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Large-sized TiAl/Ti_3Al multilayer thin sheet: Microstructures, mechanical properties and degradation mechanism

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A B S T R A C T

A large-sized TiAl/Ti_3Al multilayer thin sheet with a layer thickness ratio of 1:1 was prepared by electron beam physical vapor deposition (EB-PVD). The structure and morphology of the TiAl/Ti_3Al multilayers were characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM) and energy dispersive X-ray spectroscopy (EDS). The tensile properties of the TiAl/Ti_3Al multilayers were evaluated with a static tensile test at room temperature. Furthermore, a static tensile test was used to assess the TiAl/Ti_3Al samples before and after hot isostatic pressing. According to the experimental results, the prepared material had a visible multilayer structure and was composed of Ti_3Al and TiAl phases. The TiAl/Ti_3Al multilayer sheet had high tensile strength and good tensile elongation due to the anomalous strengthening behaviour of the intermetallic layers and the presence of multilayer interfaces. The degradation mechanism was investigated by heat treatment at different temperatures. Based on the XRD results and FESEM observations, the heat treatment temperatures played a key role in the evolution of the structure and morphology.

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1. Introduction

In recent years, intermetallic composites received considerable attention as materials for high temperature applications in modern aircraft engine components, shape memory devices and in power generation industry [1–4]. Among these composites, Ti-Al intermetallic alloys are fascinating materials due to their low density, high stiffness and good creep properties [2,5,6]. However, the metallic bonding in these intermetallics would lead to insufficient ductility at room temperature [7,8].

For the purpose of industrial applications, much effort has been made to improve mechanical properties of intermetallic alloys, particularly by controlling the microstructure and alloying. According to the literature, Ti-Al-Cr based intermetallic layers provide effective protection to TiAl alloys [9–12]. Large-sized Ti-43Al-9V-0.2Y alloys and TiB_2/TiAl *in situ* composites exhibit a higher yield strength and an ultimate tensile strength with increasing Al content [13,14]. Furthermore, the fabrication of hierarchical microstructures has been in focus of extensive research due to their enhanced mechanical and functional properties [15]. In recent decades, multilayer materials have been developed as a new class of microstructural materials. These multilayer materials are designed to improve ductility and fracture toughness due to the size effect and multi-interfacial effect [16–18]. The fabrication of intermetallic multilayers is important to optimize the strength and stiffness of the intermetallic materials [19,20].

Currently, it is difficult to prepare an alloy sheet with width higher than 300 mm and thickness below 0.5 mm using the conventional technologies such as rolling and hot forming [21]. Hence, the development of fabrication technology to prepare large-sized (>Φ 300 mm) and thin sheet (<3.0 mm) Ti-Al alloys with sufficient mechanical properties is important. A new technology for thin sheet fabrication, electron beam physical vapor deposition (EB-PVD), can be used to prepare multilayer materials and has many advantages, including a higher deposition speed and thermal efficiency, yielding a purer and a near-net shaped product [22].

Herein, a large-sized TiAl/Ti_3Al multilayer thin sheet with layered thickness ratio of 1:1 was prepared by EB-PVD technology. The TiAl/Ti_3Al multilayer sheet had a high tensile strength and a good tensile elongation due to the anomalous strengthening behaviour of intermetallic layers and multilayer interfaces. On the basis of temperature-dependent SEM and XRD studies, the degradation mechanism was established and was related to the heat

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treatment temperature regimes. Furthermore, the proposed synthesis strategy for intermetallic composites may provide a new pathway for the designing and fabrication of novel multilayer thin sheets with high mechanical properties.

2. Experimental

2.1. Fabrication of TiAl/Ti_3Al multilayer thin sheet

The primary material used in this study was a Ti-Al alloy target that was Φ 68.5 × 125 mm in size. The chemical composition of the alloy given in atomic percent was Ti-25%Al and Ti-50%Al. The stainless steel substrate (Φ 400 × 5.0 mm in size) was polished with SiC paper followed by sand blasting. The substrate was then ultrasonically washed in distilled water for 30 min. Subsequently, the substrate was washed in distilled water and ethanol, and dried at 100 °C for 1 h. The experimental equipment used in this study was the UE-204B type EB-PVD.

In order to easily separate the multilayer sheet from the substrate, a boron nitride separating layer was deposited onto the substrate before the deposition. The TiAl and Ti_3Al alloys were evaporated and deposited onto the substrate, respectively. The

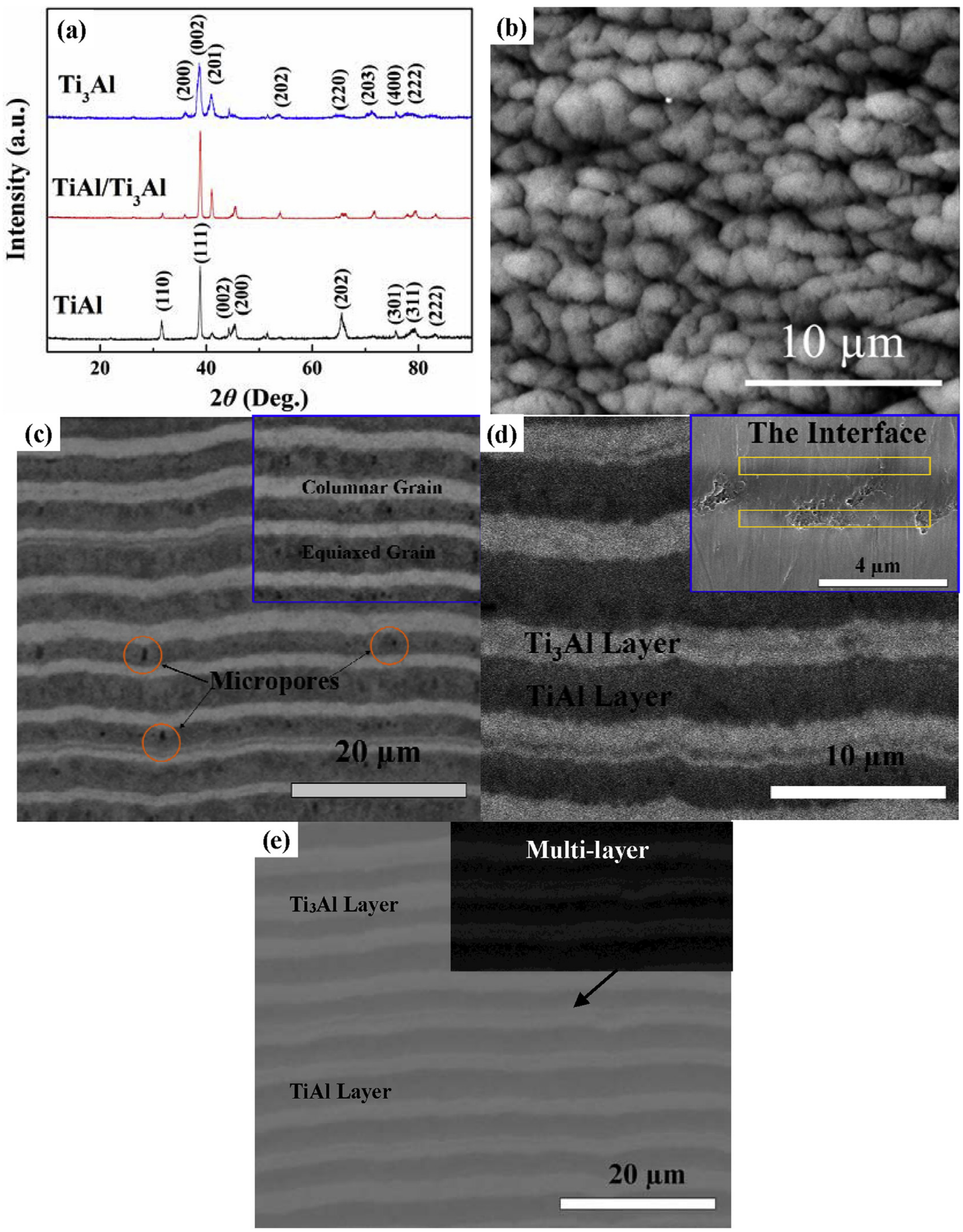

Fig. 1. (a) XRD patterns for TiAl, Ti_3Al and TiAl/Ti_3Al samples, respectively; (b) surface morphology of TiAl/Ti_3Al; (c) and (d) cross-section morphology of deposited TiAl/Ti_3Al; (e) cross-section morphology of TiAl/Ti_3Al after hot isostatic pressing.

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