# Reactive nanomaterials for non-conventional applications

**A.S. Ramos**[1], A.J. Cavaleiro[1], M.T. Vieira[1], S. Simões[2], F. Viana[2], M.F. Vieira[2]

[1]CEMUC®, Department of Mechanical Engineering, University of Coimbra, R. Luís Reis Santos, 3030-788 Coimbra, Portugal.
[2]CEMUC®, Department of Metallurgical and Materials Engineering, University of Porto, R. Dr. Roberto Frias, 4200-465 Porto, Portugal.
sofia.ramos@dem.uc.pt

**Abstract**

A few energetic nanolayered systems composed of materials with high negative heat of reaction have been investigated for joining applications. Relying on the rapid release of energy during the mixing of reactant layers, these nanomaterials show potential as localized heat sources. The deposition by magnetron sputtering allows reactive multilayer foils/films with equiatomic chemical composition and with controlled nanoscale modulation period (bilayer thickness) to be produced (figures 1 and 2).

Reactive multilayers are composed of tens, hundreds, or thousands of alternating individual nanolayers of reactants having a large negative enthalpy of mixing. For certain designs, these multilayers exhibit fast, high temperature reactions that could be ignited by an external energy source such as an electric spark or a mechanical load. Local heating initiates the reaction locally, releasing heat that drives the reaction forward. The reaction moves in a self-propagating wave.

For some years now, the heat released by the exothermic reaction in Ni/Al multilayer foils is being used to melt braze alloys, promoting joining [1,2]. In the **reactive brazing** process a free-standing reactive multilayer foil is placed between two solder alloys. Reactive multilayers can also be used to enhance the diffusion bonding process by taking advantage of the improved diffusivity and reactivity of the alternating nanolayers – **reaction assisted diffusion bonding**. Ti/Al and Ni/Al nanometric multilayer thin films have been successfully used to assist the diffusion bonding process of advanced materials, namely titanium aluminides [3-5]. The use of reactive nanomaterials as fillers allowed sound joints to be obtained at reduced temperature and/or pressure and/or bonding time (figures 3 and 4). The diffusion bonding process comes very close to the ideal indistinguishable joint, which makes this process suitable for micro-sized components. The possibility of adapting multilayer thin films in order to enable direct joining without solder or braze alloys is also anticipated. In this **non-conventional joining approach**, joints are made by stacking two coated components facing each other. If the multilayer thin films reaction could be locally ignited, the coated parts stacked facing each other would be diffusion joined at room-temperature in any atmosphere or under vacuum without the need of external heat sources. The multilayer coated parts are stacked with the surface of the thin films facing each other and the joining process takes place after ignition. Besides the reactive multilayer thin films of the Ni-Al system (medium enthalpy of reaction), low (Ti/Al, Ni/Ti) and high (Pd/Al) reaction enthalpy multilayer thin films are also being developed to be used in joining applications [6-8]. Recently, NiTi shape memory alloys have been diffusion bonded to a Ti-6Al-4V alloy using Ni/Ti multilayer thin films as a filler nanomaterial. The multilayer thin films control the diffusivity and reactivity at the joining interfaces and could also act as a localised heat source. Moreover, the use of the reactive multilayer thin films made possible to avoid the liquid phase formation during joining and to reduce the temperature, pressure and time required to successful join the coated materials (figure 5). So far, the most promising reactive nanolayers for non-conventional joining applications are those from the Ni-Al system with intermediate modulation period (between 10 and 20 nm).

Joining is presented as an example of reactive nanolayers' potential. However, the application field is not limited to joining. A whole new branch of opportunities is open up for this kind of nanomaterials.

**References**

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**Figures**

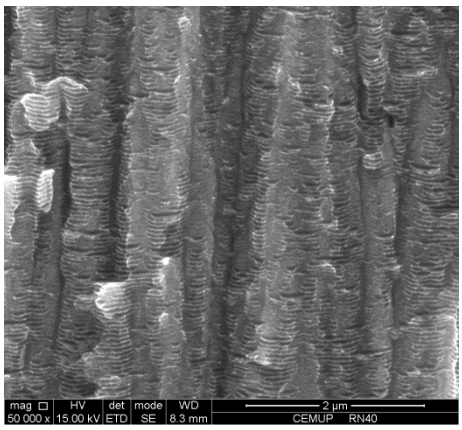


Fig. 1 – SEM micrograph of a Ni/Al nanofoil with 60 nm period.

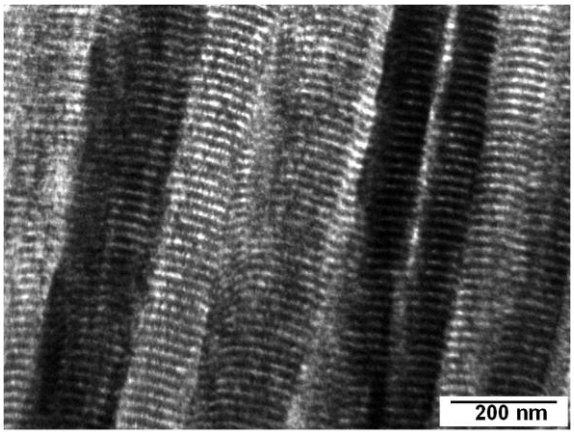


Fig. 2 – TEM micrograph of a sputtered Ti/Al multilayer thin film with 20 nm period.

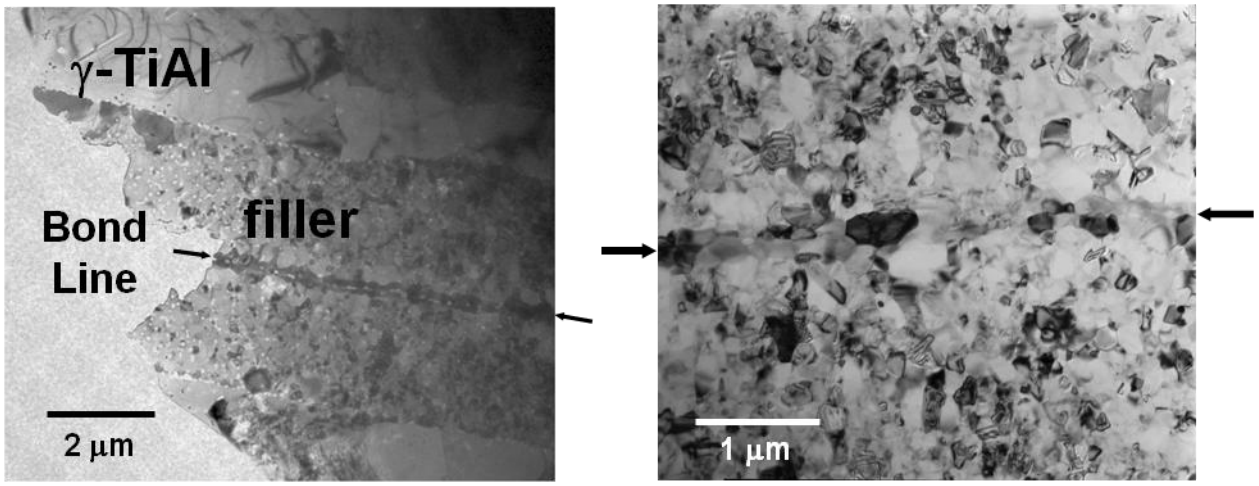


Fig. 3 – TEM micrographs of a TiAl joint processed at 900ºC/ 50 MPa/ 1h using a Ti/Al multilayer thin film.

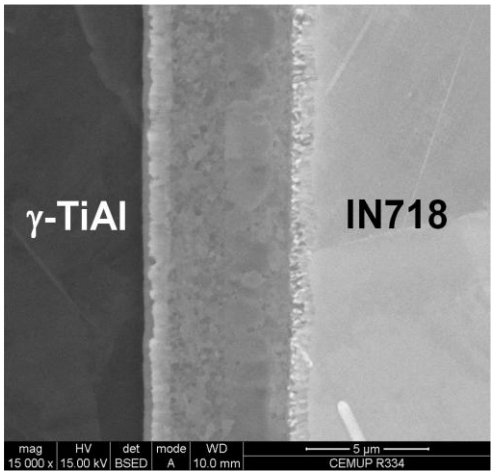


Fig. 4 – SEM micrograph of a TiAl/Inconel joint processed at 800ºC/ 5 MPa/ 1h using a Ni/Al multilayer thin film.

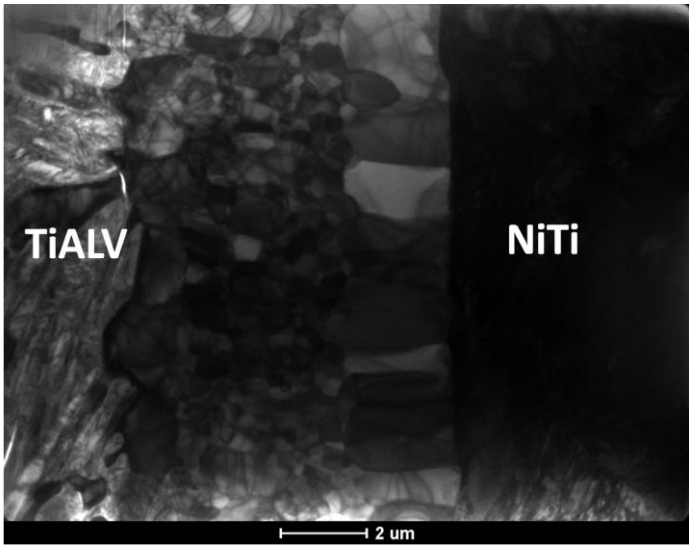


Fig. 5 – TEM micrograph of a NiTi/Ti-6Al-4V joint processed at 850ºC/ 5 MPa/ 1h using a Ni/Ti multilayer thin film.