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Original Research Paper

Development of NiFe-CNT and Ni_3Fe-CNT nanocomposites by mechanical alloying

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ABSTRACT

NiFe-CNT and Ni_3Fe-CNT nanocomposites were fabricated by high energy mechanical alloying method. X-ray diffraction (XRD) analysis, scanning electron microscopy (SEM) and optical microscopy were employed for evolution of phase composition, morphology and microstructure of the powder particles. Ball milled powders were heat treated at 500 °C for 1 h to release the milling induced stresses. Bulk samples were prepared by sintering of cold pressed (300 MPa) samples at 1040 °C for 1 h. XRD patterns of powders, as-milled and after annealing at 500 °C did not show any peak related to CNTs or excess phases due to the interaction between CNTs and matrix. SEM micrographs showed that the addition of CNTs caused a reduction of powder particles size. The hardness value of as-milled NiFe and Ni_3Fe powders reach to 660 and 720 HV, respectively. According to optical microscopy evaluations, the amount and size of the porosities of the composites bulk samples decreased in comparison with matrix ones.

1. Introduction

Nanocrystalline Ni-Fe alloys are promising soft magnetic materials and many investigations have been done on the production of these alloys by various methods [1–4]. In some applications such as surface hardening, NiFe alloys need improved mechanical properties. Some of studies demonstrate the effect of addition of some elements such as Mo, Ti and Cr on mechanical and magnetic properties of these alloys [5–7], but the synthesis of Ni-Fe/CNT nanocomposites have not been reported yet. Carbon nanotubes are raising a great interest in the investigations as a new kind of reinforcement material for the production of novel composites, because of their excellent mechanical properties. Most of the studies in the field of CNTs are on their application as structural reinforcement and their application in magnetic matrixes has not been investigated. In this study, we applied CNTs as structural reinforcements in Ni-Fe matrix by mechanical alloying procedure. Amongst several routes were applied to produce nanostructured Ni/Fe alloys [8–10], mechanical alloying is an appropriate procedure because the process parameters such as type of mill, ball to powder weight ratio, milling atmosphere and milling time, can be easily controlled to achieve desired structure. Besides, mechanical alloying helps in uniformly distributing of CNTs in the matrix [11].

Distribution of CNTs on matrix particles was investigated by SEM. Also the effect of CNTs on density and porosity of bulk samples were studied. Some of the mechanical properties of the composites prepared such as hardness and wear properties are being investigated to show the structural reinforcing effect of the CNTs. Besides we are studying some of the magnetic properties of mechanically alloyed NiFe-CNT and Ni_3Fe-CNT nanocomposites. The results of the CNTs effects on the mechanical and magnetic properties of the composites prepared will be presented in another paper.

2. Experimental

Elemental Fe and Ni powders produced by Merck company were of more than 99% purity and 150 and 10 μm particle size, respectively. Fe and Ni powders were weighted separately and mechanical alloying process was performed in a planetary high-energy ball mill under argon atmosphere.

Stainless steel balls were of 20 mm diameter and the volume of the vial was 120 ml. The ball to powder weight ratio was 10:1 and the vial rotation speed was 400 rpm [12]. The multiwalled carbon nanotubes used in this work were synthesized by catalytic chemical vapor deposition method at Tehran Research Institute of Petroleum Industry. The nanotubes were 60–80 nm in diameter, several micrometers in length with a purity more than 85%. The CNTs were dispersed in alcohol with the aid of ultrasonic agitation. Appropriate amount of matrix powder was added to this solution and ultrasonically agitated for 30 min to obtain 2 wt % CNTs in final product. The resulting slurries were dried in an oven and were subsequently ball-milled for 5 h. The powdered composites were annealed at 500 °C for 1 h to release internal stresses induced by milling and to study the interaction of CNTs and matrixes upon annealing.

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