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Original Research Paper

Synthesis and structural characterization of nanocrystalline (Ni, Fe)$_3$Al intermetallic compound prepared by mechanical alloying

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ABSTRACT

Synthesis of (Ni, Fe)$_3$Al intermetallic compound by mechanical alloying (MA) of Ni, Fe and Al elemental powder mixtures with composition $Ni_{50}Fe_{25}Al_{25}$ was successfully investigated. The effects of Fe-substitution in Ni_3Al alloy on mechanical alloying process and on the final products were investigated. The structural changes of powder particles during mechanical alloying were studied by X-ray diffractometry, scanning electron microscopy and microhardness measurements. At the early stages, mechanical alloying resulted in a Ni (Al, Fe) solid solution with a layered nanocrystalline structure consisting of cold welded Ni, Al and Fe layers. By continued milling, this structure transformed to the disordered (Ni, Fe)$_3$Al intermetallic compound which increased the degree of $L1_2$ ordering upon heating. In comparison to Ni–Al system, Ni (Al, Fe) solid solution formed at longer milling times. Meanwhile, the substitution of Fe in Ni_3Al alloy delayed the formation of Ni (Al, Fe) solid solution and (Ni, Fe)$_3$Al intermetallic compound. The microhardness for (Ni, Fe)$_3$Al phase produced after 80 h milling was measured to be about 1170HV which is due to formation of nanocrystalline (Ni, Fe)$_3$Al intermetallic compound.

1. Introduction

Intermetallic compounds are well known as high temperature structural materials having excellent physical and mechanical properties [1]. The alloys based on Ni–Al may offer significant advantages because of the attractive combination of the properties including high melting temperature, low density, high hardness, good thermal stability and high creep resistance, good corrosion and oxidation resistance at elevated temperatures [2,3]. Ni_3Al intermetallic compound shows excellent physical and mechanical properties. Furthermore, the yield strength of Ni_3Al increases with increasing temperature up to 600–800 °C. The major impediment for the use of Ni_3Al is its low ductility and toughness at ambient temperature [3–6]. This can be overcome by several ways including refinement of the grain size [7]. Several methods such as self propagating high temperature synthesis (SHS), powder metallurgy [8] and mechanical alloying (MA) have been introduced for the synthesis of a wide array of intermetallic compounds [5]. Among these methods, MA process is well known for synthesis compounds and nanocomposites [9,10].

Enayati et al. [11] investigated the formation of Ni_3Al intermetallic compounds by MA and reported that during mechanical alloying of $Ni_{75}Al_{25}$ powder mixture, a Ni (Al) solid solution was formed initially and then transformed into the disordered nanocrystalline Ni_3Al intermetallic compound on further milling. However there are few reports in the literature on MA of ternary Ni–Fe–Al system. Recently much attention has been given to the investigation of ternary systems by mechanical alloying.

Rafiei et al. [12] synthesized nanostructured (Fe, Ti)$_3$Al intermetallic compound powder by mechanical alloying of $Fe_{50}Al_{25}Ti_{25}$ powder mixture and studied the formation mechanism and microstructure changes during MA process.

Liu et al. [13] studied the effects of Fe-substitution for Al in NiAl alloy. Investigations were performed on the mechanical alloying of $Ni_{50}Al_{50-x}Fe_x$ (x = 5, 10, 15, 20, 25, 30) powders mixture. The results demonstrated that addition of Fe meliorates the ability of the alloys to plastically deform, reduces the tendency of fracture during milling and results in the formation of larger alloy particles with crystals in the nanometer range. In this work nanocrystalline (Ni, Fe)$_3$Al intermetallic compound was synthesized by mechanical alloying. The microstructural changes during MA process were investigated.

2. Experimental

The powders of Ni (99.8%), Al (99.5%) and Fe (99.8%) were mixed with the composition of $Ni_{50}Fe_{25}Al_{25}$ (at.%). MA was performed, nominally at room temperature using a high-energy planetary ball

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