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Arc-discharge법으로 합성된 Nano자성입자의 특성 (Characterization of Magnetic Nanoparticles Synthesized by arc-discharge)

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1. Introduction

Nanoparticles have a wide range of potential applications[1,2], including magnetic recording media, catalyst, electric conductive or resistive paste, ferrofluids, sintering accelerator, etc. Investigation have been done for magnetic nanoparticles such as Fe, Co, Ni and their alloys[3-6]. The difference between magnetization of the bulk and the nanoparticles has been attributed either to the presence of nonmagnetic surface oxides or to the canting of magnetic moments in the oxide coating. In magnetic nanoparticles, the hysteresis behavior was found to be strongly dependent on the amount of surface oxidation and the magnetic interaction at the core-shell interface was claimed to be responsible for the high coercivity. The oxide layer on Fe particles was composed of divided fine crystallites which had a large spin canting at low temperature. The spins of iron near the interface were more or less pinned to the local spin directions of those fine crystallites and gave an increment of the coercivity. The decrease in magnetization with decreasing particle size was due to the increased volume fraction of oxide in smaller particles and to the canting of the surface moments whose contribution was also higher in the smaller particles. In this work, nanoparticles of Fe, Co, Ni and their alloys with various composition were prepared by arc-discharge synthesis. The phase structures, surface species, hyperfine fields and magnetic properties were systematically investigated.

2. Experimental details

By arc-discharge synthesis method, pure Fe, Co, Ni and their alloys to be evaporated served as the anode, while a carbon rod served as the cathode. After the chamber was evacuated, a mixture of hydrogen and argon was introduced as a source of hydrogen plasma and a condensing atmosphere. X-ray diffraction was performed to identify the phases existing in as-prepared particles. The particle size was determined by analysising transmission electron microscopy micrographs. The as-prepared powder samples were compacted into round plates of 10 mm diameter and about 1 mm thickness for measurement by a RIBER LAS-3000 Mk-2 XPS spectrometer while the MgK line was used as X-ray source. The surfaces of compacted samples were then cleaned by argon ion bombardment. Both the samples with surface cleaned and uncleaned were analyzed by XPS spectroscopy for determination of the species which covered the surface of nanoparticles. In order to estimate the extent of oxidization for the particles, oxygen determinator (LECO TC-437) was used to determine the contents of absorbed and combined oxygen as well as total oxygen. Magnetization was measured by a vibrating sample magnetometer (VSM) in a field up to 0.8 T. Mössbauer absorption spectra were recorded with a conventional constant acceleration spectrometer using a ^{57}Fe source at room temperature. Mössbauer data were analyzed using a least-square computer program. The relative line intensities were applied to determine the relative amounts of ferromagnetism and paramagnetism in the samples.

3. Results and discussion

It is shown that the nanoparticles prepared under the conditions of this work are roughly spherical in TEM micrographs and the mean particles size is about 20 nm. In contrast to bulk Fe-Co and Fe-Ni systems, their corresponding nanoprticles have different phase constitution. In Fe-Co nanoparticles system, two phases of fcc and bcc coexist below 40 wt.% Co, a bcc single phase exists near about 45 wt.% Co, two phases coexist again above about 50 wt.% Co, a single fcc phase exists in pure Co particles. In Fe-Ni nanoparticles system, two phases of bcc and fcc structure coexist in all composition regions. A transition from paramagnetism to ferromagnetism occurs near about 20 wt.% Co in Fe-Co nanoparticles. Two Mössbauer sub-spectra, i.e. ferromagnetism and paramagnetism, coexist in Fe-Ni nanoparticles. The maximum of the saturation magnetization at 36 wt.% Co in bulk Fe-Co alloys is shifted to be at 45 wt.% Co in the ultrafine particles, meanwhile, a minimum appears at about 10 wt.% Co in the nanoparticles system.

4. References

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