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Joining of TiAl alloys using Ni/Al multilayers

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The development of joining processes for TiAl alloys is fundamental to integrate them into functional structures and to widen their application field. Diffusion bonding has become the most reported technique for joining TiAl alloys but have the disadvantage of requiring high temperature stages. Diffusion bonding of TiAl at the 950-1200ºC temperature range has been reported to produce defect-free bonds. Çam *et al.* [1], successfully joined TiAl at 950 ºC/30 MPa/3 h and 1000 ºC/30 MPa/1 h, however, the bond interfaces were clearly visible.
In this work, we joined TiAl to TiAl with Ni/Al multilayer thin films to reduce the temperature and time of the diffusion bonding cycle. Making use of the improved diffusivity of these nanometric layers and of the heat evolved from the exothermic reaction that occurs in the multilayer to enhance diffusion and achieve bonding at lower temperatures/time or pressure [2]. The multilayer was deposited into TiAl samples by d.c. magnetron sputtering with periods of 5, 14 and 30 nm. The microstructure of the Ni/Al multilayer was studied by transmission electron microscopy (TEM) and scanning transmission electron microscopy (STEM), Cross-section images of Ni/Al multilayers with 14 nm of period reveal the layered structure (TEM image in Fig 1A) while the ring-like diffraction pattern confirms the fine grain size observed in as-deposited sample. The period of the multilayer was confirmed by STEM image (Fig1b).
Joining experiments were performed in a vertical furnace with a vacuum level better than 10^{-4} mbar. Diffusion bonding joints were produced at a temperature of 900ºC, pressure of 5 MPa and bonding times of 30 and 60 min. The microstructure of the cross-sections of the bond interfaces were analysed by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). The observation of the interface for 30 and 14 nm period multilayer with 60 min. of bonding time, presented in Fig. 2 and 3, revealed regions with an apparent soundness, while for 5 nm period porosity and cracks inside the interlayer thin film can be observed,**.** The interface could be divided into two distinct zones: one with columnar grains adjacent to the TiAl alloy (zone 1) and a central one with equiaxed grains (zone 2). The EDS chemical composition indicated that zone 1 is a reaction layer between the TiAl substrate and the multilayer, while zone 2 corresponds to the NiAl multilayer zone with small amounts of Ti (2 - 4 at.%) . For sample bonded for 30 min. (Fig 3A) we observed a joint without pores or cracks; however we can clearly identify the bond line. The central region of the interface presents a mixture of small and large grains the later being observed close to bond line. The joining mechanism appears to depend on the diffusion of Ni and Ti across the interface, as confirmed by the net flux of Ni towards the TiAl alloy and of Ti towards the multilayer, evidenced by the composition profile in Fig. 3.

[1] G. Çam, M. Koçak, Journal of Materials Science 34 (1999) 3345
[2] L. Duarte, A. S. Ramos, M. F. Vieira, F. Viana, M. T. Vieira and M. Koçak, Intermetallics 14 (2006) 1151

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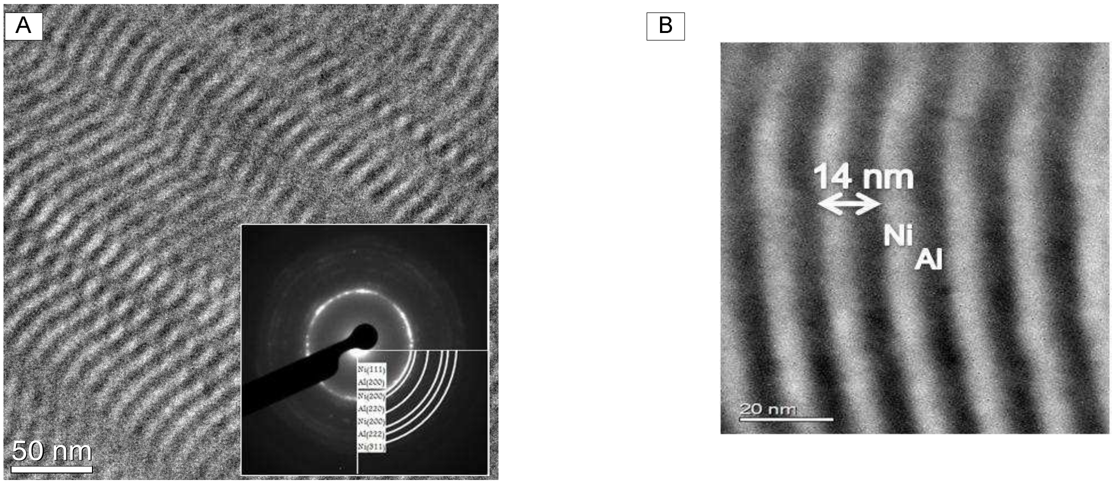

Fig. 1 – Ni/Al multilayer with 14 nm of period: A. TEM image and ring-like diffraction pattern; B. STEM image where the bright layers is Ni and the dark layers is Al.

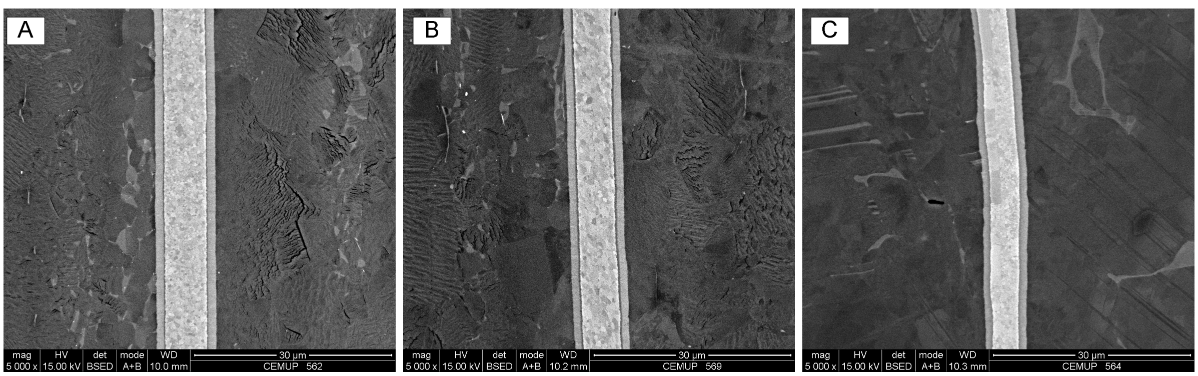

Fig. 2 - SEM images of the joints obtained at 900ºC, during 60 min with 5MPa pressure and multilayers with periods of: A. 30 nm; B. 14 nm; C. 5 nm.

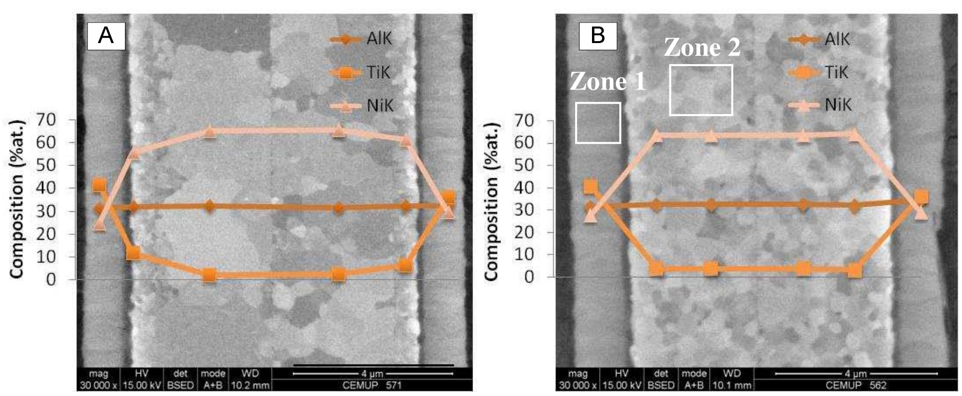

Fig. 3 - SEM images of the joint obtained at 900ºC with 5MPa for samples with 14 nm of period multilayer: A. bonding time of 30 min.; B. bonding time of 60 min.

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