Hyperfine Interact
DOI 10.1007/s10751-011-0492-4

Mössbauer study of mechanical deformation induced order-disorder transition in $Fe_{75}AlSi$ alloys

Estibaliz Legarra · Fernando Plazaola · Estibaliz Apiñaniz · Jose Angel Garcia · Jose Javier Saiz Garitaonandia

Abstract We study the influence of different Al/Si ratios on the magnetic and structural properties of mechanically disordered powder $Fe_{75}Al_{25-x}Si_x$ alloys. The results indicate that addition of Si to binary Fe-Al alloys makes the disordering more difficult. The study of the hyperfine fields indicates that there is an inversion of the behavior of the hyperfine field of the Fe atoms surrounded by 8 Fe atoms with disordering. The magnetic and hyperfine measurements indicate that the influence of Si is opposite to the one of Al in the magnetism of Fe atoms.

Keywords Fe based ternary alloys · Mössbauer spectroscopy · Mechanical deformation

1 Introduction

There is not much information about the influence of the mechanical deformation in the magnetism of Fe-Si alloys [1, 2]. However, there are many studies about the influence of the mechanical deformation in the magnetism of Fe-Al alloys, where the order-disorder transition induces a dramatic reinforcement of the magnetism of the samples [3]. The most common explanation to this phenomenon is related to changes in the nearest-neighbor configuration with the disordering, that is to say, to the disorder around Fe atoms. However, Hernando et al. [4], taking into account the

E. Legarra · F. Plazaola (✉) · J. A. Garcia · J. J. S. Garitaonandia
Zientzia eta Teknologia Fakultatea, Euskal Herriko Unibertsitatea,
UPV/EHU, p. k. 644, 48080 Bilbao, Spain
e-mail: fernando.plazaola@ehu.es

E. Apiñaniz
Fisika Aplikatua I Saila, Euskal Herriko Unibertsitatea, UPV/EHU,
Urkixo zumarkalea z/g, 48013 Bilbao, Spain

Published online: 29 November 2011

lattice parameter increase associated with the disorder of these alloys, suggested that the magnetic reinforcement was also related to changes in volume.

In this work we study systematically the influence of different Al/Si ratios on the magnetic and structural properties of mechanically disordered powder $Fe_{75}Al_{25-x}Si_x$ alloys by means of Mössbauer spectroscopy, X-ray diffraction and magnetic measurements.

2 Experimental

The samples have been obtained by means of induction melting. Afterwards, they were powdered and annealed to obtain large domains of ordered structures. The annealed samples were milled by means of a planetary ball mill Retsch PM4. The milling was made with a ball:powder rate of 10:1 and three balls of 10 mm diameter at 295 rpm. Jars and balls were of Chrome steel. We have used Co K_α radiation with a Broker-AXS Discover Bragg-Brentano difractometer and the Rietveld method to analyse the diffractograms. The Mössbauer spectroscopy has been performed in transmission geometry with a ^{57}Co-Rh source. The spectra were fitted with NORMOS Program [9]. Magnetic measurements were performed in a SQUID magnetometer (Quantum Design MPMS) at 300 K from 0–7 T.

3 Results and discussion

The main non-equivalent positions in ordered $Fe_{75}Al_{25-x}Si_x$ are the ones corresponding to Fe atoms surrounded by 8 Fe atoms (8Fe) and 4 Fe atoms (4Fe).

Figure 1 shows Mössbauer spectra of milled alloys for 1 and 5 milling hours. The spectra fit indicates that the disorder is very high (characterized by disordered A2 structure content, in which the binomial distribution gives population probabilities of around 10% to 8Fe and 4Fe environments) in all samples after 5 milling hours. However, after 1h of milling time $Fe_{75}Si_{25}$ alloy is not highly disordered, as subspectra related to the most populated 8Fe and 4Fe non-equivalent positions of stoiquiometric D03 structure are majority (only 28% of A2 structure). Nevertheless, the disorder of the alloy increases with Al content in the alloy. The content of A2 structure versus milling time (not shown) indicates that after 3h of milling time all the samples are highly disordered, but while the disorder of ternary alloys continues increasing towards 100% A2, the disorder on $Fe_{75}Si_{25}$ alloy saturates at 83%.

Figure 2 shows that the evolution of the saturation magnetization (M_s) with milling time and Si content in the alloy is similar to the one shown by $<B_{hf}>$, the mean hyperfine field. Their values decrease with milling time in the alloys with Si content higher or equal to 12.5at%, but increase in the alloys with Si content less or equal to 7.5at%. The behaviour observed clearly indicates that the introduction of Si in the binary $Fe_{75}Al_{25}$ alloy opposes the magnetic behaviour induced by Al in the magnetism of Fe in these alloys [3]. Indeed, for alloys with Si content below around 10 at% the magnetic behaviour of the completely disordered alloys is like the one found in alloys of the Fe rich side of the FeAl phase diagram, M_s and $<B_{hf}>$ increase

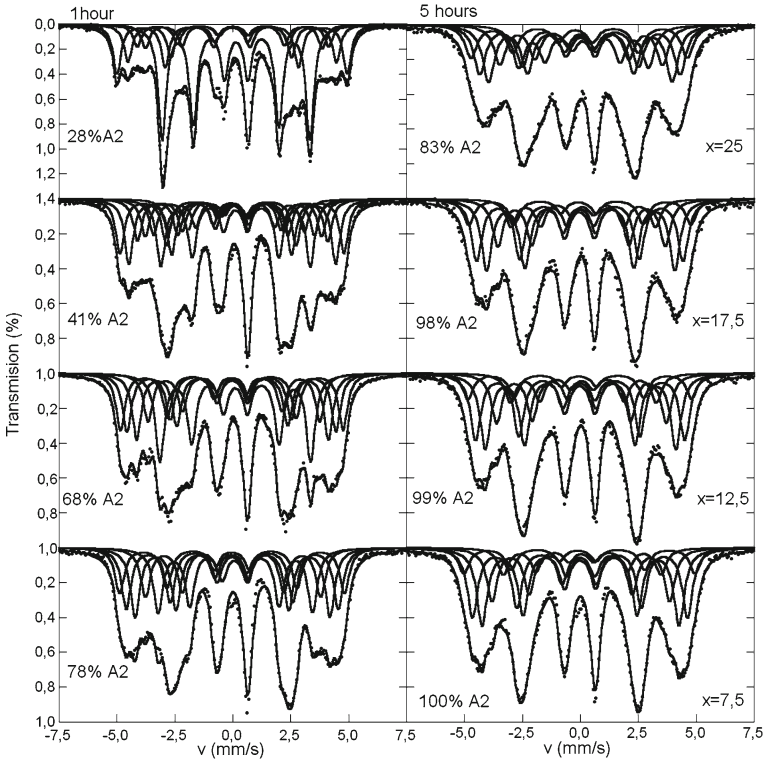

Fig. 1 Mössbauer spectra of 1 hour and 5 hours milled $Fe_{75}Al_{25-x}Si_x$ alloy series

with disorder [5]; however, in the case of alloys with a Si content above ~10 at% the behavior is the opposite: M_s and $<B_{hf}>$ decrease with disorder.

Figure 2 shows the evolution of B_{hf} with the disorder for 4Fe and 8Fe non-equivalent positions, B_{hf}(4Fe) and B_{hf}(8Fe), too. It is observed that the behaviour of B_{hf}(4Fe), the most populated in D03 structure, follows a relatively similar trend to the one found in $<B_{hf}>$, but in the case of the alloy $x = 7.5$ there is a small decrease of the B_{hf}(4Fe) in the first 2 hours of milling, and it increases afterwards. On the other hand, B_{hf}(8Fe) is very sensitive to the disorder introduced and it shows an inversion in the trend in respect to the one found in the ordered alloy (0 h). In the ordered alloys B_{hf}(4Fe) increases with Si decrease and this trend is maintained in the disordering. However, in the case of the ordered B_{hf}(8Fe) it increases with Si content in the alloy but this trend changes during milling time to show, in the completely disordered samples, the opposite behaviour. Therefore, after complete deformation of the alloy, both non-equivalent Fe positions show the same trend (opposite to that of the ordered alloys); that is to say, the B_{hf}(4Fe) and B_{hf}(8Fe) increase with Si content decrease. The inversion of the B_{hf} behaviour in the disordering process makes 8Fe non-equivalent position very sensitive to the degree of disordering in $Fe_{75}Al_{25-x}Si_x$ alloy system.

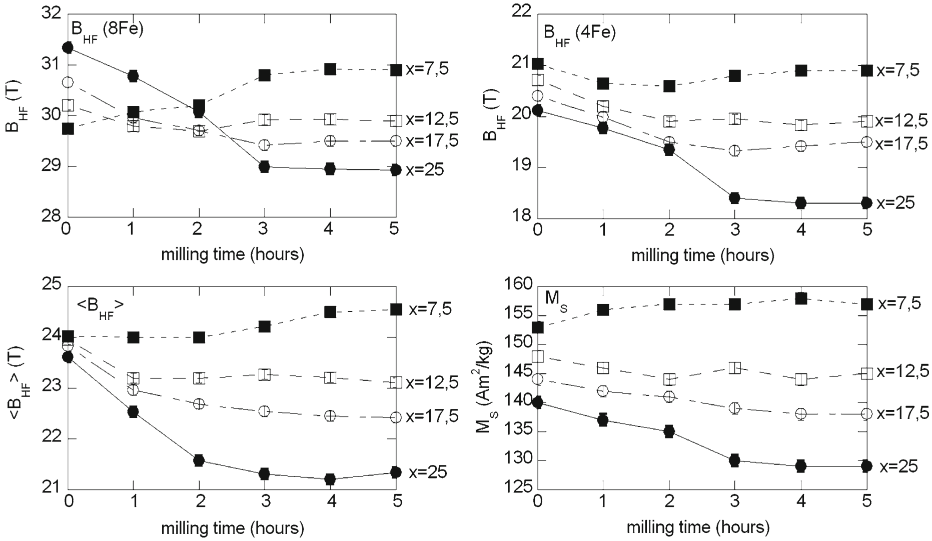

Fig. 2 B_{hf} versus milling time of 4Fe and 8Fe positions, $<B_{hf}>$ and M_S of $Fe_{75}Al_{25-x}Si_x$

4 Conclusions

The addition of Si to binary $Fe_{75}Al_{25}$ alloy makes the disordering more difficult. The hyperfine fields of $Fe_{75}Al_{25-x}Si_x$ alloy series indicate that there is a redistribution of non-ferrous atoms around Fe atoms with the disordering; indeed, there is an inversion of the behavior of the hyperfine field of non-equivalent positions of Fe atoms. The addition of Si to binary $Fe_{75}Al_{25}$ alloys opposes the magnetic behavior induced by Al in the magnetism of Fe in these alloys.

Acknowledgements Authors want to acknowledge the Basque Government and the Spanish CICYT under Grants IT-443-10 and MAT2009-14398.

References

1. Elsukov, E.P., Konygin, G.N., Barinov, V.A., Voronina, E.V.: J. Phys.: Condens. Matter **4**, 7597 (1992)
2. Lehlooh, A.F., Fallad, S.M., Mahmood, S.H.: Hyperfine Interact. **139/140**, 335 (2002)
3. Apiñaniz, E., Plazaola, F., Garitaonandia, J.S., Martín, D., Jiménez, J.A.: J. Appl. Phys. **93**, 7649 (2003)
4. Hernando, A., Amils, X., Nogues, J., Suriñach, S., Baro, M.D., Ibarra, M.R.: Phys. Rev. B **58**, 11864 (1998)
5. Zamora, L.E., Perez Alcaraz, G.A., Velez, G.Y., Betancur, J.D., Marco, J.F., Romero, J.J., Martinez, A., Palomares, F.J., Gonzalez, J.M.: Phys. Rev. B **79**, 094418 (2009)