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Original Research Paper

Structural and microwave absorption properties of nanostructured Fe–Co alloys

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ABSTRACT

We analyzed nanostructured $Fe_{60}Co_{40}$ alloy obtained by mechanical alloying using a planetary ball mill. The prepared powders were characterized using X-ray Diffraction (XRD), Laser particle-measurement, scanning electron microscopy (SEM), X band waveguide and cavity resonator associated with Network analyzer. Obtained results are discussed according to milling time.

XRD patterns show after 12 h of milling the formation of a disordered solid solution having body-centerd cubic (bcc) structure. After 36 h milling, morphological studies indicated that the average crystallites size is around 13 nm and the particles average diameter is about 3.6 μm. The microwave absorbing characteristic was enhanced between 0 and 54 h of milling (from −0.8 to −13.807 dB) with decreasing in the relative dielectric permittivity ε_r.

1. Introduction

Recently, we have witnessed a considerable development in nanomaterials science and technology. Nanomaterials are elaborated thanks to varied ways, high-energy mechanical alloying is one technique that has many potentialities of application [1–3]. It can be used to induce various reactions in the solid state such as amorphization, formation of solid solutions and alloys synthesis. During milling process, repeated collisions between balls, powders and container walls generate severe plastic deformations, and consequently new physical, mechanical and chemical properties appear as compared to those of the same materials with coarse grains [4–5].

Conventional Fe–Co system is a magnetically soft alloy with high Curie temperature, high saturation magnetization, high permeability and low coercivity [6]. These properties are shown to be superior at the nanoscale. The present work aims to study the formation of nanostructured $Fe_{60}Co_{40}$ alloy obtained by high-energy mechanical alloying. Structure, morphology and micro-wave absorbing characteristic are examined. The use of absorbing materials to reduce electromagnetic reflection is of great interest for many applications [7].

2. Experimental procedures

Elemental powders of 99.9% purity of Fe (average particle size of 50 μm) and Co (average particle size 30 μm) were mixed under argon atmosphere in stainless steel vials with 16 steel balls (2 cm in diameter, 20 g in mass) with ball to powder weight ratio fixed at 50:1.

High energy ball milling was performed in a planetary RETSCH PM 400 (Pulverisette 7 model) at 380 rpm and extended up to 54 h. The crystal structure of the powder was examined by X-ray diffractometer (Siemens D500) with $CuK\alpha_1$ radiation. The particles size distribution was measured by means of a laser diffraction scattering method using a particle size analyzer (LS-230, Beckman Coulter Inc.) The morphology at different stages of milling was analyzed by means of a scanning electron microscope (XL 30S FEG). After structural analysis, available powders were compacted (293 K, 2GPa) during 90 min to get bulk samples (13 mm in diameter and 2 mm thickness), these samples were used to investigate the microwave absorbing characteristic. Frequency dependence of the relative dielectric permittivity ε_r was characterized in a cavity resonator associated with network analyzer (AGILENT 8719 ES) and reflection loss (R_L) was measured in metallic wave-guide (PM 7001X).

3. Results and discussion

3.1. Structural properties

Structural characterization via X-ray Diffraction reveals that bcc ($Fe_{60}Co_{40}$) solid solution with disordered structure was confirmed after 12 h of milling. Fig. 1 shows X-ray spectra for elemental and milled powders when peaks related to pure cobalt phase disappeared after 12 h of milling confirming the diffusion of Co into the Fe matrix. Disordered solid solution with (bcc) structure

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