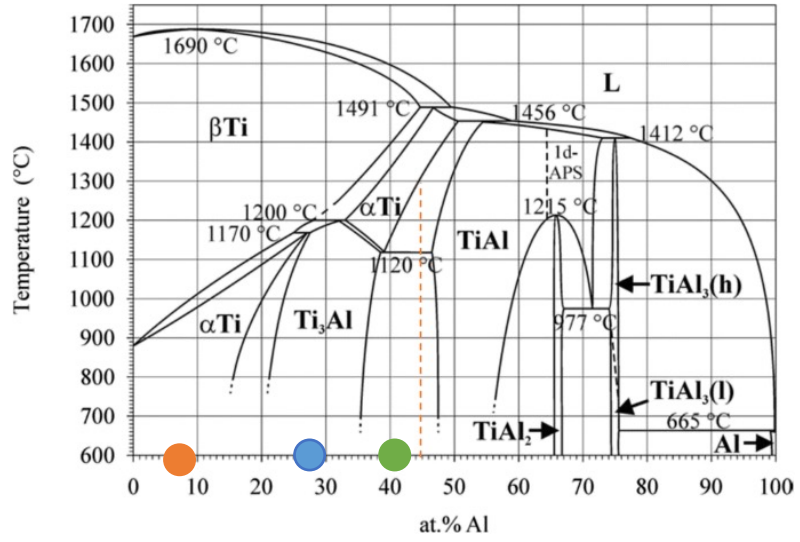








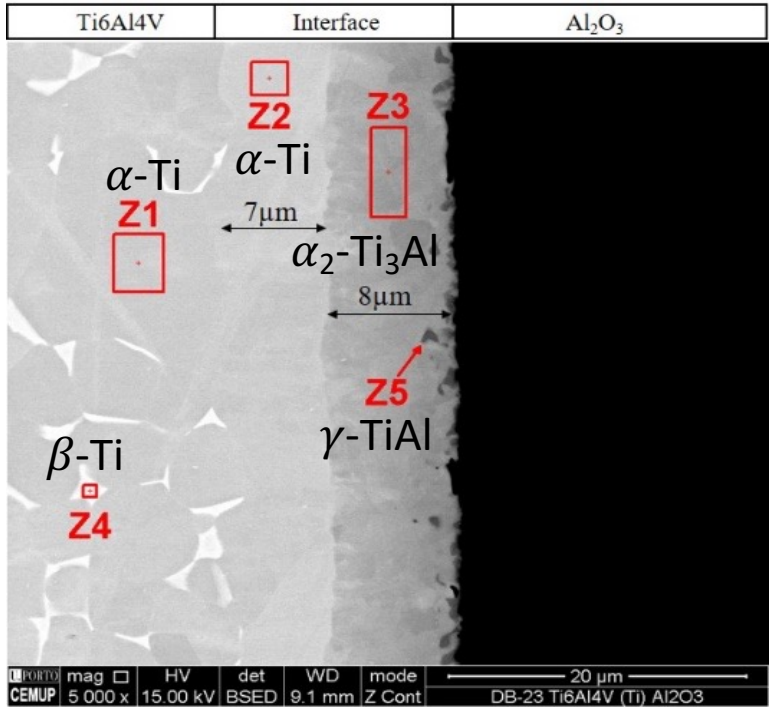
The EDS results show an intense diffusion of Al from Al_2O_3 and of Ti and Al from Ti6Al4V to the interface, despite the short bonding time



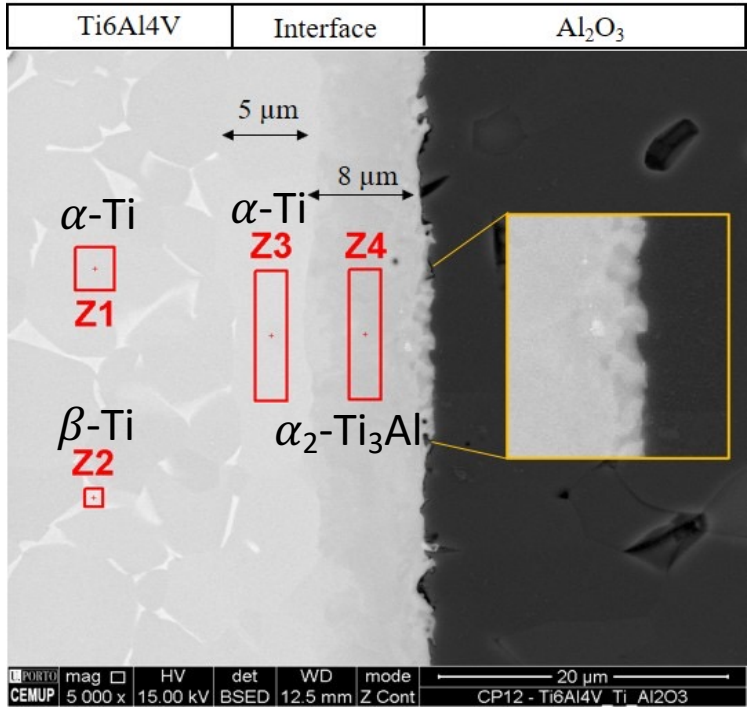
$Ti6Al4V/Al_2O_3$ joints

Ti thin film

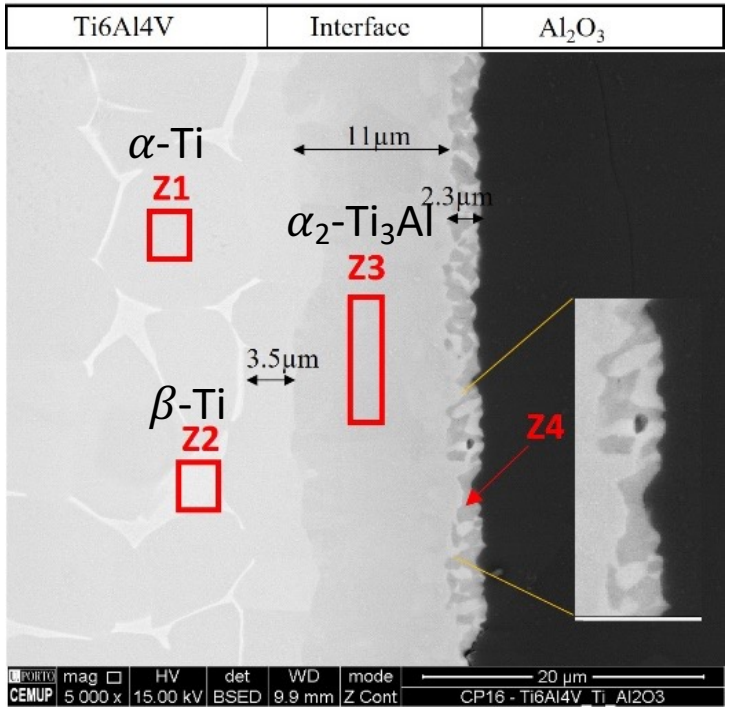
950 °C/ 60 min



1000 °C/ 10 min



1000 °C/ 60 min

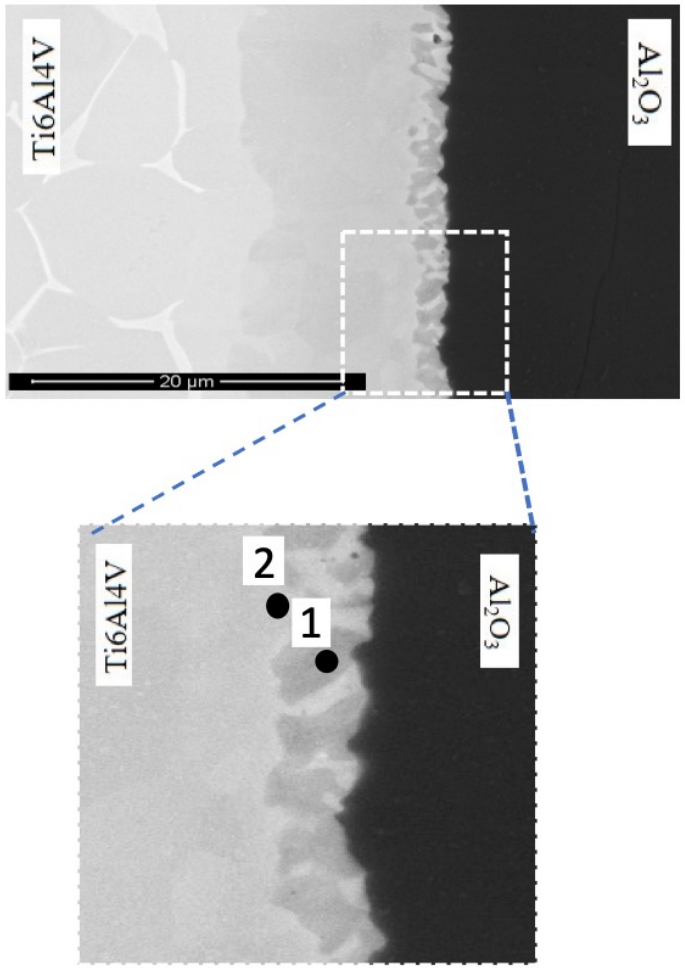


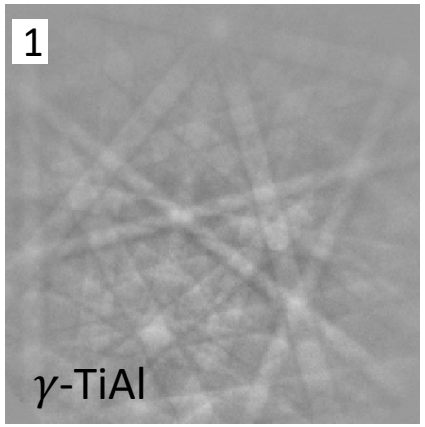
EDS combined with phase diagrams

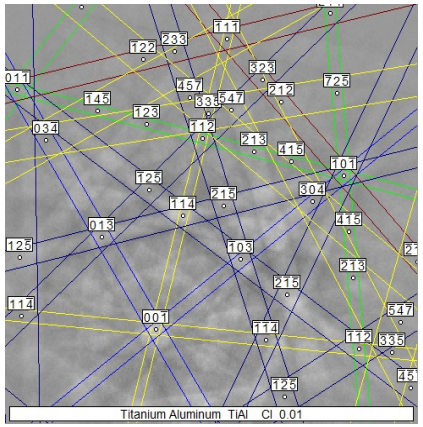
$Ti6Al4V/Al_2O_3$ joints

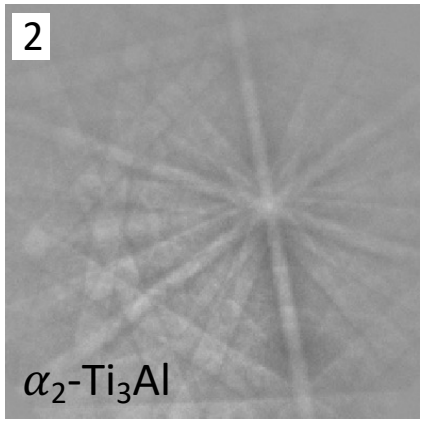
Ti thin film

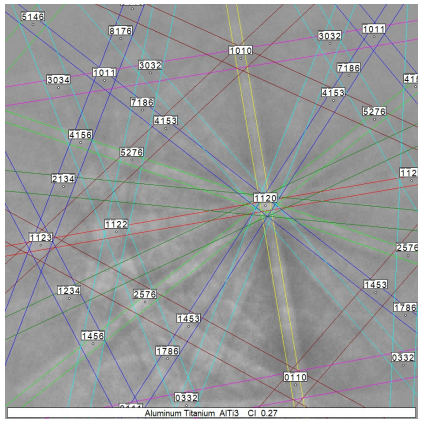
1000 °C/ 60 min

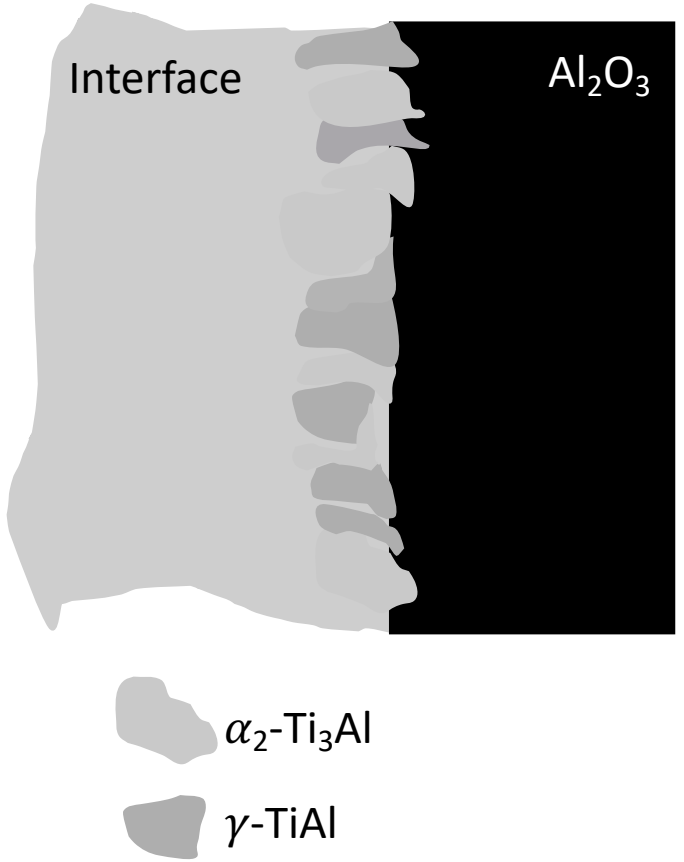








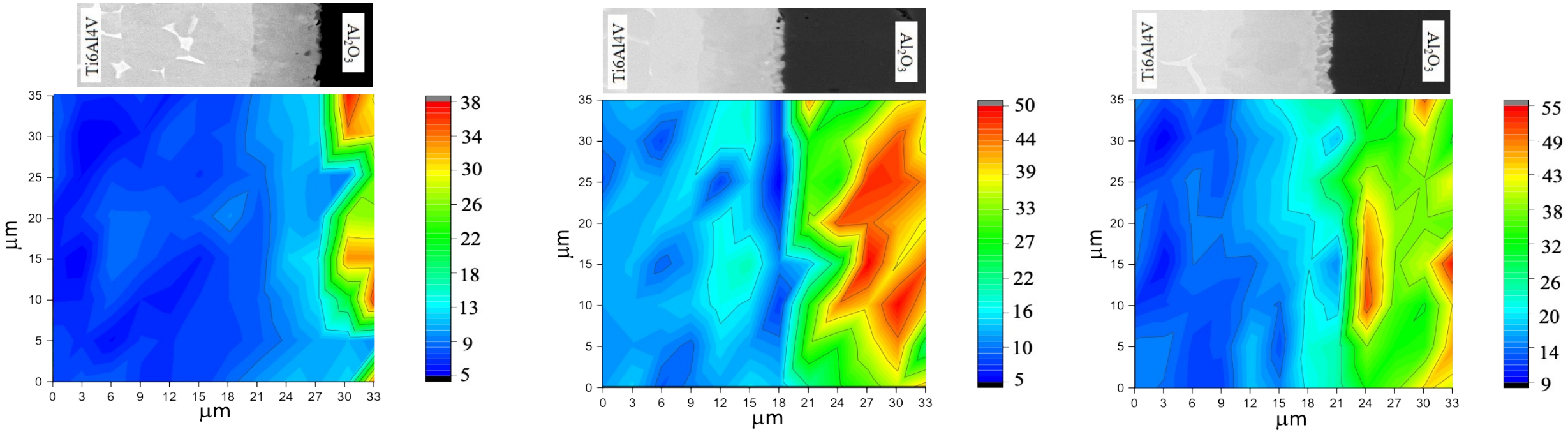




EBSD phase identification

$Ti6Al4V/Al_2O_3$ joints

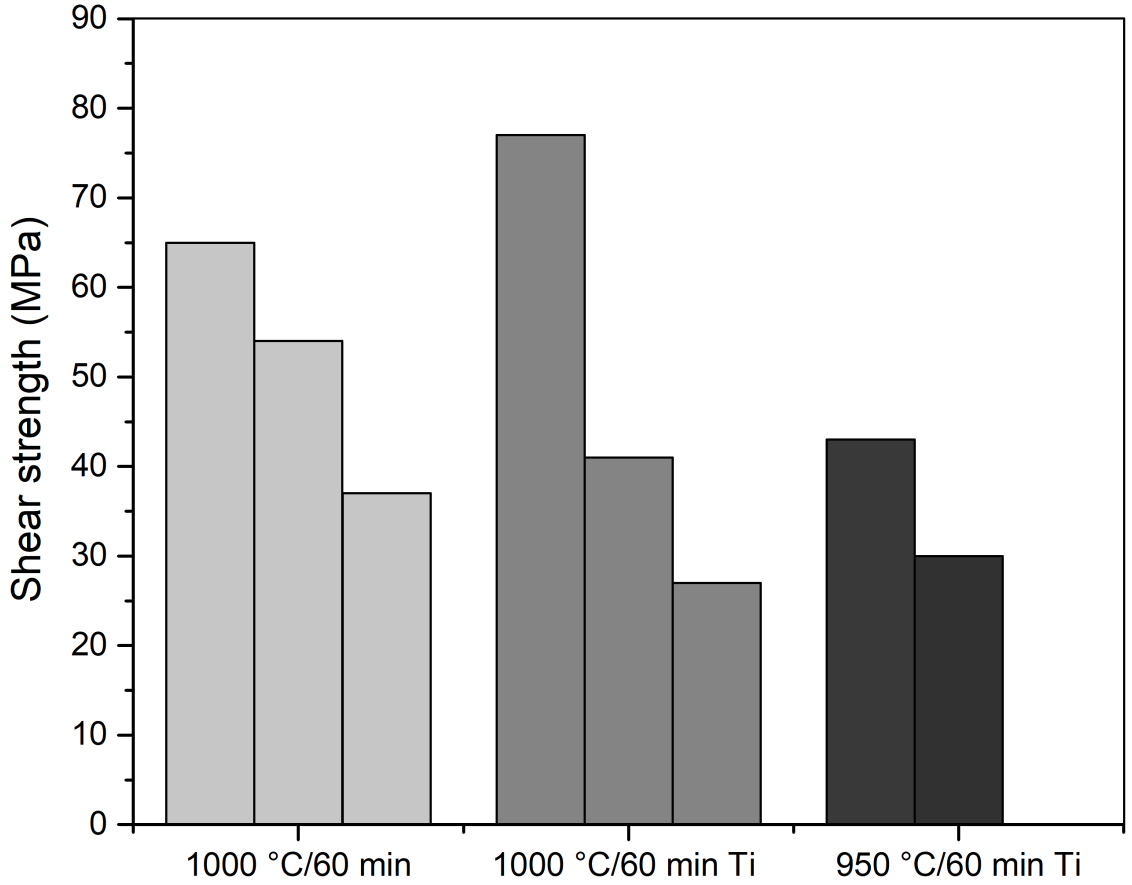
Ti thin film

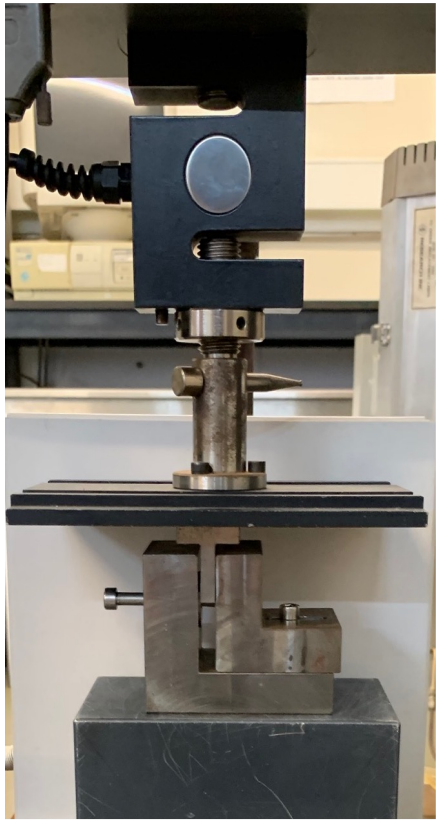


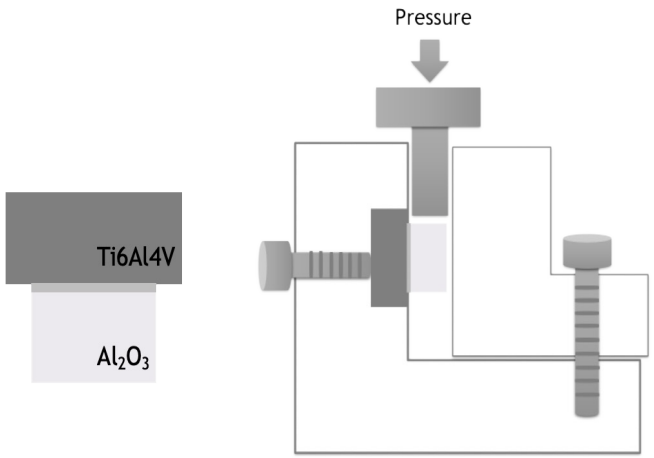
The interface hardness is similar to that of titanium alloy but increases slightly near the Al_2O_3 base material. The increase in temperature and time of diffusion bonding promotes an increase in the hardness of the interface.

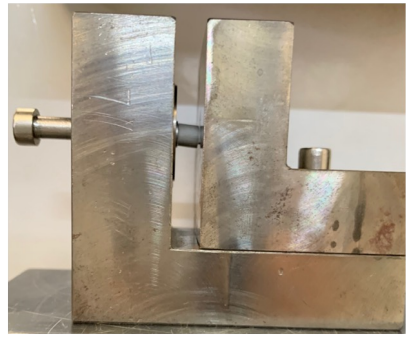
Ti6Al4V/Al_2O_3 joints

Shear tests



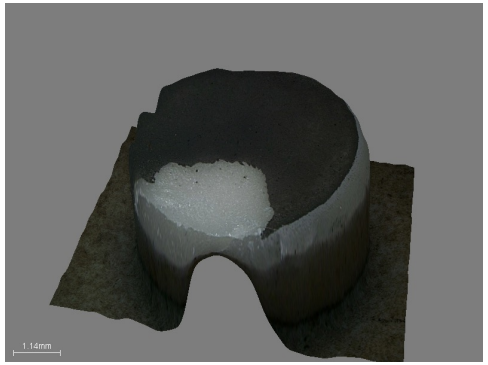


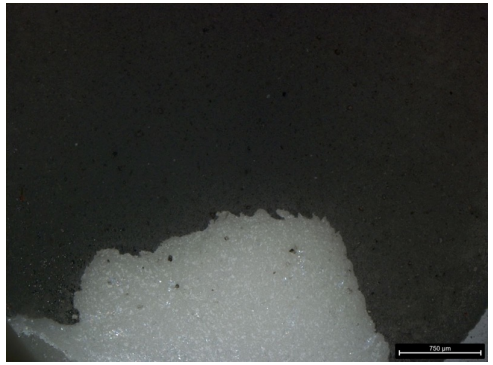


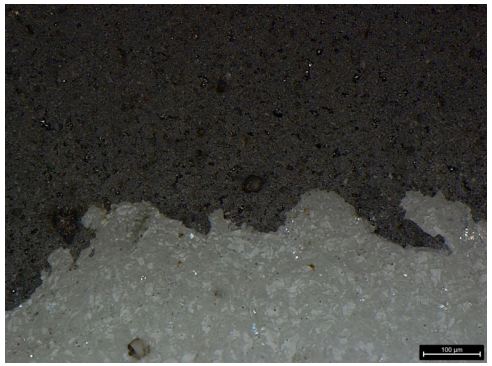


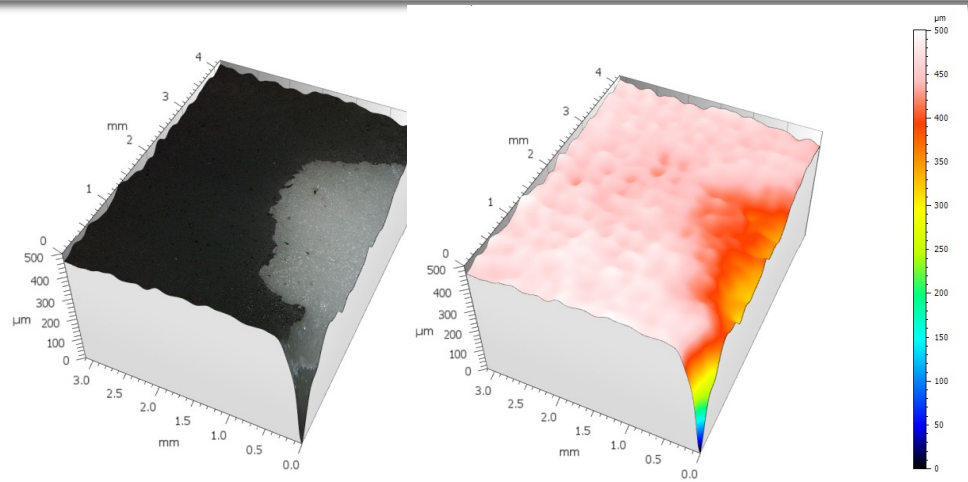
$Ti6Al4V/Al_2O_3$ joints

Without interlayer

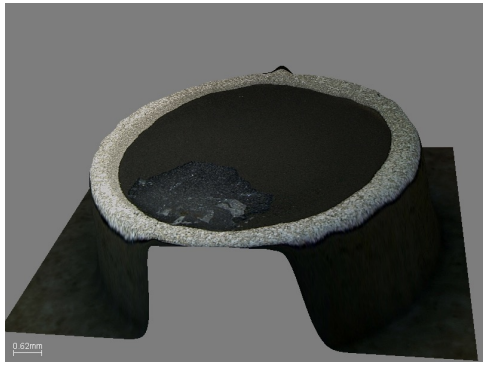


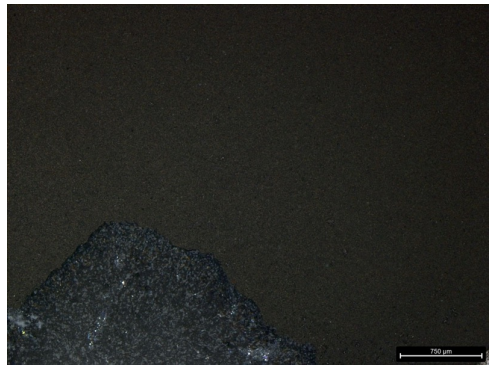


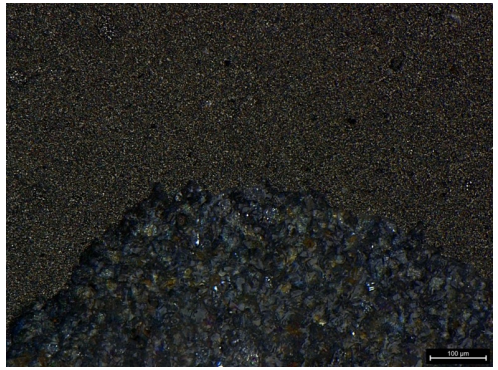


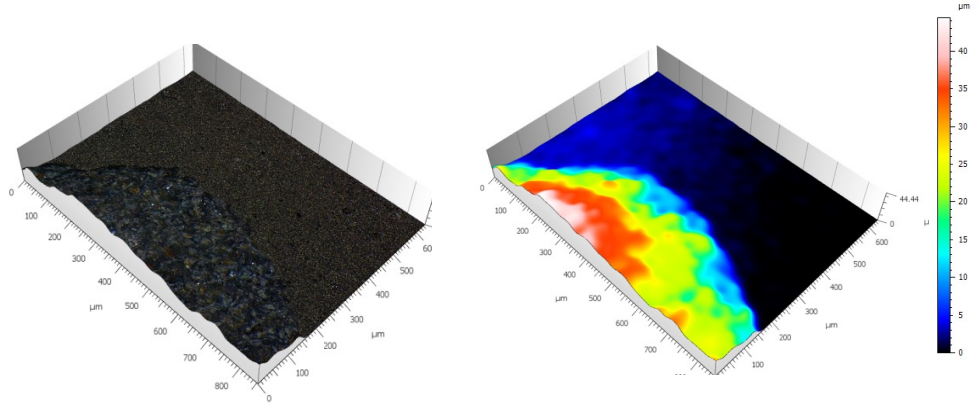


Al_2O_3





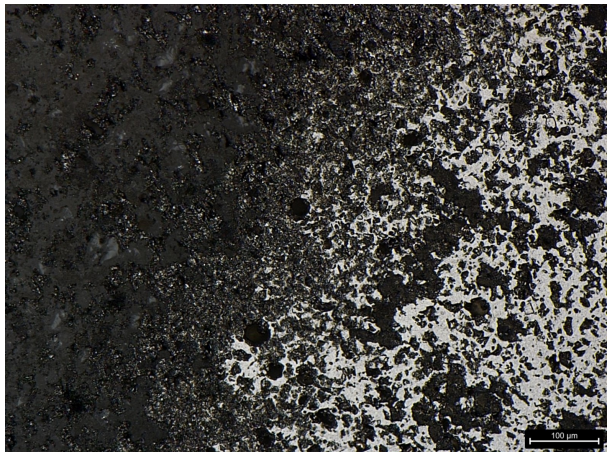




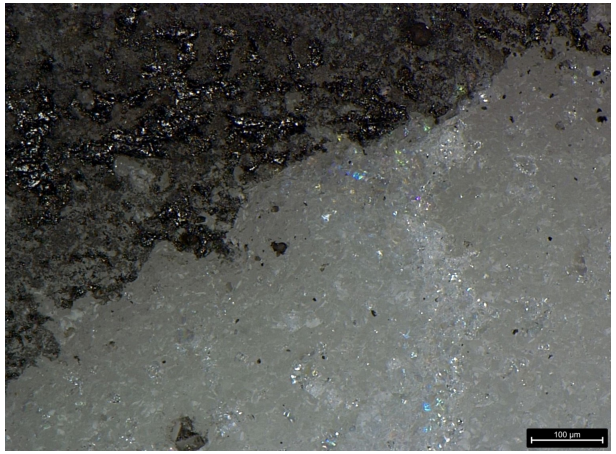
Ti6Al4V

Ti6Al4V/Al_2O_3 joints

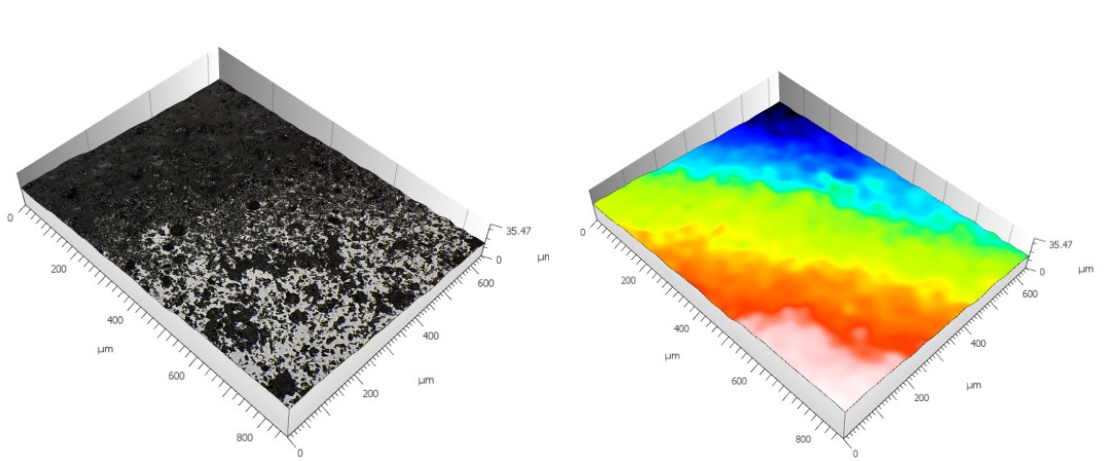
Ti thin film

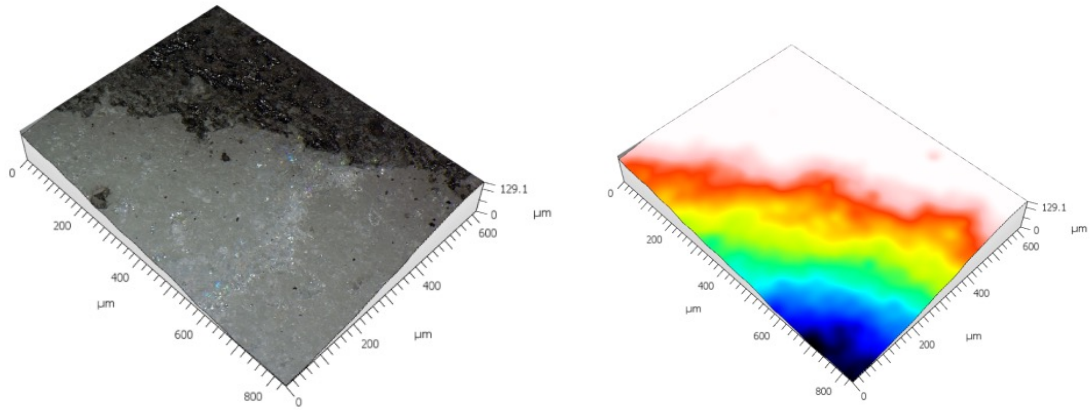


Al_2O_3



Al_2O_3

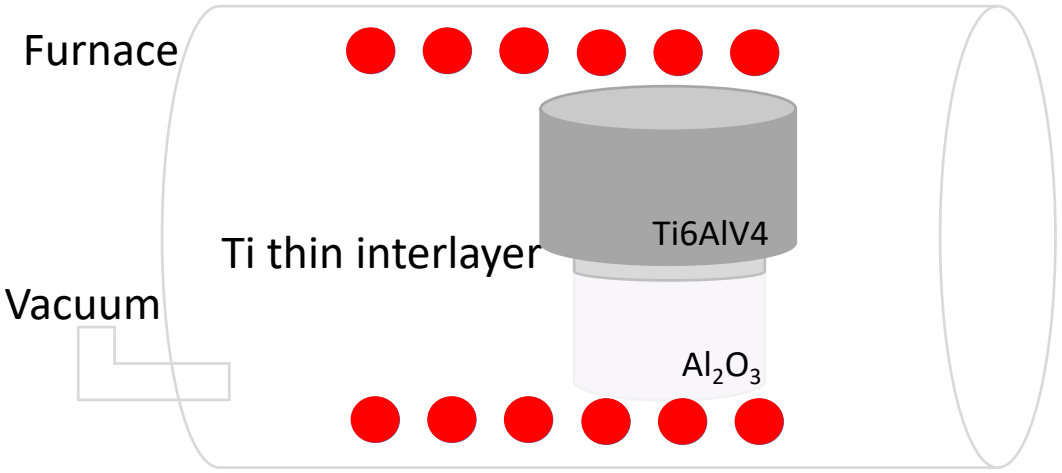


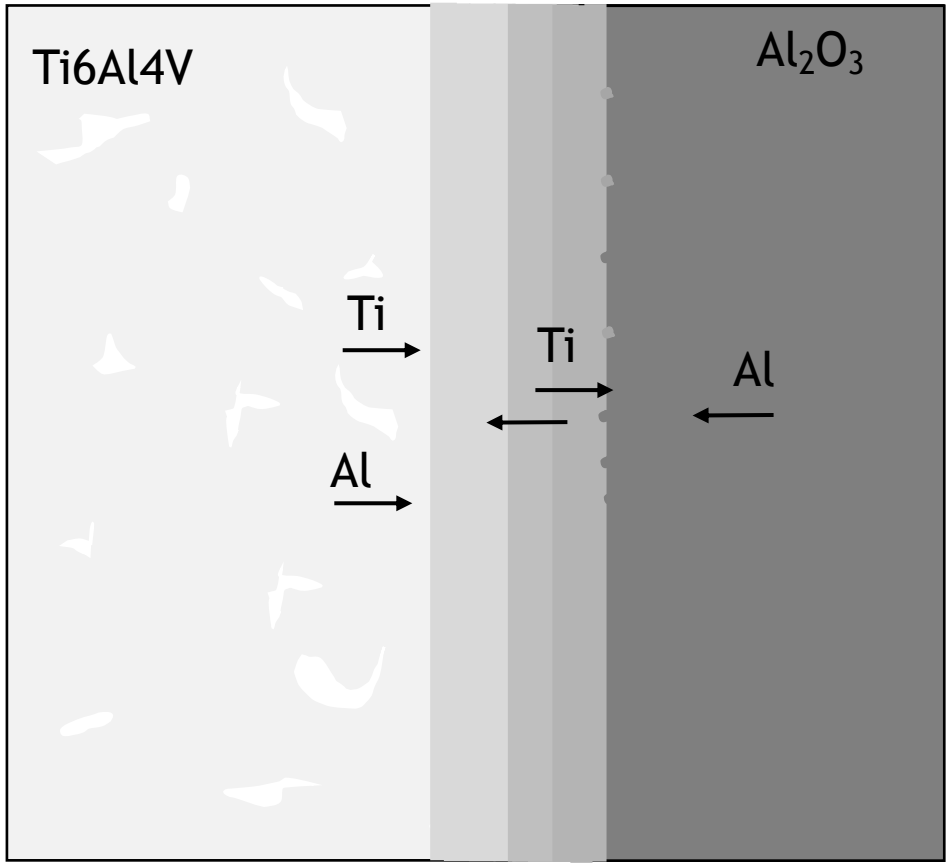


$Ti6Al4V/Al_2O_3$ joints

Ti thin film

Mechanism for the evolution of microstructure of the interface



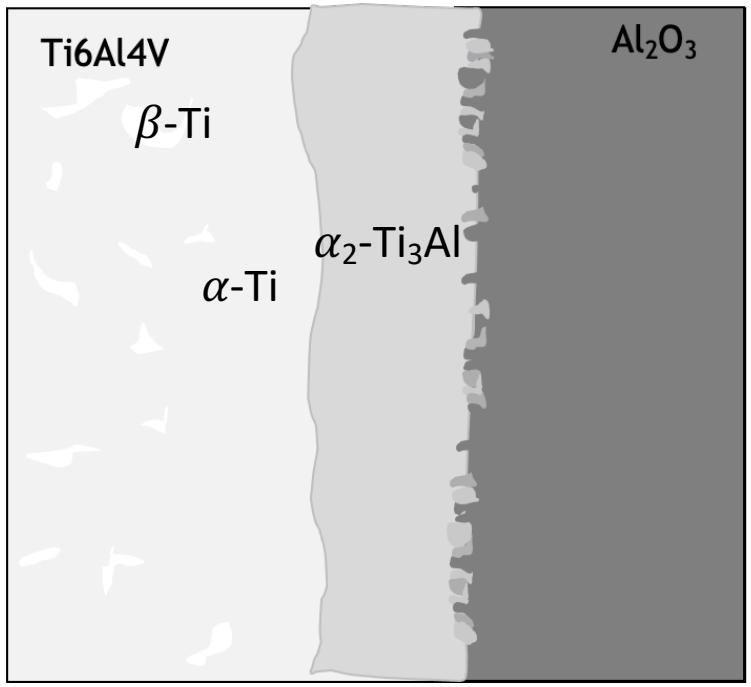


Initial microstructure

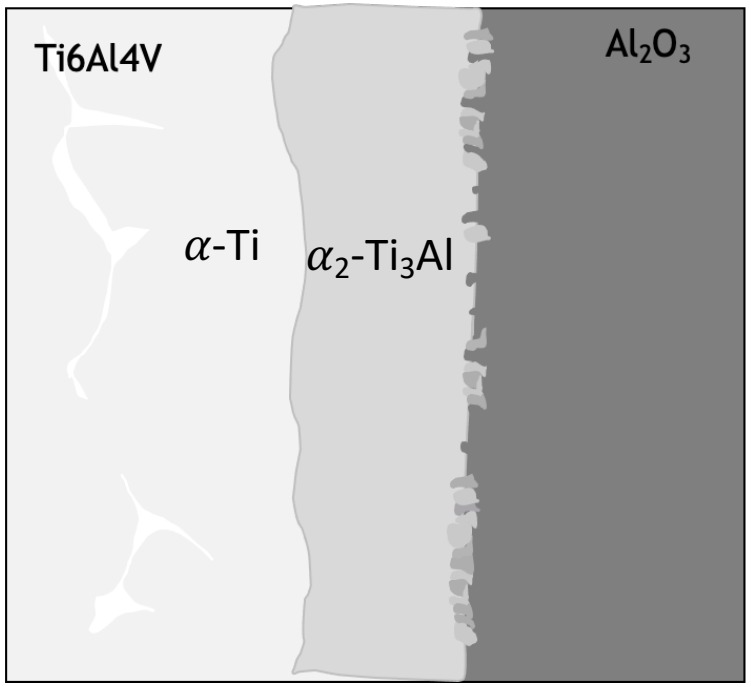
Ti6Al4V/Al_2O_3 joints

Ti thin film

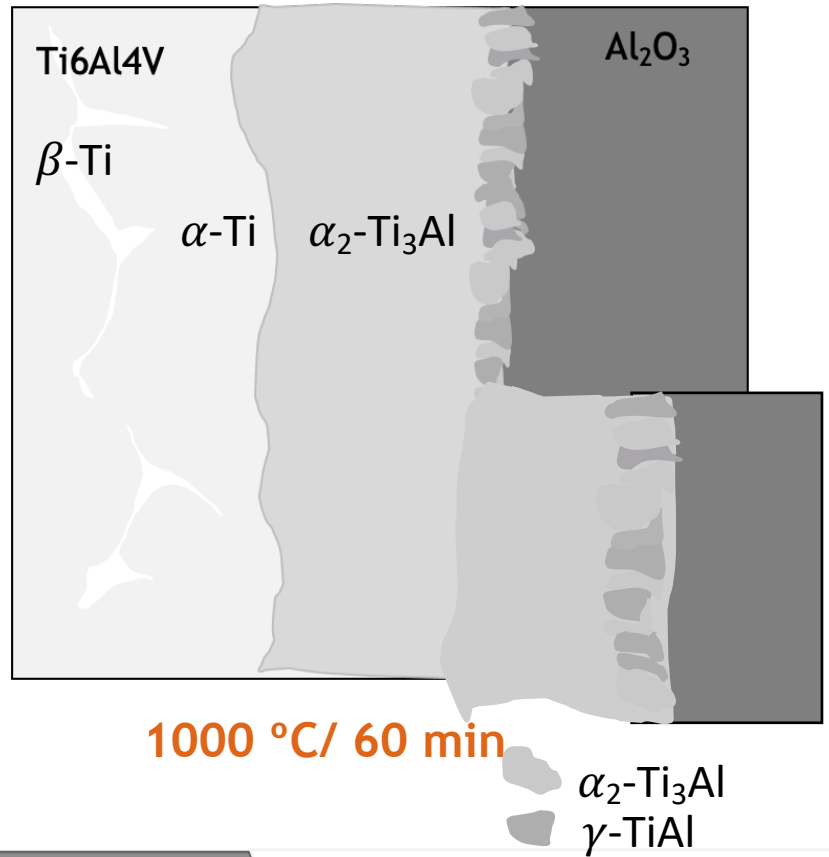
Mechanism for the evolution of microstructure of the interface



950 °C/ 60 min



1000 °C/ 10 min



1000 °C/ 60 min

Conclusions

- Diffusion bonding using titanium thin film as interlayer was performed at 950 and 1000 °C for 60 min to joint Al_2O_3 to Ti6Al4V.
- Joining was ensured by the formation of the interfaces consisted mainly of α-Ti and Ti3Al.
- The interface hardness is like that of titanium alloy but increases slightly near the Al_2O_3 base material.
- The shear strength of joints processed with and without are very similar. With interlayer it is possible reduced the bonding temperature to 950 °C.
- The results demostrate that the use of a titanium thin film is a good approach to improve the diffusion bonding of Al_2O_3 to Ti6Al4V joining.

Acknowledgements

This work was financially supported by: Project NanoTiC-POCI-01- 0145-FEDER - funded by FEDER funds through COMPETE2020 - Programa Operacional Competitividade e Internacionalizaçao (POCI) and by national funds (PIDDAC) through FCT/MCTES

Thank you for your attention