Intermetallics 27 (2012) 14–20

Contents lists available at SciVerse ScienceDirect

Intermetallics

journal homepage: www.elsevier.com/locate/intermet

Improvement of compressive strength and ductility in NiAl–Cr(Nb)/Dy alloy by rapid solidification and HIP treatment

L.Y. Sheng [a,b,*], F. Yang [c], T.F. Xi [b], Y.F. Zheng [b], J.T. Guo [d]

[a] PKU-HKUST ShenZhen-Hong Kong Institution, Shenzhen 518057, China
[b] College of Engineering, Peking University, Beijing 100871, China
[c] Shenzhen Airlines, Shenzhen Bao'an International Airport, Shenzhen 518128, China
[d] Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China

A R T I C L E I N F O

Article history:
Available online 10 February 2012

Keywords:
A. NiAl
C. Rapid solidification
D. Microstructure
E. Mechanical properties
C. HIP treatment

A B S T R A C T

The NiAl–Cr(Nb)/Dy alloy was fabricated by conventionally casting and rapid solidification and treated by hot isostatic pressing treatment (HIP). The results reveal that Cr_2Nb phase contains much of Ni and Al elements and retains the C14 crystal structure at room temperature. The rapid solidification refines the NiAl phase, Cr_2Nb phase and needle-like Cr_2Nb precipitates in NiAl matrix. Moreover the rapid solidification increases α-Cr phase and results in the formation of Cr_7Ni_3 phase with stacking faults and microtwins inside. The HIP treatment transforms the needle-like Cr_2Nb precipitate in the NiAl phase into sphere shape and blunts the tip of the Cr_2Nb phases along the NiAl phase boundary. In addition, the HIP treatment leads to some moveable dislocations in the alloy, which is beneficial to the compressive ductility. The mechanical test shows the rapidly solidified alloy with HIP treatment has the best mechanical properties, whose compressive ductility is more than ten times that of the as cast alloy.

1. Introduction

It is well known that inadequate strength at elevated temperatures and low fracture toughness at ambient temperatures is the major deficiencies that handicap B2 structural NiAl to use as an advanced structural material at high temperatures [1–3]. In order to promote its industrial application, many methods have been adopted to conquer the shortcomings of the NiAl intermetallic compound and many kinds of NiAl based alloys have been developed [4–9]. Among them the NiAl alloy reinforced by Laves phase has been considered as one most promising alloy to apply in industry [10–12]. Because it exhibits many advantages compared with the Ni based superalloy, such as higher melting points (about 1733 K), lower densities (6.20-6.35 g/cm^3), higher thermal conductivity and excellent oxidation resistance. However, the previous investigations [13–16] reveal that the alloys prepared by conventional ingot casting exhibit coarse-grained microstructure and serious brittle fracture at ambient temperatures. On the other hand, the alloys processed by powder metallurgy with finer microstructure show improved room temperature mechanical properties but seriously lowered yield stresses at high temperatures [7]. It is well known that the mechanical properties of these alloys sensitively depend on the grain size of NiAl matrix and the morphology and distribution of strengthening Laves phase, which can be controlled by adjusting processing parameters, microalloying and heat treatment [17,18]. And moreover, recent studies [19,20] have shown that the rapid solidification and subsequent hot isostatic pressing (HIP) treatment can well improve the mechanical properties of the NiAl based alloy. In addition, the previous researches have revealed that appropriate addition of rare earth elements is beneficial to improving the properties of NiAl-based alloys [12,18,21]. So in the present study, a trace Dy doped Laves phase strengthening NiAl alloy with the composition of Ni-45Al-7.5Cr-2.5Nb-0.1Dy (at.%) was chosen and prepared by rapid solidification and treated by HIP, and its microstructure evolution and mechanical properties were investigated.

2. Experimental

The master alloy of Ni-45Al-7.5Cr-2.5Nb-0.1Dy (at.%; NiAl–Cr(Nb)/Dy for short) was prepared by induction melting from starting materials of 99.99% Ni, 99.9% Al, 99.9% Cr, 99.9% Nb and 99.9% Dy, respectively. The melted alloy was casted into rods. Some of them were investigated at as-cast state, and the remaining ones were crushed into pieces for rapid solidification. Rapid solidification experiments were conducted with water-cooled copper mold

* Corresponding author. PKU-HKUST ShenZhen-Hong Kong Institution, Shenzhen 518057, China. Tel.: +86 (0) 18665806226; fax: +86 (0) 755 26984814.
E-mail address: lysheng@yeah.net (L.Y. Sheng).

0966-9795/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.intermet.2012.01.014

method. The water-cooled copper mold method was usually utilized to prepare bulk metallic melts, having significant ability for rapid cooling. Some rapidly solidified and as-cast samples were treated by HIP treatment, which involved holding the experimental specimen at 1573 K under a pressure of 150 MPa for 3 h.

The samples for microstructure observation and compression test were cut from the as-cast and rapidly solidified alloy with and without HIP treatment. Microstructural characterization on the alloy with different states was carried out by S-3400 scanning electron microscope (SEM) with energy dispersive spectrometer (EDS). The foils for transmission electron microscope (TEM) observation were prepared by the conventional twin jet polishing technique using an electrolyte of 10% perchloric acid in methanol at 253 K after mechanical polishing to 50 μm and cutting into disc with a diameter of 3.0 mm. The TEM observation was performed by a JEM-2010 high-resolution transmission electron microscope operated at 200 kV.

The compressive specimens with size of $4 \times 4 \times 6\ mm^3$ were cut from the alloy with different states by electro-discharge machining (EDM) and all surfaces were mechanically ground with 600-grit SiC

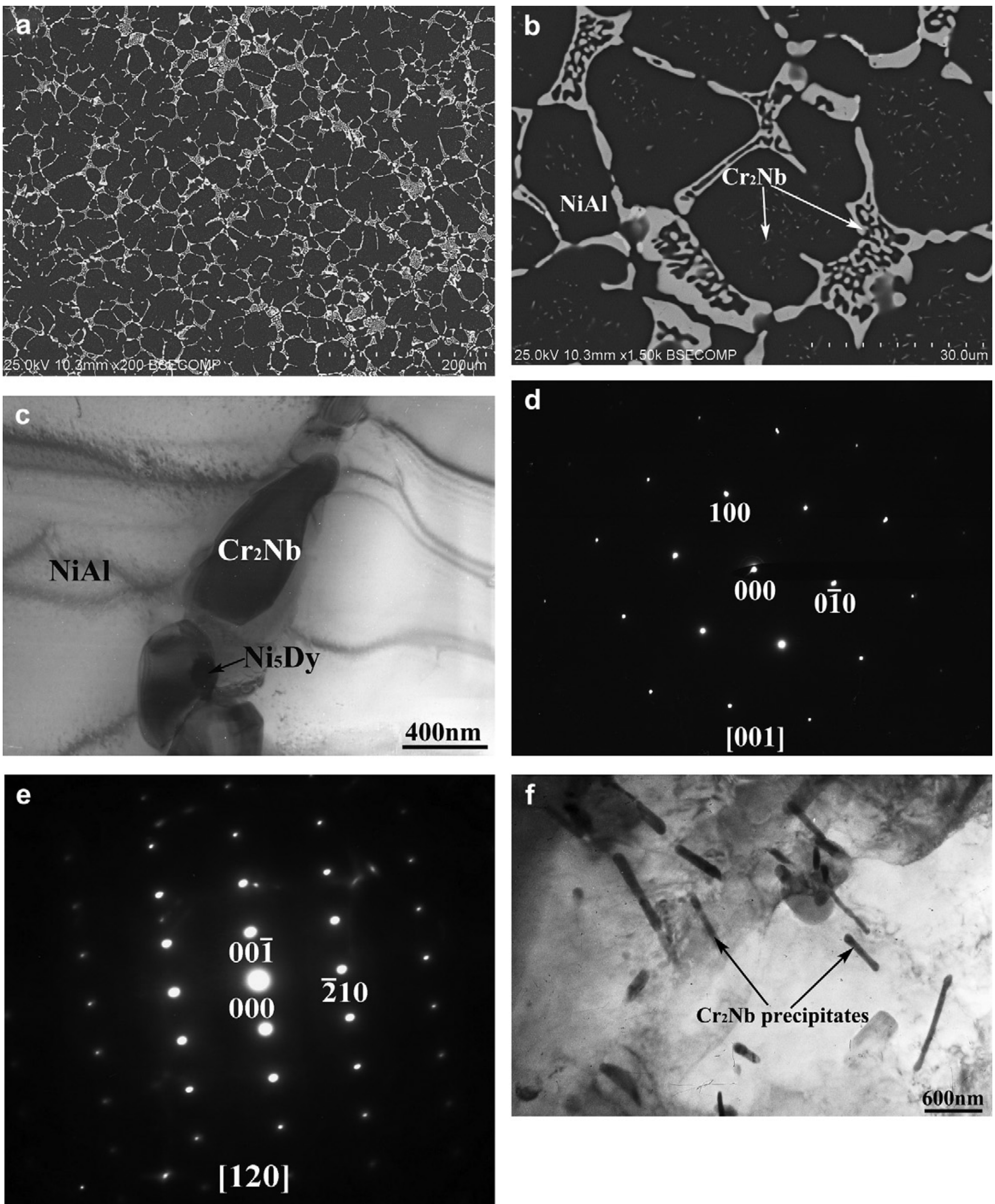

Fig. 1. (a) SEM image of the as-cast NiAl–Cr(Nb)/Dy alloy; (b) Morphology of needle-like Cr_2Nb precipitates in NiAl phase and NiAl/Cr_2Nb eutectic structure along NiAl phase boundary; (c) Bright-field TEM image of the Cr_2Nb and Ni_5Dy phases; (d) SAED pattern of Cr_2Nb particle; (e) SAED pattern of Ni_5Dy particle; (f) Bright-field TEM image of Cr_2Nb precipitates with long-needle shape.