MÖSSBAUER STUDIES OF AMORPHOUS FeSi COMPOSITIONALLY MODULATED THIN FILMS

B. Martínez, A. Ruiz*, A. Labarta**, X. Obradors**, F. Briones* and J. Tejada**
ICMAB, C.S.I.C., c/ Martí i Franqués, s/n. Apartado de Correos 30102.08028 BARCELONA.
* CNM - C.S.I.C., c/ Serrano, 144 28006 MADRID
** Facultad de Física, U. de Barcelona, Diagonal, 647, 08028 BARCELONA
SPAIN

Abstract

Conversion electron Mössbauer spectra of composition modulated FeSi thin films have been analysed within the framework of a quasi shape independent model in which the distribution function for the hyperfine fields is assumed to be given by a binomial distribution. Both the hyperfine field and the hyperfine field distribution depend on the modulation characteristic length.

Introduction

Thin solid films are of active scientific interest as well as of great technological importance and considerable theoretical and experimental works to understand the electronic and magnetic structures of surfaces and interfaces have been undertaken in recent years[1-2]. Several Mössbauer works[3-4] have been carried out with the aim to study the iron "in contact with" diverse material by using the hyperfine magnetic fields as a test for the interfacial effects. The main conclusions of the Mössbauer studies refer that the moment of the "interfacial" Fe is different from the bulk value and depends on the coating material[3].

Experimental results

Our FeSi composition modulated thin films were prepared in a special triode-sputtering system onto glass substrates held at room temperature. Films were grown by codeposition from two independently polarized Fe and Si cathodes [5]. The resulting films were magnetically soft with an induced uniaxial anisotropy axis in their plane, which was deduced from transverse biased initial susceptibility (TBIS) measurements [5,6]. In this work we have studied single layers of an amorphous alloy of composition $Fe_{75}Si_{25}$ with different thicknesses separated by amorphous single layers of Si. The total thicknesses of the samples, of about 1000Å, were determined by using a Tolonsky interferometer. The amorphous character of the films was determined by X-ray diffraction. By means of low angle X-ray scattering we have tested the modulating structure of the multilayers. X-ray results agree well with the λ values predicted by the preparation method.

In Table I we sumarize the thickness and composition of the samples.

Table I: Thickness and composition of the different samples.

$Fe_{75}Si_{25}$ single layer thicknesses (Å)	Amorphous Si single layer thicknesses (Å)	Characteristic modulation length λ(Å)
4.4	2.2	6.6
8.8	4.4	13.2
17.6	8.8	26.4
35.2	17.6	52.8

The electron conversion Mössbauer studies have been carried out by using a home made acetone gas detector The single line source was 20 mCi of ^{57}CoRh. All the spectra were recorded at room temperature and the experimental arrangement is that the gamma rays are perpendicular to the substrate plane.

Because of in amorphous systems a wide distribution in local neigbourhood of the iron atoms exists as a consequence of both chemical and structural disorder, the

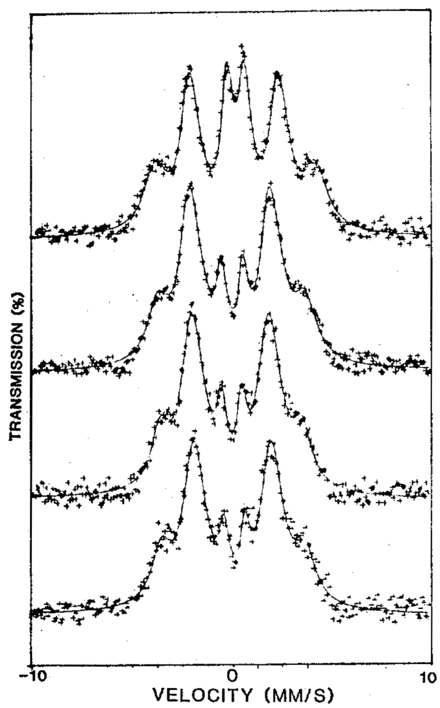

Figure 1: Spectra of $Fe_{.75}$ $Si_{.25}$ modulated structures for different λ values.

Mössbauer spectra of our sample show 6 broad partially overlapped lines (see Figure 1). That means that in order to get a correct information regarding the local surroundings of the iron atoms we have to do further assumptions.

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For the analysis of the Mössbauer spectra we have assumed that: 1) the distribution functions for the isomer shift and quadrupole interaction are so narrow compared with the distribution function for the magnetic hyperfine field (P(H)) that they can be approximated with δ-functions, 2) P(H) is given by a binomial distribution[7]:

$$P(X,n) = \binom{z}{n} X^n (1 - X)^{z-n} \qquad (1)$$

with $H(n)= H_o+n\Delta H$. We have fixed the number of fields to 21 and consequently z=20 and n varies between 0 and z. Furthermore we have assumed that the intensity ratio for all the samples is 3:4:1, as indicate magnetic measurements[8-9]. The least-squares fitting procedure run to find the optimun values of the shape-parameter x, the internal width ΔH, the lower limit H_o and the line width of the basic sextuplet[4]. We have also introduced a pure quadrupole doublet in order to take account for the existence of non magnetic Fe atoms.

In Table II we summarize the hyperfine parameters obtained from the above exposed fit procedure and in Figure 2 we show the evolution of the resulting P(H) distributions with the increase of the modulation characteristic length λ .

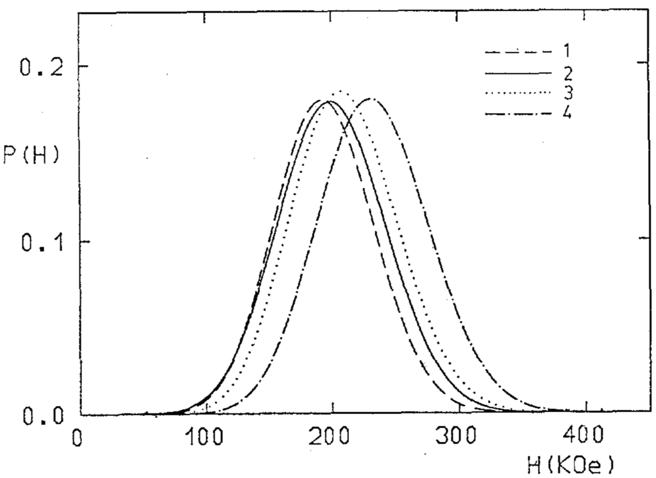

Fig. 2. Binomial distribution of the hyperfine fields.

Table II. Hyperfine parameters of the magnetic irons.

Sample	isomer shift(mm/s)	<H>(KOe)	Line widht (mm/s)
1	0.13(1)	200	0.33(1)
2	0.12(1)	204	0.42(1)
3	0.12(1)	215	0.36(1)
4	0.07(1)	240	0.38(1)

<H>= mean field value of the binomial distribution.

Discussion

The fact that the P(H) functions corresponding to samples having λ ⩽ 6Å have practically the same values for the mean <H> and width allow us to interpret them as due mainly to interfacial irons. Hence we assume that the interface has an extension of about 6Å in agreement with the results obtained by Van Noort et al.[4] in the Cu-Fe compositionally modulated thin films.

The P(H) distributions for the samples having λ>6Å have been deconvoluted in two P(H) distributions. One of them has the H_{hf} distribution attributed to interfacial effects and the second one corresponds to the iron located at the bulk of the amorphous $Fe_{75}Si_{25}$ single layers. The area of this second distribution increases when increases the thickness of the amourphous $Fe_{75}Si_{25}$ single layers, as it is shown in Figure 4.

The magnitudes of the hyperfine fields of the interfacial irons are smaller than those of the irons located at the bulk which agrees well with the fact that the iron magnetic moment decreases when increases the number of Si first and second neighbours.

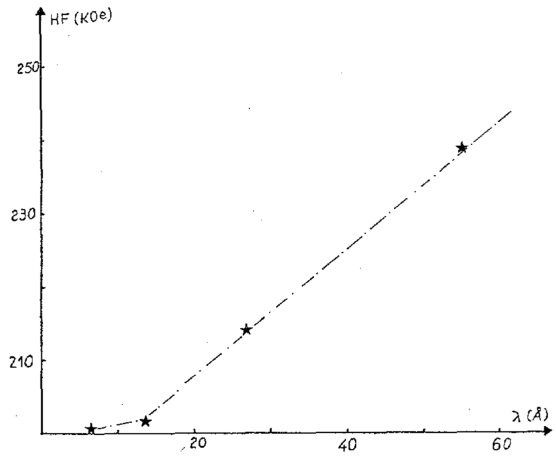

Figure 3: Variation of mean hyperfine field as a function of λ.

Increasing the characteristic modulation length, λ, the P(H) distribution of the "bulk" iron moves to higher fields (see Figures 2 and 4). This may not be attributed to variation in the magnetic moments but to an increase of the exchange interactions and consequently in the Curie temperatures[10].

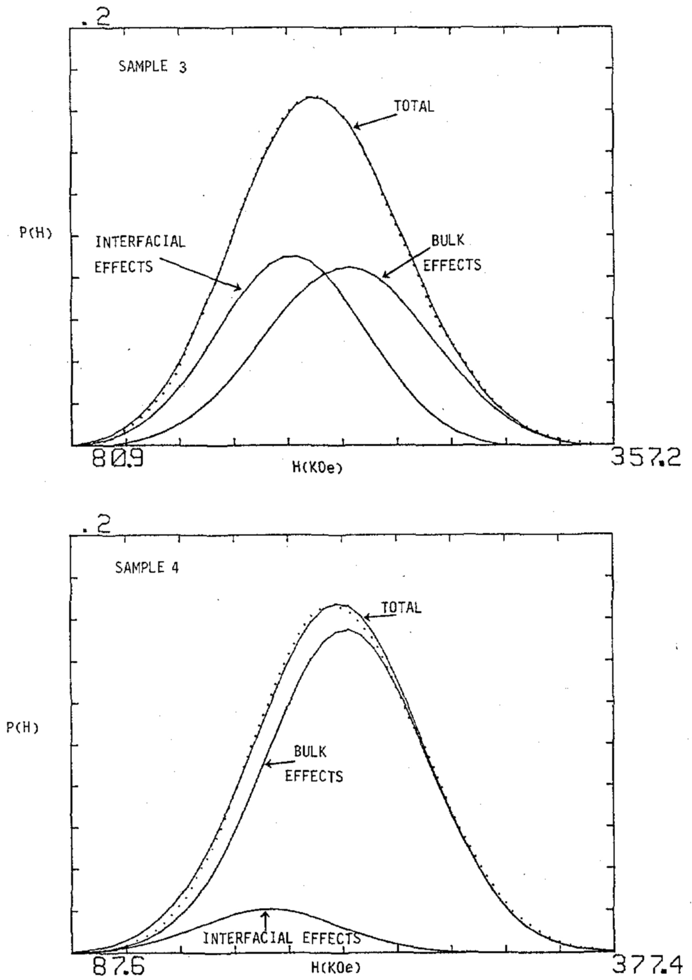

Figure 4: deconvolution of hyperfine field distribution for sample 3 and 4. Dasehd lines correspond to distributions of Figure 2.

The intensity of the quadrupole doublet introduced to fit the spectra increases with the thickness of the Si amorphous sublayers (see Table III). This effect can be explained taking into account the increase of both, the interface region [11] and the non magnetic Fe atoms present in the bulk as increasing the modulation length.

Table III. Hyperfine parameters of the quadrupole doublet

Sample	Isomer shift(mm/s)	Q.E.(mm/s)	Intensity (arbitrary units)
1	0.28(2)	−1.58(2)	7990
2	0.21(1)	−1.28(1)	8250
3	0.16(1)	−1.52(1)	9920
4	0.18(1)	−0.73(1)	24270

We thanks the CAICYT for financial support, contract number 916/84

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