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Microstructural evolution of Fe-C alloy using by EXAFS study

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1. Introduction

EXAFS (extended X-ray absorption fine structure) technique has examined the local structure and local ordering around a concerned atoms in amorphous, nanocrystalline, crystalline and various solids. Also EXAFS is very sensitive on the variation of the radial distribution of atoms due to the physical and thermal disturbance. Recently metal-carbon systems such as metal containing diamond or diamond like carbon thin films have been extensively studied for application to mechanical and electronic devices. It is important to know the local structure and the ordering between atoms in the metal-carbon system to understand the formation of these alloys.

In this work, amorphization of Fe-C alloys were examined for $Fe_{80}C_{20}$ alloy produced by the mechanical alloying by XRD and EXAFS. The variation of local structure and the local ordering during the alloying process of $Fe_{80}C_{20}$ were analyzed by EXAFS. The magnetic properties were measured by the vibrating sample magnetometer (VSM) for comparison of structural variation and magnetic properties.

2. Experimental

Mixtures of appropriate amounts of Fe and Carbon (-80 mesh, 99.9 %) powders were mechanically alloyed by using SPEX 8000 mixer and mill with stainless balls and vial with the balls to powder weight ratio of 6 : 1. Mechanical alloying was peformed under an Ar atmosphere. Metastable $Fe_{80}C_{20}$ alloys were formed during 1, 2, 4, 6, 12 and 24 hours milling time, respectively. The magnetizations of milled samples were measured by VSM under a maximum field of 10 KOe. Structural change for each sample was examined by X-ray diffraction (XRD) and EXAFS spectroscopy.

3. Results and discussions

The variations of magnetization as processing times shows a formation of supersaturated solid solution. In the initial stage of mechanical alloying, magnetization decreased rapidly and then slightly changed after 12 hours. With increasing processing time, welding and fracture of powders are repeated and interdiffusion of Fe and Carbon increased, resulting in magnetic dilution i.e. decreases in magnetization.

The structural evolution as a function of processing times were carried out using by XRD and EXAFS measurements. From XRD pattern, as-mixed powders shows sharp diffraction peaks and all the peaks could be analysed into a mixture of bcc Fe and hcp Carbon. With increasing milling

time, diffraction peaks from Carbon disappeared after 1 hr and the remaining peaks from the bcc Fe phase become weaker and broader. The higher peaks disappeared completely for samples milled for 12 and 24 hours. As increasing milling time, lattice parameter was increased as a function of milling time. Because the Carbon atoms interstitial diffuse into bcc Fe structure during mechanical alloying.

The EXAFS spectra obtained from absorption spectra were Fourier transformed which is called as a shell. The shell represents the nearest neighbors or a group of atoms in a radial direction from the central atom. Figure 1 is the Fourier transformed EXAFS spectra for samples processed for the indicated times. The peaks in the Fourier transformed spectra decreased as increasing the milling time. In 6 hours milling time, the position of the first peak begins to shift to a lower distance which means that the dominant atoms around the iron central atom begin to change. In 12 hours milling time, the shift of first peak increased and higher shells than the third disappeared. In 24 hours milling time, there is no more change from the 12 hours milling indicating that the alloying process has been completed.

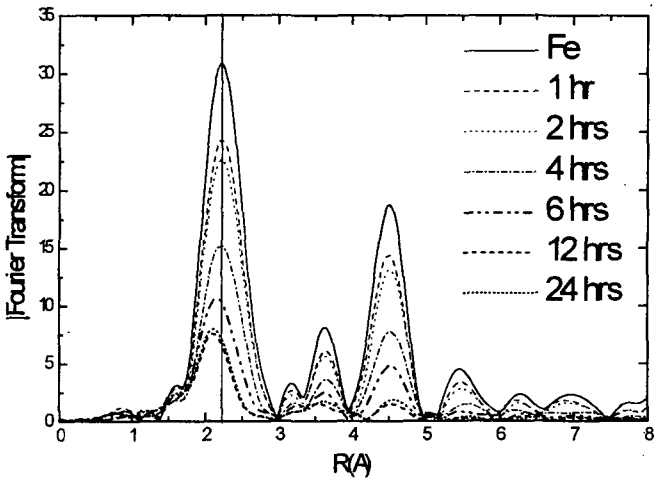

Fig. 1 Fourier transform of EXAFS spectra of $Fe_{80}C_{20}$ alloy with milling times.

The order or the disorder between the central and the neighboring atoms can be shown more effectively in the graph of radial distribution which is obtained by fitting the filtered spectra. Fe-C ordering increased but bonding distance was not changed as the milling time increases from 6 to 12 hours. The distribution of Fe-Fe has been broadened significantly and also, the bonding distance was increased. It shows that the disorder of Fe-Fe atoms generates significantly as the milling time is changed from 6 to 12 hours. This results is consistent with magnetization and XRD measurement.

4. Conclusion

From EXAFS analysis, we found that the structure of mechanically alloyed $Fe_{80}C_{20}$ became the nanostructural state at 6 hours milling time, and transformed to a mixture of amorphous and nanocrystalline state at 12 hours milling time. It is also shown that Fe-C ordering increases and the Fe-Fe ordering decreases in the amorphization process. The reduction of magnetization was interpreted by the variation of local structure around Fe atoms in $Fe_{80}C_{20}$ alloy.