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Synthesis of nickel/Ba-hexaferrite magnetic nano-composite via mechanical alloying route

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Abstract. In this study, nickel and Ba-hexaferrite powders were subjected to high energy mechanical milling in argon atmosphere to produce nickel/Ba-hexaferrite magnetic nano-composite. Effects of milling time and Ni amount on the phase evolution, morphology and magnetic properties of the products have been investigated by XRD, FESEM/SEM and VSM, respectively. XRD analysis of nano-composite indicated only Ni peaks after 5 h milling which implied the embedding of Ba-hexaferrite particles inside the metallic nickel. FESEM results revealed that the increasing of the milling time up to 30 h reduced nano-composite particles size into 20 nm. VSM results showed that the magnetic properties of the nickel/Ba-hexaferrite nano-composite were affected by the process conditions. The highest saturation magnetization (33.8emu/g) was obtained for the sample containing 30 wt% Ni milled for 20 h Ni series of powder mixture. In addition, it was found that by increasing the milling time coercive field decreases.

Introduction

The M-type ferrites, $MFe_{12}O_{19}$ (M= Ba, Sr or Pb), are interesting magnetic materials. They are well-known as permanent magnets, microwave device materials and high-density magnetic recording media [1-3]. Several methods such as co-precipitation, sol–gel, and solid state conventional have been employed to process ultrafine particles of Ba-hexaferrite [4]. If Ba-hexaferrite and an element, with known values of saturation magnetization (M_s) and coercivity (H_c), are assumed to produce a composite, the weight percent of each part can alter the magnetic properties [5,6]. In this study, the $BaFe_{12}O_{19}$ and Ni were used as hard and soft magnet, respectively, which can be considered as an exchange coupled system. The exchange-spring system, which is based on the exchange couple of hard and soft ferromagnetic phases, contemporary satisfies the high magnetization of soft phase with the high H_c of hard phase to obtain a high energy product, $(BH)_{max}$ [7].

Experimental

Mixtures of barium carbonate ($BaCO_3$, 99%) and hematite (Fe_2O_3, 99%) powders with a Fe/Ba molar ratio of 11 were grinded in a Jar mill for 2 h. The rotation speed and Ball to Powder mass Ratio (BPR) were 60 rpm and 50:1, respectively. The mixed powders were then calcined at 1100 °C for 1 h [8,9]. Two powder mixtures of 30 wt% Ni/70 wt% Ba-hexaferrite (A) and 50 wt% Ni/50 wt% Ba-hexaferrite (B) were milled in a high energy planetary ball mill at room temperature in argon atmosphere. The vial and balls were both made from hardened chromium steel. The rotation speed and BPR were 300 rpm and 20:1, respectively.

The phase structure was studied by X-ray Diffraction XRD (Philips X'pert pro) using Cu K_α radiation (λ=1.540598 Å). The morphology of the as-milled samples was examined by Scanning Electron Microscopy, Cam Scan MV2300 SEM. The micro-structures and morphology of nano-composites investigated by Field Emission Scanning Electron Microscope, Hitachi S4160 FESEM equipped with the EDS point chemical analysis. The magnetic properties of nano-composites were measured by a Vibratory Sample Magnetometer (VSM) under the maximum magnetic field of 10 kOe.

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