

MÖSSBAUER AND X-RAY STUDY OF $\text{Fe}_{1-x}\text{Al}_x$, $0.2 \leq x \leq 0.5$, SAMPLES PRODUCED BY MECHANICAL ALLOYING

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ABSTRACT

In this work we report the magnetic and structural properties of the $\text{Fe}_{1-x}\text{Al}_x$, $0.2 \leq x \leq 0.5$, alloys produced by mechanical alloying obtained by Mössbauer spectroscopy and X-ray diffraction. Alloys with $x = 0.2, 0.3, 0.4$ and 0.5 , were for milled 12, 24, 36, and 48 hours. All the obtained alloys are in the bcc phase. The obtained Mössbauer spectra are characteristic of disordered ferromagnetic system. It can be noted a tendency to a paramagnetic behaviour when x increases as a consequence of the magnetic diluter character of the Al atoms. The lattice parameter remains nearly constant ($\sim 2.91 \text{ \AA}$) for all the milling time and composition. The mean grain size along the (110) direction, for all the samples, are nearly constant with the milling time. However it decreases with the Al concentration from $\sim 15.5 \text{ nm}$ for 20 at. % Al up to $\sim 11 \text{ nm}$ for 40 at. % Al, then remains nearly constant with a value $\sim 11 \text{ nm}$. This result is a consequence of the fragile character induced by the Al atoms. For the 20 at. % sample the mean grain size in the (211) direction decreases from 10.5 up to 8.5 nm when the milling time changes from 12 up to 24 hours then remains nearly constant. For other Al contents it remains nearly constant. This mean grain size decreases from 10.5 nm at 12 hours, for 20 at. % Al, and from 8.5 nm, for the other milling times, up to $\sim 6 \text{ nm}$ for 40 at. % Al, and the remains nearly constant. The difference between the mean grain sizes in the two reported directions show that the grains are of prolate spheroid form.

INTRODUCTION

Mechanical alloying is one of the most efficient methods to produce materials with nanocrystalline size. An advantage of mechanical alloying over many other techniques is that it is a solid state technique and consequently problems associated with melting and solidification are bypassed. The Fe-Al system is of interest due the potential commercial application of these alloys as structural or magnetic materials. In the last years a number of studies have been reported on mechanically alloyed FeAl [1, 2, 3]. In this work we report a study of FeAl samples with an Al concentration varying from 20 to 50 at. %. They were prepared by using a high energy planetary ball milling. We studied the magnetic and structural properties dependency on the concentration and the milling time.

EXPERIMENTAL DESCRIPTION

Samples of the $\text{Fe}_{1-x}\text{Al}_x$ system with $x = 0.2, 0.3, 0.4$ and 0.5 were prepared by mechanically alloying using high purity iron and aluminium powders and a Frish planetary ball mill of high energy at 280 rpm in an Argon environment. The milling was made in hardened stainless steel vials provided with four balls of the same material with 1.25 cm of diameter.

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A total of 8 grams of mixture of powders was prepared. The ball mass to powder mass ratio used was 16:1. The milling periods were of 12, 24, 36 and 48 hours. The powders of the milled samples were measured in a transmission Mössbauer spectrometer using a radioactive Co-57/Rh source. The spectra were fitted with hyperfine field distribution (HFD) and doublets using the NORMOS program and the fitted spectra were imagined with the aid of the ORIGIN program. The x-rays analysis to establish the structure and other properties of the lattice were obtained at room temperature for all samples using a RINT20001 diffractometer with the Cu K α radiation.

RESULTS AND DISCUSSION

Room temperature Mössbauer spectra for the different Fe-Al samples are shown in figures 1. It appear in these figures the different spectra of the samples with $x=0.2, 0.3, 0.4$ and 0.5 , respectively, for milling times of 12, 24, 36 and 48 hours. It can be observed that the samples with $x=0.2$ and 0.3 , for all the milling times, are disordered and ferromagnetic with high hyperfine fields. Samples with $x=0.4$ and 0.5 additionally present a wide paramagnetic site for all the milling times, as a result of the greater Al content, which behaves as magnetic hole. Additionally it can be observed that samples with 50 at. % Al are totally paramagnetic for milling times bigger that 12 hours. Remembering that disordered alloys of this system are paramagnetic for this composition when they are prepared by melting, it can be conclude that milling times bigger that 12 hours can result in a very similar sample produced by arc melting [4]. Figure 2 shows the x-rays diffraction pattern of the samples with $x=0.2, 0.3, 0.4$ and 0.5 , respectively, for milling times of 12 and 48 hours. All the patterns are similar and their X-rays analysis indicates that in all the samples the phase is BCC. The lattice parameter remains nearly constant ($\sim 2.91 \text{ \AA}$) for all the milling times and compositions.

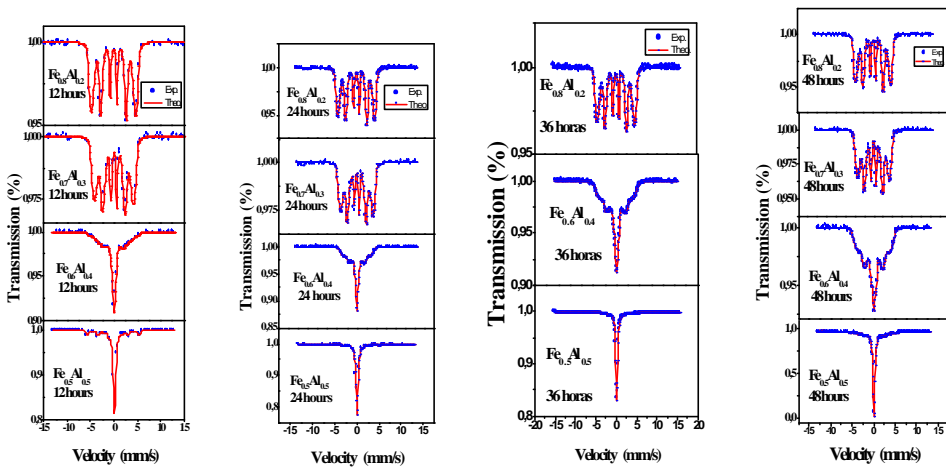


Fig.1. Mössbauer spectra of Fe1-xAlx with $0.2 \leq x \leq 0.5$ for 12, 24, 36 and 48 hours.

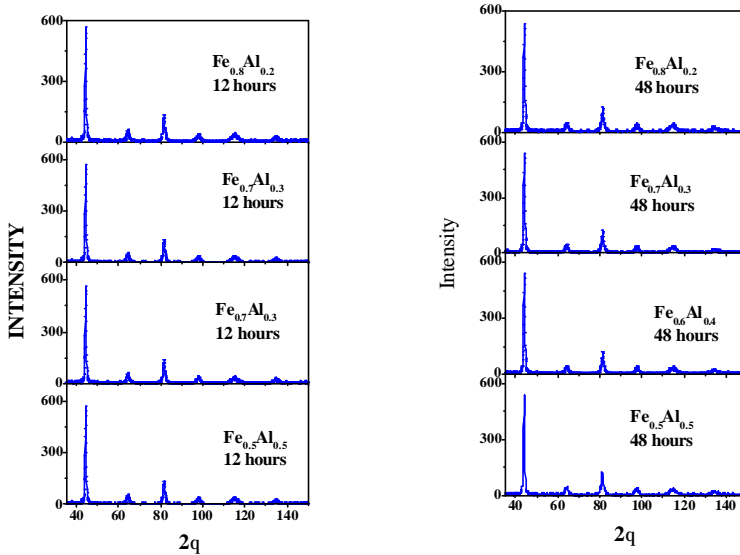


Fig.2. X-ray diffraction of $Fe_{1-x}Al_x$ with $0.2 \leq x \leq 0.5$ for 12 and 48 hours.

The figures 3 and 4 show the dependence of the mean grain size with the milling time and Al concentration, respectively, along the (110) direction. The mean grain size along the (110) direction for all the samples are nearly constant with the milling time. However it decreases with the Al concentration from ~ 15.5 nm for 20 at. % Al up to ~ 11.0 nm for 40 at. % Al and then remains nearly constant with a value ~ 11.0 nm. This result is a consequence of the fragile character induced by the Al atoms.

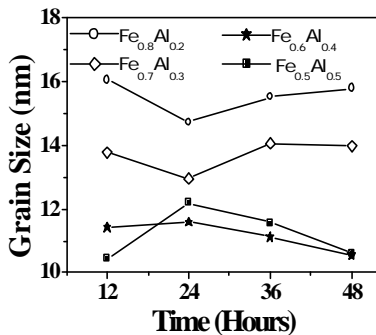


Fig. 3. Dependence of the mean grain size with the milling time along the (110) direction size

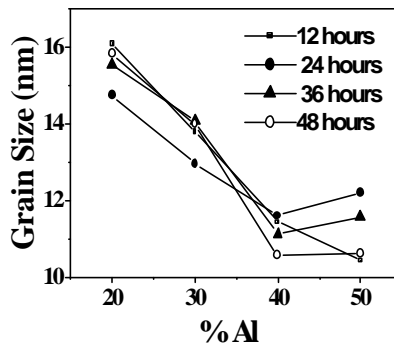


Fig.4. Dependence mean grain size with the Al concentration along the (110) direction

The Figures 5 and 6 show the dependence of the mean grain size with the milling time and Al concentration, respectively, along the (211) direction. The mean grain size in the (211) direction for the 20 at. % sample decreases from 10.5 up to 8.5 nm when the milling time changes from 12 up to 24 hours, then it remains nearly constant. For other Al contents it remains nearly constant. This mean grain size decreases from 10.5 nm at 12 hours, for 20 at. % Al, and from 8.5 nm, for the other milling times, up to ~ 6 nm for 40 at % Al, and then remains nearly constant. The difference between the mean grain sizes in the two reported directions shows that the grains are of prolate spheroid form.

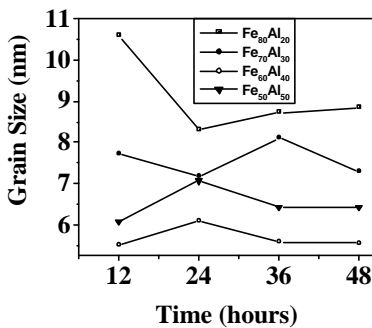


Fig. 5. Dependence of the mean grain size with the milling time along the (211) direction

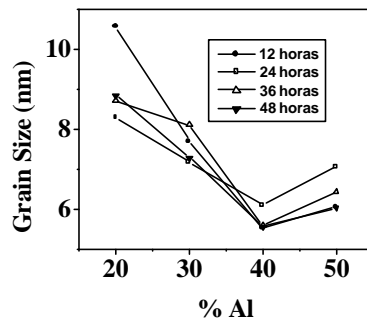


Fig. 12. Dependence of the mean grain size with the Al concentration along the (211) direction

CONCLUSION

Mechanical alloying has been used to produce $Fe_{1-x}Al_x$, $0.2 \leq x \leq 0.5$, alloys. All the obtained alloys are in the bcc phase and behave as a ferromagnetic disordered system with a tendency to a paramagnetic behaviour for $x \geq 0.3$. This is a consequence of the magnetic diluter character of the Al atoms. The difference between the mean grain sizes in the (110) and (211) directions shows that the grains are of prolate spheroid form.

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