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Synthesis by Mechanical Alloying and Characterization of $FeNi_3$ Nanoalloys

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Abstract : There is a growing interest on the synthesis and characterization of nanoalloys since the unique chemical, and physical properties of nanoalloys can be tuned and, consequently, new structural motifs can be created by varying the type of constituent elements, atomic and magnetic ordering, as well as size and shape of the nanoparticles. Due to the fine size effects, magnetic nanoalloys have considerable attention with their enhanced mechanical, electrical, optical and magnetic behavior. As an important magnetic nanoalloy, the novel application area of Fe-Ni based nanoalloys is expected to be widened in the chemical, aerospace industry and magnetic biomedical applications. Noble metals have been using in biomedical applications for several years because of their surface plasmon properties. In this respect, iron-nickel nanoalloys are promising materials for magnetic biomedical applications because they show novel properties such as superparamagnetism and surface plasmon resonance property. Also, there is great attention for the usage Fe-Ni based nanoalloys as radar absorbing materials in aerospace and stealth industry due to having high Curie temperature, high permeability and high saturation magnetization with good thermal stability. In this study, $FeNi_3$ bimetallic nanoalloys were synthesized by mechanical alloying in a planetary high energy ball mill. In mechanical alloying, micron size powders are placed into the mill with milling media. The powders are repeatedly deformed, fractured and alloyed by high energy collision under the impact of balls until the desired composition and particle size is achieved. The experimental studies were carried out in two parts. Firstly, dry mechanical alloying with high energy dry planetary ball milling was applied to obtain $FeNi_3$ nanoparticles. Secondly, dry milling was followed by surfactant-assisted ball milling to observe the surfactant and solvent effect on the structure, size, and properties of the $FeNi_3$ nanoalloys. In the first part, the powder sample of iron-nickel was prepared according to the 1:3 iron to nickel ratio to produce $FeNi_3$ nanoparticles and the 1:10 powder to ball weight ratio. To avoid oxidation during milling, the vials had been filled with Ar inert gas before milling started. The powders were milled for 80 hours in total and the synthesis of the $FeNi_3$ intermetallic nanoparticles was succeeded by mechanical alloying in 40 hours. Also, regarding the particle size, it was found that the amount of nano-sized particles raised with increasing milling time. In the second part of the study, dry milling of the Fe and Ni powders with the same stoichiometric ratio was repeated. Then, to prevent agglomeration and to obtain smaller sized nanoparticles with superparamagnetic behavior, surfactants and solvent are added to the system, after 40-hour milling time, with the completion of the mechanical alloying. During surfactant-assisted ball milling, heptane was used as milling medium, and as surfactants, oleic acid and oleylamine were used in the high energy ball milling processes. The characterization of the alloyed particles in terms of microstructure, morphology, particle size, thermal and magnetic properties with respect to milling time was done by X-ray diffraction, scanning electron microscopy, energy dispersive spectroscopy, vibrating-sample magnetometer, and differential scanning calorimetry.

Keywords : iron-nickel systems, magnetic nanoalloys, mechanical alloying, nanoalloy characterization, surfactant-assisted ball milling
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