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Hierarchical porous $TiAl_3$ intermetallics synthesized by thermal explosion with a leachable space-holder material

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ABSTRACT

Porous $TiAl_3$ intermetallics were synthesized by thermal explosion (TE) reaction with NaCl as space holder material, from Ti-75Al at.% elemental powders. Results showed that the actual temperature of specimen climbed rapidly from 667 °C to 1106 °C. As a consequence, porous $TiAl_3$ intermetallics with high open porosity (> 80%) can be easily achieved when adding NaCl particles above 50 vol%. XRD patterns showed that only single-phase $TiAl_3$ compound was synthesized via TE. Hierarchical porous $TiAl_3$ materials displayed three pore structures, including large pores replicating from original NaCl particles, small pores among the skeletons, and tiny pores precipitated from particle skeletons. Moreover, porous $TiAl_3$ intermetallics exhibited a uniform pore size distribution and formed an open-cellular structures allowing for the liquid-gas separation and filtration applications.

1. Introduction

Intermetallics are the potential structural and functional materials with a mixture of metallic and covalent bonds. The excellent mechanical properties and oxidation/corrosion resistance enable their applications at room and elevated temperatures [1–3]. Among various intermetallics, titanium aluminides are regarded as an innovative high-temperature engineering materials [4], and their outstanding performances such as relatively low density, high specific strength, good corrosion resistance and oxidation resistance at elevated temperatures obtained extensive industrial applications [5,6], including automotive industry and energy generation [7,8]. Recently, porous TiAl-based intermetallics have been prepared by reaction sintering process, which can be used for applications in catalyst carriers, filters and heat insulation components at special environments [9–11].

Numerous technologies have been developed to prepare porous Ti-Al intermetallic compounds, mainly including α_2-Ti_3Al, γ-TiAl and $TiAl_3$ [4,12]. Currently, a novel method to fabricate these intermetallics was adopted through TE reaction [5,13] which has drawn special attention due to its advantages of time-saving, low energy consumption and simplicity of sintering procedure [8]. In regard to porous TiAl-based materials with high porosity and tailored pores, space holder method can be well performed by adding space-holder material to the reactant, followed by the removal process. Particularly, leachable space-holder materials, such as NaCl particles, can be easily removed by dissolving in deionized water before sintering. This combination process represents an environment-friendly as well as economical merits. Kobashi et al. [9] synthesized porous TiAl intermetallics with space holder (NaCl) up to 80 vol%, then soaked the obtained samples in boiling water after sintering process. While NaCl particles could not be removed completely from sintered samples, and the molten NaCl have corrosive effect in TiAl monoliths and destroy the graphite die [14]. Actually, porous $TiAl_3$ intermetallics have the higher oxidation resistance compared to Ti_3Al and TiAl phases and relative low density [4,8,12,15]. Shi et al. [13] have studied the oxidation kinetics curves of Ti-Al porous materials, the specimens with Ti/Al molar ratio of 1:3 shows the superior high-temperature oxidation resistance at 650 °C. Consequently, it is worth preparing porous $TiAl_3$ intermetallic compounds with high open porosity (e.g. more than 80%) which can be applied to heat insulation and separation materials, due to the better oxidation resistance in elevated temperature as compared to Ti_3Al and TiAl [15].

In the present study, a novel processing method based on the TE reaction with a leachable space holder material was performed to fabricate porous $TiAl_3$ intermetallics. Space holder of NaCl particles were removed sufficiently by water leaching before

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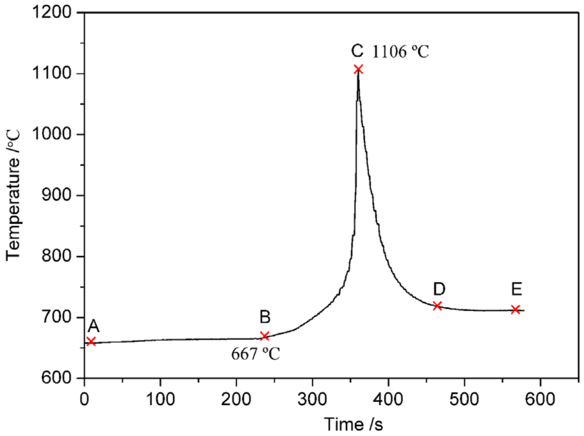

Fig. 1. Temperature-time profile of the Ti/Al powder compacts during sintering.

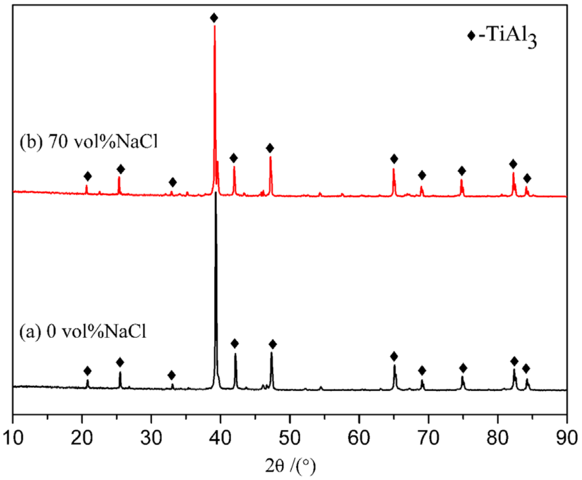

Fig. 2. XRD patterns of sintered specimens with (a) 0 vol% and (b) 70 vol% NaCl.

sintering. Besides, the effects of NaCl content on phase compositions, open porosity and pore-structures were investigated.

2. Experimental

The elemental titanium (48 μm, 99.6% purity) and aluminum (25 μm, 99.9% purity) powders were mixed with Ti/Al molar ratio of 1/3. The NaCl (200–500 μm, 99.5% purity) were selected as temporary space holder material, which were manually mixed together with Ti-Al powders, and the volume ratios of NaCl are 0%, 50%, 60%, 65% and 70%. In order to avoid segregation of dissimilar particles, a few drops of ethanol were added during blending. Then the Ti/Al-NaCl mixture experienced a compaction process (including die-pressing and cold isostatic pressing) under 300 MPa, the cylindrical green compacts were formed with 16 mm in diameter and ~3 mm in height. Subsequently, green compacts were put in a beaker equipped with deionized water and NaCl particles were removed through water leaching at 70 °C for 3 h, and the water was refreshed every half an hour. Then the samples were dried at 40 °C for 24 h. The green compacts were initially sintered to 600 °C for 1 h, then heated to 1100 °C for 1 h under vacuum (7.6×10^{-3} MPa). The heating rate was set to 5 °C/min during the whole sintering process. Meanwhile, the same experiment was carried out in a tube furnace with flowing argon, and a pair of WRe3-WRe25 thermocouples was placed between two specimens to record the actual temperature of the compact. The reactant compact is wholly heated in the furnace with a constant heating rate, and once it has been heated to the ignition temperature, a sharp rise in temperature is observed, which means that the simultaneous combustion mode occurs, often referred as TE [16].

The porosity of final products was measured by Archimedes principle [5,12,13]. The phase compositions were determined by X-ray diffraction (XRD) on a Bruker D8ADVANCE machine with Cu target (λ=0.15406 nm), radiation at 40 kV and 150 mA settings. Quanta 250 scanning electron microscope (SEM) was also applied to observe the pore structures of sintered specimens.

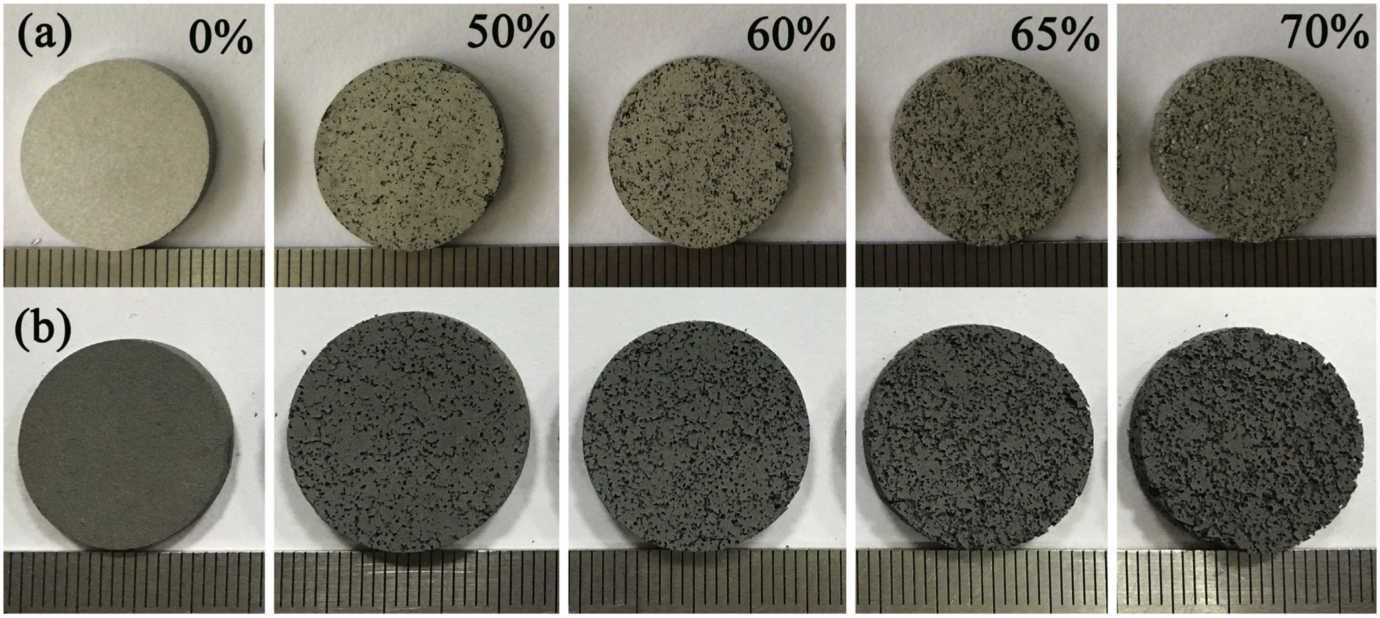

Fig. 3. Macrographs of (a) green compacts after NaCl dissolution and (b) sintered TiAl$_3$ discs. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)