Structural and Magnetic Properties of $Fe_{100-x}Al_x$ Nanocrystalline Alloys

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It is known that besides ferromagnetic and paramagnetic behaviors, $Fe_{100-x}Al_x$ alloys exhibit spin-glass and superparamagnetic behaviors. The magnetic spin-glass behavior is found in compounds with x = 25 - 30 while the superparamagnetic one has been found for the compound with $x \approx 30$[1]. The fabrication of nanocrystalline alloys can be carried out by mechanical milling (MA), including two important effects: (i) the disordering of the structure, and (ii) the decrease in the grain size. Basically, $Fe_{100-x}Al_x$ alloysprepared by MA exhibit magnetic behaviors dependent on Al content and the milling conditions[1-3].

This work reports the results of structural and magnetic studies for metastable alloys of $Fe_{100-x}Al_x$ (x = 10, 30, 50, 70, and 90) prepared by MA, used a SPEX 8000 mixer, and the stainless steel vial and balls. The precursors of high-purity Fe and Al powders were combined stoichiometrically, and then milled for 24 hrs in Ar ambient. Final obtained products were studied structural characterization by using an x-ray diffractometer (XRD) and X-ray absorption spectroscopy. The morphology and the particle size are examined by scanning electron microscope (SEM). Their room-temperature magnetic properties were investigated by means of vibrating sample magnetometer (VSM).

The structural analyses reveal that all the compounds were alloyed after 24-hrs milling. When varying Al content, XRD peaks related to $Fe_{100-x}Al_x$ alloys become weaker and broader due to the deformation of structure and variation in the particle size. Fig. 1 shows extended x-ray absorption fine structure (EXAFS) spectra for the samples. One can see that when Al content is increased with x = 10 - 50, the spectral amplitude is decreased and there is a phase shift. The crystal structure of these samples is the same as that of Fe, indicating the incorporation of Al atoms into the Fe host lattice. However, for x = 70 there is the presenceof two structures related to Fe and Al host lattices. The increase in Al content above this value of x = 90 enhances the phase separation, probably caused by two tendencies Al-diffused and Fe-diffused Al. In our case, the value of x ≈ 70 could be considered as the threshold concentration. These results are in good agreement with the XRD results.

Concerning magnetic behaviors, the data obtained from VSM exhibit that both saturation magnetization (Ms) and coercivity (H_c) depend strongly on Al content, see Fig. 2. Here, Ms decreases gradually from 250 emu/g (for x = 10) to 8 emu/g (for x = 90), which is assigned to the dilution of the magnetic lattice of Fe caused by the Al doping. For H_c, it becomes stable at ~60 Oe as Al content varying in the range of x = 10 - 70, but enhances rapidly to about 260 Oe as x = 90, as can be seen in Fig. 2. This phenomenon can be related to changes in the structure and/or attributed to defects at alloyed Fe-Al grain boundaries.

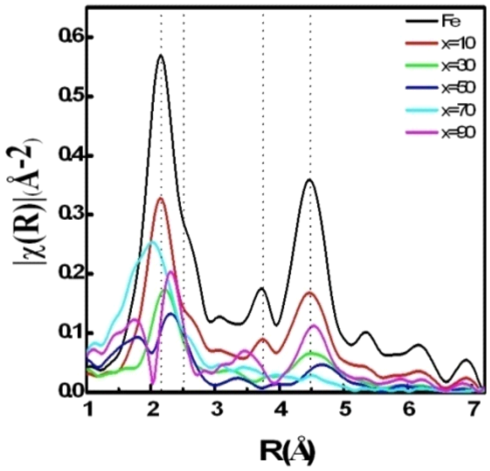

Fig. 1. Fourier transform of EXAFS spectra weighted with k_2 measured at Fe K-edge (dot linesare first, second, third and fourth shells of pure Fe as which are guidelines to compare with alloyed samples).

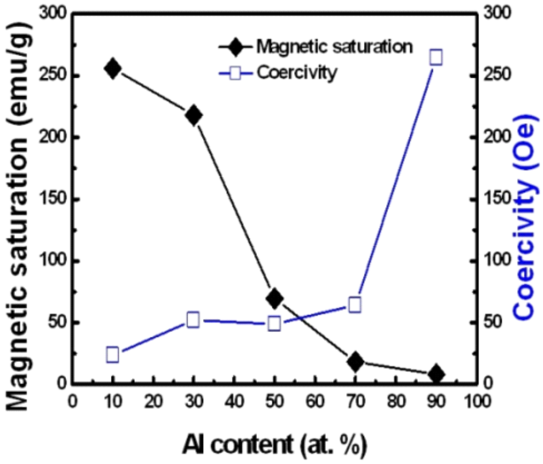

Fig. 2. The saturation magnetization (M_s) and coercivity (H_c) as a function of Al content (x).

References

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