Available online at www.sciencedirect.com

Intermetallics 13 (2005) 1122–1133

Intermetallics

www.elsevier.com/locate/intermet

Microstructural aspects of plain aluminide and Pt-aluminide coatings on Ti-base alloy IMI-834

S.P. Trivedi, D.K. Das*

Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad 500058, India

Received 8 October 2004; received in revised form 7 January 2005; accepted 15 February 2005
Available online 9 April 2005

Abstract

One of the major limitations of the near-α titanium alloys such as IMI-834 and IMI-829 that is currently restricting their use at high temperatures is their poor oxidation resistance. Several protective coatings including diffusion aluminide coatings are currently being examined to enhance the oxidation performance of these alloys in the temperature range of 600–750 °C. In the present study, various microstructural aspects of plain aluminide and Pt-aluminide coatings on Ti-base alloy IMI-834 have been studied. Plain aluminide coating shows a single layer consisting of only Al_3Ti phase in the as-aluminized state. Pt-aluminide coating consists of three layers, namely an outer platinum-rich layer, an intermediate Al_3Ti layer, and the inner interdiffusion layer. The above structure of Pt-aluminide coating on IMI-834 alloy is very similar to that reported on Ni-base superalloys. It has further been found in the present study that the structure of Pt-aluminide coating depends on its Pt and Al contents. The nature of such dependence is similar to that reported for Pt-aluminide coatings on Ni-base superalloy substrates.

Keywords: A. Titanium aluminides, based on TiAl; A. Trialuminides; B. Phase identification; C. Coatings, intermetallic and otherwise; F. Microscopy, various

1. Introduction

IMI-834, a near-α Ti-base alloy, is currently being used as the material for fabrication of compressor parts in modern gas turbine engines. The maximum temperature of use for this alloy is approximately 600 °C. For protecting this alloy from oxidation damage during application, several coatings such as physical vapour deposited TiAlN, aluminides, silicides and MCrAlY have been reportedly used [1–7]. Bulk titanium aluminides such as γ-TiAl and Ti_3Al alloys have been reported to possess very good oxidation resistance at high temperatures [8]. Aluminide coatings (both plain aluminide and Pt-aluminide) on Ti-alloys such as IMI-834 have also been shown to be very effective in combating oxidation damage [1,9,10]. Nicholls et al. [9], Gurrappa and Gogia [10], and, more recently, Das and Trivedi [11] have reported the effectiveness of Pt-aluminide coating on IMI-834 against oxidation damage at high temperatures up to 800 °C. Both the study by Das and Trivedi [11] and that by Gurrappa and Gogia [10] have also shown the superiority of Pt-aluminide coating over its plain aluminide counterpart in air in the temperature range 650–800 °C. Despite the reported excellence in oxidation performance of diffusion aluminide coatings (both plain aluminide and Pt-aluminide) on IMI-834 alloy, the microstructural aspects of these coatings on Ti-alloys have not been well investigated [11–14].

Diffusion aluminide coatings have long been used on superalloys for combating high temperature oxidation. Therefore, the microstructural details of these coatings on superalloys have been well reported [15–23]. The plain aluminide coating formed on Ni-base superalloys using a high activity aluminizing process typically has a three layer structure as shown in Fig. 1(a) [19]. Both the outer and the intermediate layers of the above coating are constituted of β-NiAl phase although the outer layer additionally contains numerous fine precipitates. The inner layer is usually referred to as the interdiffusion layer and contains a large number of complex particles which emerge as a result of Ni depletion from this region (see Fig. 1(a)) [16–18].

---

* Corresponding author. Tel.: +91 40 2458 6504; fax: +91 40 2434 1439.
E-mail address: dipakd1004@yahoo.co.in (D.K. Das).

0966-9795/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.intermet.2005.02.006

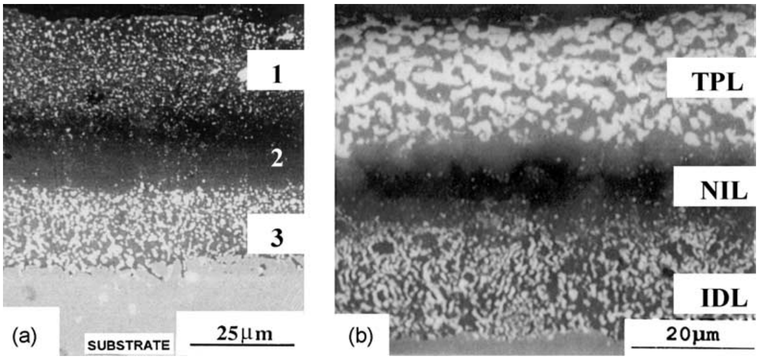

Fig. 1. Typical three-layer microstructure of a high activity (a) plain aluminide coating [18] and (b) Pt-aluminide coating formed on superalloy substrates [19]. While 1 and 2 represent the two outer β-NiAl layers, 3 represents the interdiffusion layer of the coating. TPL, NIL and IDL represent the outer two-phase layer, intermediate β-NiAl layer and the inner interdiffusion layer respectively, of the Pt-aluminide coating.

The corresponding Pt-aluminide coating (Fig. 1(b)) [20] also shows a three-layer microstructure [21–23]. While the outer layer of the coating consists of β-NiAl and $PtAl_2$ phases, the intermediate layer consists of β-NiAl having a certain amount of Pt in solid solution. The inner layer of the coating is the interdiffusion zone as mentioned for the plain aluminide coating [16–18]. In the present study, microstructures of plain aluminide and Pt-aluminide coatings formed on Ti-base alloy IMI-834 have been investigated. The similarities and the differences in coating structures on Ti-based alloy and superalloy substrates have also been discussed.

2. Experimental details

IMI-834 alloy supplied by Timetal Inc., UK (product name TIMETAL® 834) has been used as substrate for formation of Pt-aluminide coating in this study. The nominal composition (wt%) of the above alloy is Ti-5.8Al-4.0Sn-4.0Zr-0.75Nb-0.50Mo-0.4Si-0.06C-0.05Fe-1000 ppm O-1500 ppm N-60 ppm H. The β transus, i.e. temperature for $\alpha \rightarrow \beta$ transition, for this alloy is 1055 °C. The alloy was available in the form of 20 mm diameter forged rods which were in fully heat treated condition, i.e. solution treated at 1020 °C for 2 h followed air cooling and, subsequently, aged at 700 °C for 2 h. In the above condition, the alloy has the usual structure consisting of primary α and transformed β, as shown in Fig. 2. The amount of primary α phase present in the alloy is approximately 15 vol.%. Discs of 2 mm thickness were sliced from the rods and used as substrates for coating formation. Pt aluminide coating formation on these samples was carried out in four steps. Firstly, the samples were deposited with a layer of Pt using an electroplating method. Pt layers of six different thicknesses, namely 0.5, 1, 2, 5 and 8 and 13 µm, were deposited and the plated samples were subsequently given a diffusion treatment (henceforth referred to as prior diffusion treatment) at 1020 °C for 5 h in Ar atmosphere. Some of the diffusion treated samples were then pack aluminized using a low temperature high activity (LTHA) aluminizing process [17]. Aluminization was mostly carried out at 700 °C for 6 h. On certain occasions when a higher Al pick-up was needed, aluminizing at 800 °C for a longer duration (up to 15 h) was also carried out. The pack used for aluminization consisted of pure Al powder (15 wt%), NH_4Cl (2 wt%) and calcined alumina powder (balance 83 wt%). The other details of the aluminizing process can be obtained from one of our earlier papers [18]. The samples were weighed before and after the aluminization for determining the Al pick-up during the process. The as-aluminized samples were subjected to a two-step post-aluminization treatment which was essentially the same as the usual heat treatment for IMI-834 alloy, i.e. solution treatment at 1020 °C for 2 h followed by aging for 2 h at 700 °C. It can be appreciated that the Pt content of the Pt-aluminide coatings in this study has been altered by changing the thickness of the Pt plated layers. Throughout this paper, the Pt content of a coating has been referred to in terms of the thickness of the Pt electroplated layer used for coating formation. Al content of any coating, on the other hand, refers to its Al pick-up (mg cm^{-2}) value that was achieved during aluminization.

Fig. 2. Microstructure of the IMI-834 alloy used as substrate for coating formation. The bright phase represents primary α and the matrix phase transformed β in the above figure.