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Microstructure, precipitates and compressive properties of various holmium doped NiAl/Cr(Mo, Hf) eutectic alloys

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ABSTRACT

The microstructure and mechanical properties of NiAl–28Cr–6Mo–0.2Hf eutectic alloys with various holmium additions have been investigated by using of SEM, TEM and compression test. The results reveal that minor Ho addition could optimize the microstructure by refining the lamella inside of eutectic cell and controlling the coarsening of intercellular region. However the minor Ho addition results in the Ni_2Al_3Ho phase, which has hexagonal crystal structure and an orientation relationship with NiAl phase of $[1\,2\,0]_{Ni_2Al_3Ho}//[1\,1\,1]_{NiAl}$ and $(0\,0\,\bar{2})_{Ni_2Al_3Ho}//(1\,\bar{1}\,0)_{NiAl}$. Moreover the $Ni_{17}Ho_2$ phase is found in the Ni_2Al_3Ho phase, which has twin crystal inside and an orientation relationship with Ni_2Al_3Ho phase of $[1\,2\,3]_{Al_{17}Ho_2}//[1\,2\,4]_{Ni_2Al_3Ho}$ and $(1\,1\,\bar{1})_{Al_{17}Ho_2}//(\bar{2}\,1\,0)_{Ni_2Al_3Ho}$. In addition, the Ho addition promotes the precipitation of Ni_2AlHf phase. More Ho addition coarsens the Cr(Mo) phases along the intercellular and results in more strengthening precipitates inside eutectic cell. When the Ho addition comes to 0.5 at.%, the alloy almost loses the cellular eutectic characteristic and exhibits a microstructure with coarse NiAl, massive Cr(Mo) and Ni_2Al_3Ho phases. The microstructure optimizations improve the mechanical properties of the alloy significantly, especially the alloy with 0.1 at.% Ho content.

1. Introduction

The B2 structured intermetallic compound NiAl has excellent properties, such as high melting point, low density, good thermal conductivity and excellent oxidation resistance, which make it as a potential high temperature structure material [1–3]. However the room temperature (RT) brittleness and inadequate elevated temperature strength handicap it is application in industry. Recent studies [4,5] on the NiAl find that its mechanical properties can get well improvement by the introduction of toughness phases. Among the NiAl alloys, the eutectic alloy of NiAl–28Cr–6Mo is much attractive, due to its well combination of RT and elevated temperature properties [6]. Though the NiAl–28Cr–6Mo eutectic alloy exhibits the relative good RT fracture toughness and elevated temperature strength [7,8], its high temperature mechanical properties still cannot reach the Ni-based superalloy [8]. Guo et al. [9] finds that the small addition of Hf can improve its high temperature mechanical properties, but unfortunately the addition of Hf decreases the ductility greatly. Previous researches [10–12] reveal that the addition of appropriate rare earth elements (REEs) can improve the RT mechanical properties of the intermetallic compound significantly. Because of its big atom radius, the REEs prefer to stay on the grain boundaries, which can arrest the S, P elements and then enhance the coalescence of the grains. The recent study [13] investigates the effect of rapid solidification on the microstructure and mechanical properties of the Ho doped NiAl based alloy. However, few researches have done to study the microstructure evolution and the precipitates characterization of the NiAl based alloy with different Ho additions, and their influences on the mechanical properties. Therefore in the present paper the NiAl–28Cr–6Mo–0.2Hf eutectic alloys with different Ho additions are fabricated. The investigations have been carried out to study their microstructure characteristics, precipitates and compressive properties.

2. Experimental procedures

The materials used for this investigation were Ni–(32.8-*x*)Al–28Cr–6Mo–0.2Hf–*x*Ho (atom percent) eutectic alloy with $x = 0$, 0.1, 0.2 and 0.5 at.%. The alloy were arc-melted under argon atmosphere from starting material of 99.9% Ni, 99.9% Al, 99.8% Cr, 99.9% Mo, 99.6% Hf and 99.7% Ho, using a non-consumable tungsten electrode. Each alloy button was turned over and remelted more than three times to get a homogeneous specimen. Since the weight losses were generally less than 0.5%, the alloy composition was considered to be equal to their nominal composition. The alloy

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