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Obtaining NiAl intermetallic compound using different milling devices

E.T. Kubaski [a,1,*], O.M. Cintho [b], J.L. Antoniassi [c], H. Kahn [c], J.D.T. Capocchi [a]

[a] Department of Metallurgical and Materials Engineering, Engineering School of the University of São Paulo, Av. Mello Moraes 2463, CEP: 05508-900, Sao Paulo, SP, Brazil
[b] Department of Materials Engineering, State University of Ponta Grossa, Av. Gal. Carlos Cavalcanti 4748, CEP: 84030-900, Ponta Grossa, PR, Brazil
[c] Department of Mining and Petroleum Engineering, Engineering School of the University of São Paulo, Av. Mello Moraes 2373, CEP: 05508-030, Sao Paulo, SP, Brazil

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ABSTRACT

NiAl intermetallic compound was synthesized by mechanical alloying technique in planetary and attritor mills. The starting powders consisted of elemental mixtures of Ni and Al at $Ni_{50}Al_{50}$ (at%) composition. In the planetary mill, compound formation occurred gradually during mechanical alloying, while the occurrence of a mechanically induced self-propagating reaction (MSR) can be suggested in the attritor mill. The NiAl obtained in both mill types was partially disordered with long-range order parameter not inferior to 0.66. Quantitative phase analysis using the Rietveld method was performed in as-milled samples, and this method was also employed to estimate changes in crystallite size and lattice strain of the NiAl produced during mechanical alloying.

1. Introduction

Nanocrystalline intermetallic compounds are said to have enhanced ductility and yield strength as compared to conventional grain-sized materials [1], and mechanical alloying in ball mills has been considered a suitable processing method capable of attaining the goal of producing nanostructured materials [2]. Not only is mechanical alloying capable of reducing grain size but it can also lead to the following changes in the material: disordering of the lattice and modification of the crystalline structure of crystals into a more symmetric, for example, cubic shape [2].

It is suggested that the work by Ivanov et al. [3] is the first report on the synthesis of nickel aluminides using mechanical alloying technique. These authors processed the compositions Ni_xAl_{100-x} ($32 < x < 90$), and milling runs were conducted in a laboratory ball mill with a ball-to-powder ratio of 10:1, and the milling media was made of hardened steel. Depending on the initial composition, the following phases were obtained: NiAl, Ni_2Al_3 and metastable solid solutions of Al in Ni. Also, the presence of amorphous NiAl was reported in the range of 65–73% (at%) of nickel.

The obtaining of NiAl intermetallic compound in attritor mill was described by Nash et al. [4] using an elemental powder mixture of $Ni_{49.5}Al_{49.5}W_1$. Afterwards, Nash and co-works consolidated and characterized powders based on NiAl [5–13] and also composite powders of NiAl reinforced with AlN and/or Al_2O_3 [14–16]. The research was conducted in a three-shaft attritor mill, employing elemental powder mixtures, and the ball-to-powder ratio was changed from 15:1 to 40:1; also, in some cases, cryogenic milling was employed at the beginning of the process, and milling times as long as 70 h were utilized.

An extensive research on synthesis of Ni–Al system intermetallics was conducted by Murty and co-workers [17–24]. Mechanical alloying of Ni and Al powder elemental mixtures in the proportions of Ni_xAl_{100-x} (x = 10, 18, 21, 25, 40, 50, 65, 68, 70, 75 and 90) was performed in a planetary mill. Single phase NiAl was found as a product after mechanical alloying of $Ni_{40}Al_{60}$ and $Ni_{50}Al_{50}$ (at%) compositions. Phase field extension of NiAl intermetallic compound was also observed; in the mechanically alloyed material, NiAl was present in the range from 25% to 65% of Ni (at%), whereas the equilibrium range goes from 46% to 59% (at%) of Ni [18]. In addition, the authors reported that contamination with iron from the milling media can promote intermetallic disordering, which would improve material ductility [20].

During mechanical alloying and depending on the milling parameters employed, NiAl intermetallic compound can take place either gradually or through a mechanically induced self-propagating reaction (MSR), which was first documented by Atzmon [25]. In fact, the time necessary for the gradual formation of NiAl and the occurrence or not of an MSR is strongly affected by process variables such as type of mill, ball-to-powder ratio, the use of process control agent (PCA) and the milling media.

The type of mill employed in the mechanical alloying process accounts for different milling mechanisms, that is, the way in which the available energy is transferred from de milling media to the material.

* Corresponding author. Tel.: +55 11 3091 5235; fax: +55 11 3091 5243.
E-mail address: evaldokubaski@hotmail.com (E.T. Kubaski).
[1] Present address: Itajara Minérios Ltda, Rua Balduíno Taques 650, CEP: 84010-050, Ponta Grossa, PR, Brazil. Tel.: +55 42 3220 3053.

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