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Characterization of TiAl diffusion bonds using Ni/Ti nanolayers

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TiAl alloys exhibit a range of attractive properties and are good candidates to replace heavier alloys in areas where weight reduction is imperative, as in the transportation industry [1,2]. However, the application of these alloys depends on the development of new joining technologies. Due to the difficulties of joining these alloys, alternative approaches to conventional processes are necessary. Diffusion bonding and brazing are promising joining technologies to bond these alloys. The diffusion bonding with reactive multilayer has been successfully used in previous studies [3,4]. A common feature of these multilayers is the large amount of heat released during the reaction between the layers to form a new phase. Also, its nanometric structure confers an inherent high reactivity and diffusivity.

In this work, a Ni and Ti multilayer is tested in the diffusion bonding of TiAl alloys. Ni and Ti nanolayers, with periods of 30 and 60 nm, were deposited by d.c. magnetron sputtering into TiAl substrates. Joining experiments were performed at 700 and 800 ºC for 60 minutes, in a vertical furnace with a vacuum level better than 3×10^{-4} mbar. Applied pressures of 5 to 50 MPa were tested. The microstructure of the cross-sections of the bond interface was analyzed by energy dispersive X-ray spectroscopy (EDS) and characterized by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Crystallographic information of the phases formed at the joining interface was collected by electron backscatter diffraction (EBSD). The mechanical characterization was performed by shear tests.

SEM images of the as-deposited Ni/Ti nanolayers (Figure 1) show a multilayer morphology; Ni and Ti alternated layers are clearly distinguished. Sound joints are obtained with the Ni/Ti nanolayers, with 30 and 60 nm of period, at 700 ºC with 50 MPa and 800 ºC with 10 MPa. Microstructural characterization of the joints shows that the bonds obtained with the 30 nm period multilayer present a larger bonded area. The interface could be divided into distinct zones (Figure 2): two other layers (Zones 4 and 3) adjacent to the TiAl alloy and a central one with small grains (Zone 2), this zone is divided in two by a thin layer rich in Ti (Zone 1). EDS chemical composition of the identified zones are listed in Table 1. These results, in conjunction with Ti-Al-Ni phase diagram, indicate that the central region (Zone 2) is composed by TiNi and Ti_2Ni, while the two layers close to TiAl substrate corresponds to the TiNi (Zone 3) and $AlNi_2Ti+Ti_3Al$ (Zone 4) phases. The identification of the phases was confirmed by EBSD analyses. The highest shear strength value was obtained for joint processed at 800 ºC during 60 min under a pressure of 10 MPa using a multilayer with a period of 30 nm. This was the joint with a larger bonded area [5].

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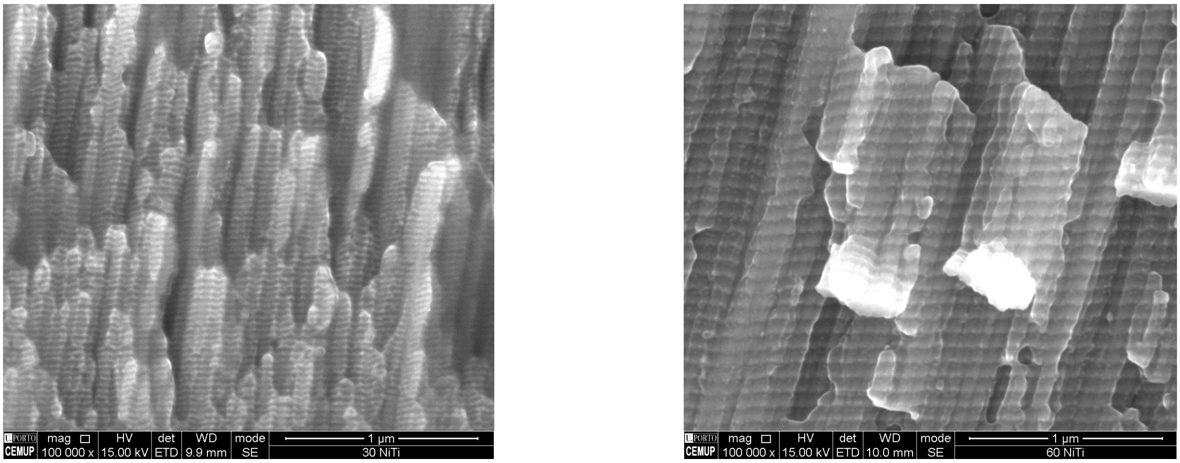
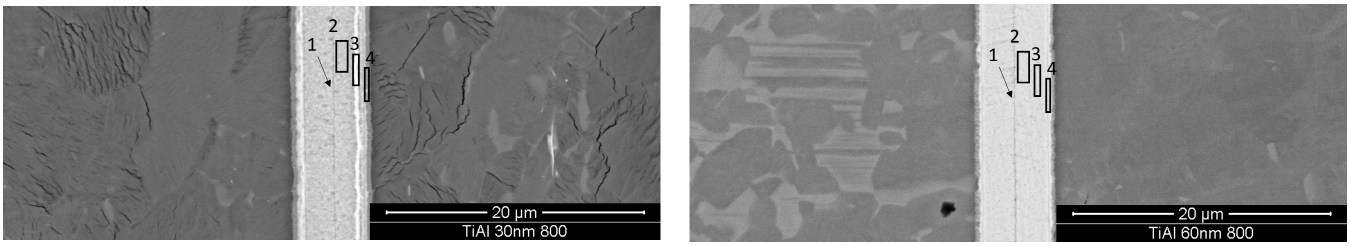


(a) (b)

Figure 1. SEM images of Ni/Ti nanolayers with (a) 30 nm and (b) 60 nm of period.



(a) (b)

Figure 2. SEM images of bonding interfaces of TiAl alloys produced at 800 ºC during 60 min under 10 MPa of pressure with Ni/Ti nanolayers with (a) 30 nm and (b) 60 nm period.

Table 1. EDS chemical composition (at.%) of the different zones (marked in figure 2) of the interface produced at 800 ºC with nanolayers with 30 and 60 nm of period.

Zones	***EDS (at. %)***									
	30 nm					**60 nm**				
	Ti	**Ni**	**Al**	**V**	**Nb**	**Ti**	**Ni**	**Al**	**V**	**Nb**
Z1	49.8	43.8	2.1	4.3	—	49.8	43.2	1.2	5.8	—
Z2	47.4	46.7	2.2	3.7	—	47.5	46.3	1.8	4.4	—
Z3	45.5	47.9	2.7	3.9	—	43.7	40.5	12.7	2.3	0.8
Z4	40.8	24.7	30.5	2.1	1.9	39.6	18.0	37.0	1.1	4.3