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Magnetic hyperfine field at diluted ^{57}Fe in vapor-quenched heavy-rare-earth films

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In this work, we combine vapor-quenching technique at low temperature (20 K) and *in situ* ^{57}Fe Mössbauer spectroscopy at different temperatures (7–300 K) to study out-of-equilibrium solubility and magnetic properties of ^{57}Fe(5 at. %) in some magnetic heavy-rare-earth (RE) metals (RE=Dy, Ho, Er, and Tm). The spectra were fitted using the full Hamiltonian including electric quadrupole and magnetic interactions. Two magnetic components are observed in the 7 K Mössbauer spectra: one with a magnetic hyperfine field (B_{hf}) varying between 5.3(2) and 1.9(2) T, which has been attributed to Fe at a substitutional site, and the other one, with a smaller field (<2.1 T), which is assumed to be due to Fe at an interstitial site. The behavior of B_{hf} for Fe at the substitutional site in the different RE metals scales with the de Gennes factor. [S0163-1829(97)10117-5]

I. INTRODUCTION

The magnetic behavior of $3d$ impurities in rare-earth (RE) metals is a classical problem and the basic physics of the interaction mechanisms involved is essentially understood.[1,2] The main point is the detailed balance between the two magnetic subsystems, namely that of the localized $4f$ electrons, resulting in localized magnetic moments and that of the $3d$ conduction electrons giving rise to itinerant magnetism. The $4f$-$3d$ coupling proceeds via the RE $5d$ electrons which hybridize with the $3d$ electrons and participate in a local $4f$-$5d$ exchange interaction.[3] Studies of dilute systems as well as of an intermetallic ($3d$-$4f$) compound can help in the better understanding of the $3d$-$4f$ interaction. In the case of very dilute transition-metal (TM) impurities in RE metals, however, only a few systems have been studied until now, for reasons which will be given below.

Mössbauer spectroscopy is a common method where the Mössbauer nucleus is used as a probe to study the magnetic behavior as well as the charge transfer due to hybridization of dilute impurities in metals. With this technique it is possible to measure simultaneously the magnetic hyperfine (hf) field and the isomer shift, which are proportional to spin and charge density, respectively, at the Mössbauer nucleus. An example is the magnetic hf field B_{hf} measured at a *nonmagnetic* probe, such as ^{197}Au or ^{193}Ir embedded in heavy RE hosts.[4,5] In these works, B_{hf} have been interpreted in the framework of the standard Rudermann-Kittel-Kasuja-Yosida (RKKY) theory, which predicts a linear decrease in B_{hf} going from Gd to Tm. In the case of magnetic $3d$ impurities, like Fe, we can expect that there is an additional contribution to the hf field coming from the Fe impurity itself, since in many cases Fe keeps part of its own magnetic moment, as was shown for Fe at the substitutional sites.[6]

In the case of TM and RE metals, the formation of thermally stable alloys of the RE$_{1-x}$TM$_x$ type is inhibited, for most of TM elements by conventional metallurgical methods, in the range of low TM concentrations, since there is a very small TM solubility in RE metals. This is the reason why only a few number of experiments have been reported at low TM concentration in RE metals. However, since the development of several methods particularly suitable to prepare out-of-equilibrium alloys, such as the vapor-quenching technique and sputtering, a great number of new materials containing Fe have been prepared.[7–10] These new materials are interesting from the fundamental physics point of view, especially in connection with their magnetic properties. In this respect, a great amount of work has been concentrated on the study of magnetism of systems based on metals which do not form any kind of solid solution or intermetallic compounds in the corresponding equilibrium phase diagram. Therefore, we have addressed the problem of Fe in RE matrices based on the vapor condensation at low temperature.

Most of the work which has been done on such TM:*RE* systems[11–13] is related to measurements of hyperfine (hf) interactions at TM impurities in *Gd* and *Tb* systems. Few years ago, Forker *et al.*[12] found that Fe:*Tb*, prepared by melting trace amounts of radioactive ^{57}Co (the parent nucleus of the ^{57}Fe Mössbauer isotope) into RE ingots, has a unique Fe site, which does not follow the magnetic behavior of the matrix. Forker explained his results assuming that Fe goes only to interstitial sites or forms some kind of micro-intermetallic compound. However, Brewer *et al.*,[13] using in-beam time-differential perturbed angular distribution (IBTDPAD), have found that in Gd and in Tb matrices 60% of the Fe atoms go to an interstitial site and 40% to a substitutional site. Both sites show magnetic order at low temperatures and follow the magnetic behavior of the matrices. The B_{hf} values obtained from IBTDPAD for Fe:*Gd* are in agreement with the values estimated from local electronic structure calculations.[2,13]

Here, we report on *in situ* ^{57}Fe Mössbauer spectroscopy measurements on a solid solution of diluted Fe atoms in a heavy RE host, prepared by the vapor-quenching (VQ) method at low temperature. The obtained results give information about the local environments of Fe as well as on its magnetic properties in these matrices, which can be considered as disordered or polycrystalline films.

II. EXPERIMENT

^{57}Fe(5 at. %):RE(RE=Dy, Ho, Er, and Tm) films were prepared in a He cryostat by thermal coevaporation of iron (90% enriched in ^{57}Fe) and RE ($4N$) metals from two independent resistively heated Ta crucibles; the deposition was performed onto kapton substrates kept at a temperature of 20 K. Before the deposition, the residual pressure in the cryostat was 5×10^{-9} mbar and during the deposition it was $\approx6\times10^{-8}$ mbar. Crystal oscillators were used to control the deposition rates and the composition of the films and all prepared films have a thickness of about 2000 Å. The details of the evaporation setup have been given elsewhere.[14] This system is especially suitable for the present experiments because, it allows *in situ* measurements, and thus avoids the oxidation of the RE metal films.

The evaporated films were analyzed by *in situ* Mössbauer spectroscopy in transmission geometry, in the temperature range 7–300 K, using a 50 mCi ^{57}Co:*Rh* source moving in sinusoidal mode. The film surface was tilted with an angle of 45° with respect to the gamma-ray direction, a geometry defined by our experimental conditions.[14] Source and absorber were kept at the same temperature during the measurements. For each spectrum obtained *in situ* the usual time of measurement varied from 6 to 144 h, depending on the ^{57}Fe thickness and the temperature range. The Mössbauer spectra were fitted using the full hyperfine Hamiltonian, since electric quadrupole and magnetic interactions have the same order of magnitude. The isomer shift (IS) values are given relative to an α-Fe absorber at room temperature (RT).

III. MÖSSBAUER SPECTRA OF THE FILMS PREPARED AT LOW TEMPERATURE

The ^{57}Fe Mössbauer spectra taken at 7 K, for all as-prepared films of the Fe:*RE* (RE=Dy, Ho, Er, and Tm) systems, are shown in Figs. 1(a) and 1(b), respectively. Their shapes depend on the different RE matrices. These are not well-resolved spectra and they contain several components with small quadrupole interaction for the spectra at 300 K, and a combined quadrupole and magnetic interaction, both of the same order of magnitude, in the case of the 7-K spectra. In order to analyze these spectra, we used the data obtained at different temperatures especially those for $T>T_C$ (T_C is the Curie temperature), where the magnetic interaction is expected to be absent.

The 300-K Mössbauer spectra [Fig. 1(a)] were analyzed with either two or three nonmagnetic components with different isomer shift (IS) and quadrupole splitting (QS) values. In the case of ^{57}Fe:*Dy* and ^{57}Fe:*Ho* films, the spectra were fitted with two doublets, but for ^{57}Fe:*Er* and ^{57}Fe:*Tm* films three nonmagnetic components were taken into account. The use of two components for ^{57}Fe:*Dy* and ^{57}Fe:*Ho* films and appearance of this third component in the ^{57}Fe:*Er* and ^{57}Fe:*Tm* samples will be discussed later.

The temperature dependences of ^{57}Fe Mössbauer spectra for the Fe:*Dy* and Fe:*Ho* films are shown in Figs. 2 and 3, respectively. From these figures one can see a change in the shape of Mössbauer spectra as the temperature increases: for example, in the case of the Fe:*Dy* film, the asymmetry changes its side. This change in the shape occurs in all Mössbauer spectra of the Fe:*RE* films and it is attributed to magnetic ordering occurring for $T<T_C$, probably due to an antiferromagnetic coupling between the Fe moments and those of the heavy RE elements, as expected from the theory,[3] such magnetic ordering was also observed by Brewer *et al.*[13] in the case of Fe:*Gd* and Fe:*Tb*. The T_C values of the films, as obtained from the Mössbauer measurements, are approximately 50% lower than the corresponding values of the pure RE metals. For example, in the case of Fe:*Ho*, T_C is about 80 K in comparison with 131 K (Ref. 15) for bulk Ho metal. The reason for the reduction of T_c could be the disordered structure of the RE films (see below).

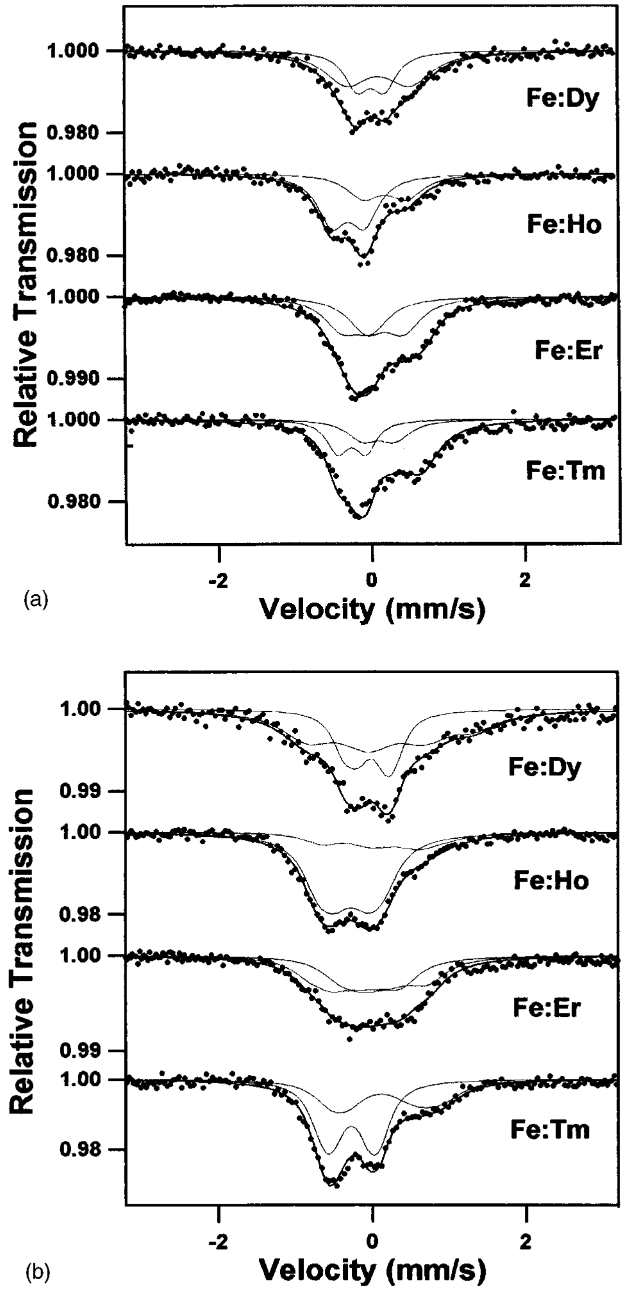

FIG. 1. (a) and (b) ^{57}Fe Mössbauer spectra taken at 300 and 7 K for as-prepared films of Fe(5%):*RE* (RE=Dy, Ho, Er, and Tm) systems. The full lines are least-squares fits as described in the text.

The thermal stability of Fe:*RE* systems has been experimentally confirmed by cooling again the samples down to 7 K after the measurements at high temperatures: the ^{57}Fe Mössbauer spectra did not show any appreciable difference as compared with those obtained for as-prepared samples.

We would like to comment here on the appearance of a third doublet in the spectra, obtained at high temperatures,

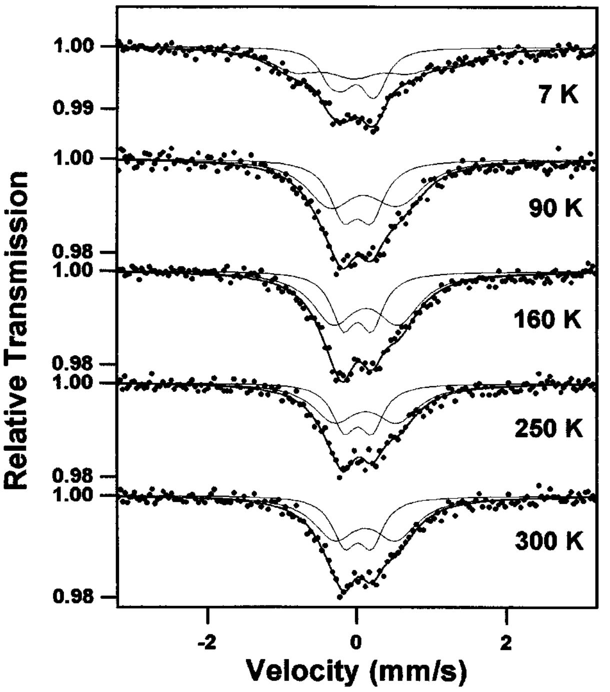

FIG. 2. Temperature dependence of ^{57}Fe Mössbauer spectra for the Fe(5%):*Dy* film. The full lines are least-squares fits as described in the text.

for the Fe:*Er* and Fe:*Tm* systems. The spectrum at low temperature for the Fe:*Tm* film, using a higher maximum velocity, is shown in Fig. 4. It shows the coexistence of one magnetic component, with a very broad magnetic hyperfine field, together with the two magnetic components located in the inner part of the spectrum [see also Fig. 1(b)]. The broader magnetic component does not have a well-defined magnetic structure, i.e., does not exhibit sharp magnetic lines and, thus, does not affect the analysis of the spectrum collected with a smaller velocity [$|\text{velocity}| < 3$ mm/s, see Fig. 1(b)] for as prepared films at low temperatures ($T < T_C$). However, at room temperature, the broader magnetic component collapses to the third doublet mentioned above [see Fig. 1(a)]. This behavior also appears for the Fe:*Er* films, as can be seen from the corresponding high-temperature spectra (300 K).

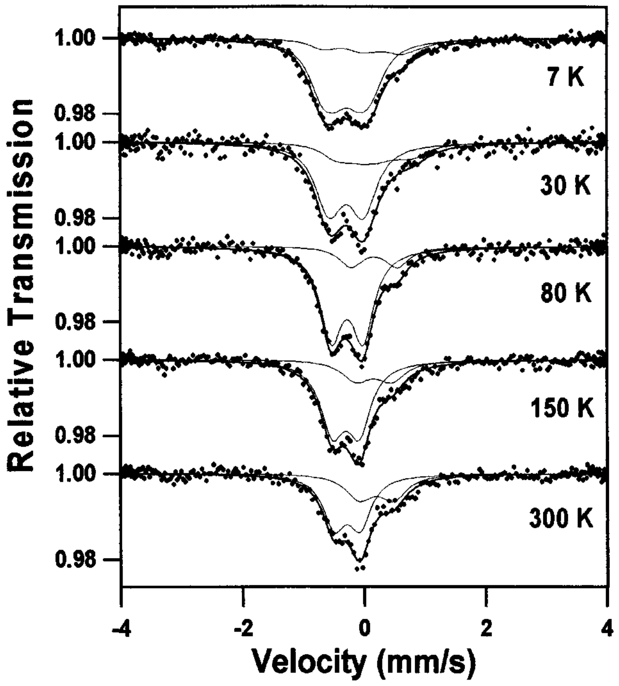

FIG. 3. Temperature dependence of ^{57}Fe Mössbauer spectra for the Fe(5%):*Ho* film. The full lines are least-squares fits as described in the text.

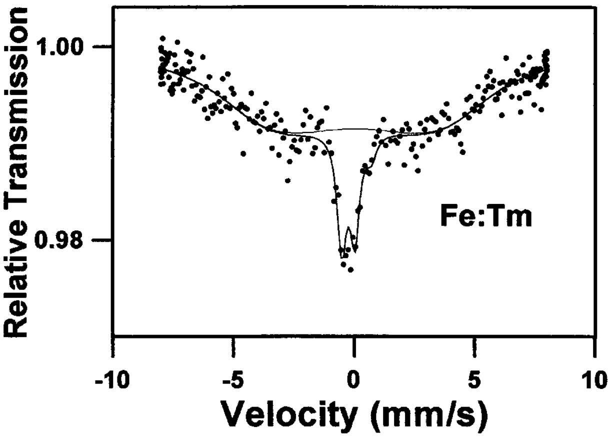

FIG. 4. ^{57}Fe Mössbauer spectra taken at 7 K for the Fe(5%):*Tm* film. The full lines are least-squares fits as described in the text.

Based on our high-temperature data and the experimental results for Fe:*Gd* and Fe:*Tb* samples obtained by Fe implantation by Brewer *et al.*,[13] we have fitted the spectra at low temperature for Fe:*Dy*, *Ho*, *Er*, and *Tm* films with two components, each of them having combined magnetic and quadrupolar interaction. For all the spectra of ^{57}Fe:*RE* films, the linewidths (Γ) are an average of the order of 0.38 mm/s for the component which has a negative IS (component B), while it is around 0.64 mm/s for the component with a positive IS (component A). These larger values for Γ could be an indication of the disordered character of the matrices. The IS values, obtained at low temperatures for these two components, are assumed to be the same as those obtained at high temperatures, since source and absorber are kept at the same temperature. The QS values, at low temperature, are about 15% larger than the values obtained at high temperature (300 K), as it is expected from the temperature dependence of QS. The main hyperfine parameters, obtained from the fits of Mössbauer spectra at 7 K, are shown in Table I for all films. The asymmetry parameter (η) has an average value around 0.2 for component A and large values, up to 1, for component B, indicating that component B has lower lattice site symmetry than those of component A. On the other hand, the angle (θ), between B_{hf} and the component V_{zz} of the electric-field gradient tensor, depends on the site and on the the RE matrix, which is an indication for different magnetic structures of RE metals. It should be mentioned at this point, that the angle θ only represents an *average* angle, since in the case of a noncollinear structure of the RE moments and a statistical distribution of the Fe atoms in the RE matrix there exist no well defined θ.

TABLE I. Hyperfine parameters obtained from the fits of Mössbauer spectra at 7 K of Fe:*RE* (RE=Dy, Ho, Er, and Tm) films.

	Component A				Component B			
Matrices	IS (mm/s)	QS (mm/s)	B_{hf} (T)	θ (°)	IS (mm/s)	QS (mm/s)	B_{hf} (T)	θ (°)
Dy	0.24(2)	0.63(2)	5.3(3)	66(6)	0.06(2)	0.41(2)	0.9(1)	47(9)
Ho	0.26(2)	0.61(2)	3.9(2)	90(15)	−0.11(3)	0.44(2)	1.5(3)	66(6)
Er	0.25(3)	0.59(3)	2.6(2)	70(18)	−0.09(2)	0.45(3)	2.1(4)	85(20)
Tm	0.19(3)	0.56(3)	1.9(2)	42(10)	−0.10(2)	0.44(3)	1.1(2)	90(2)

IV. DISCUSSION

A. Site assignment

The two magnetic components, obtained from the fits of the at 7-K Mössbauer spectra for ^{57}Fe: *Dy*, *Er*, *Ho*, and *Tm* films, have different values of the magnetic hyperfine field (B_{hf}). The component with the smaller magnetic hyperfine field (component B) has a higher s electron density at the nucleus (negative IS), in comparison to component A (positive IS), which exhibits at the same time a larger hf field. It is well known that the IS for ^{57}Fe in metals shows quite systematic trends for substitutional as well as for interstitial sites.[16] For an interstitial site a strongly increased s electron density and, therefore, more negative IS can be expected, due to a reduced volume of the Fe Wigner-Seitz cell.[16] Therefore, we assume that these two components, appearing in the Mössbauer spectra of ^{57}Fe:*RE*, correspond to interstitial (component B) and substitutional (component A) sites. From here on they will be named interstitial Fe (I-Fe) and substitutional Fe (S-Fe) sites, respectively, for most of the discussion of the data.

As mentioned above, Fe has a very low solubility in RE metals; however, Miedema[17] has shown that in the case of some solubility under equilibrium conditions between Fe in RE matrices, Fe will prefer to be localized at an interstitial site instead of a substitutional one. In order to simulate the equilibrium conditions, we have prepared films at about 300 K. The results show that at this substrate temperature only the Fe:*Tm* sample exhibits a unique site, i.e., no precipitation of Fe clusters and/or the formation of some intermetallic compounds was detected.

The Mössbauer spectra for ^{57}Fe:*Tm*, prepared at 300 K and measured at 300 and 6 K, are shown in Fig. 5. The source and absorber in this experiment were kept at different temperatures. Therefore, the spectrum at low temperature is shifted to higher velocities due to the second-order Doppler (SOD) effect. From this figure the existence of a very symmetric doublet at 300 K is clear. At 6 K the spectrum shows a little broadening, which is attributed to the appearance of magnetic order. The analysis of this spectrum shows that the component which appears in the spectrum, taken at 6 K for the ^{57}Fe:*Tm* film prepared at 300 K, is the same as the magnetic component B which appears in the Mössbauer spectrum of the ^{57}Fe:*Tm* film prepared at 20 K and measured at 7 K; this supports the assignment of component B to Fe located at interstitial sites.

At this point another possible site assignment should be mentioned, which is mainly based on the observed linewidth (Γ) values. As mentioned above, component A has a larger Γ value than component B. Therefore, one possibility is to assume that component B corresponds to some kind of microintermetallic compound,[12] while component A is associated to the formation of a solid solution between Fe and the RE metals. This approach is also supported by the fact that, in the experiments with high substrate temperature, the occurence of diffusion is more likely. This would promote the formation of this kind of microintermetallic compound leading only to the formation of component B, as seen in Fig. 5.

B. Quadrupole splitting and isomer shifts

We return now to the discussion of the behavior of the QS and the IS values for both components, obtained from the fits of the Mössbauer spectra at 7 K, for all ^{57}Fe:*RE* films (RE with hexagonal crystalline structure in the bulk). Figure 6(a) shows the behavior of the QS for the S-Fe and I-Fe against the atomic volume of RE elements. The QS of S-Fe increases smoothly from Tm to Dy, while the one of I-Fe remains almost constant. Figure 6(b) shows the behavior of the IS for both sites, S-Fe and I-Fe. The IS of S-Fe increases from Tm to Dy, while the IS of I-Fe increases much more going from Tm to Dy. This general increase of the IS (decrease in s electron density) for both sites, going from Tm to Dy, is that which one would expect from the increase in the atomic volume.[18] The larger increase for I-Fe, compared to that of S-Fe, may indicate some pressure effect for Fe at the interstitial site.

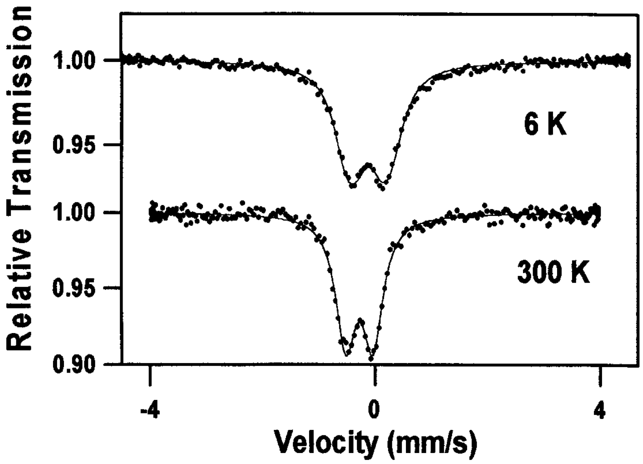

FIG. 5. ^{57}Fe Mössbauer spectra for Fe:*Tm* films prepared at 300 K and measured at 6 and 300 K. The full lines are least-squares fits as described in the text.

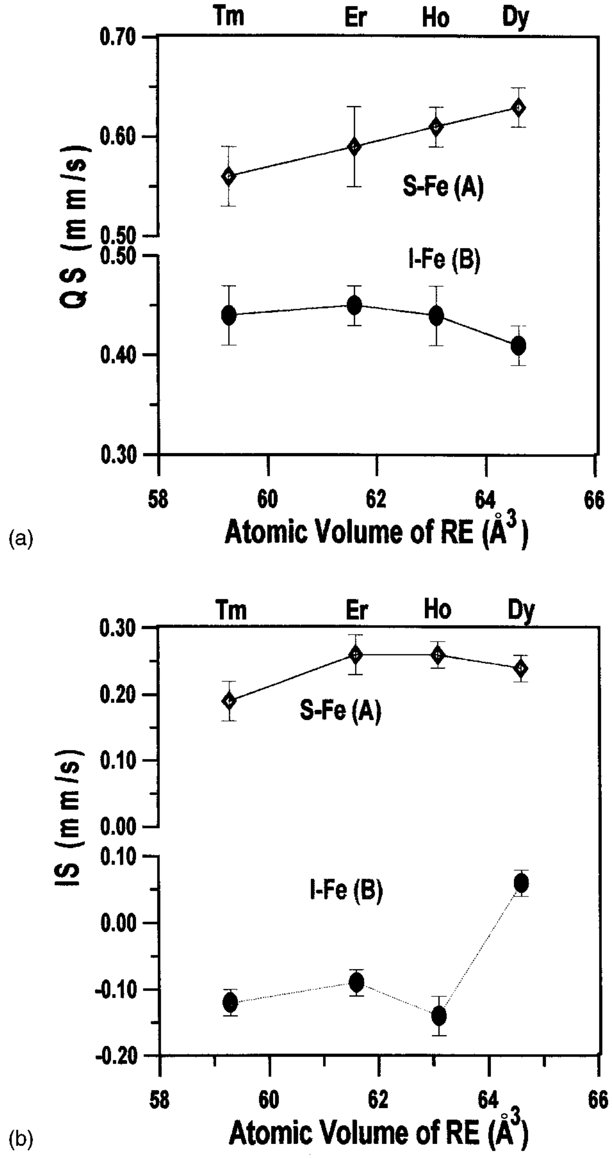

FIG. 6. (a) and (b) QS and IS for the substitutional Fe (*S*-Fe) site and interstitial (*I*-Fe) Fe site obtained from the fits of Mössbauer spectra at 7 K plotted against the atomic volume of RE elements. The dashed lines are only a guide for the eyes.

C. Magnetic hf fields

In the following, we want to discuss the behavior of the hyperfine field ($B_{\rm hf}$) for the two components in different RE hosts, as shown in Fig. 7. We have also included in this figure the values of $B_{\rm hf}$ for the two sites (substitutional and interstitial) obtained by implantation of Fe:*Gd* and Fe:*Tb*.[13] From this figure, it is quite clear that, in order, to be consistent with the results by Brewer *et al.*,[13] the component with the larger field is related to the substitutional site (*S*-Fe), while the component with the smaller field is related to the interstitial site (*I*-Fe). This identification, which is based on the assignment made by Brewer *et al.*[13] for Fe:*Gd* and Fe:*Tb*, supports the assignment made from the IS values for *S*-Fe and *I*-Fe sites, respectively (see above). It should be mentioned that LMTO-ASA calculations for Fe:*Gd* for both sites (substitutional and interstitial) not only show that the interstitial site has a higher *s* electron density, but in addition give a smaller hf field for the interstitial site as compared to that of the substitutional site,[13] in agreement with the experimental data.

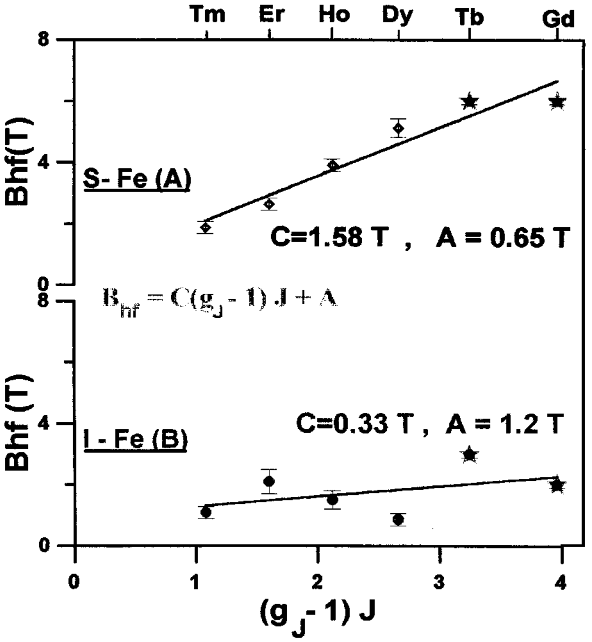

FIG. 7. $B_{\rm hf}$ dependence with $(g_J-1)J$ for the two magnetic sites, *S*-Fe and *I*-Fe. The star symbols correspond to values obtained from implantation (Ref. 12) for interstitial and substitutional sites, while the other symbols are from this work. The solid lines are the result of fits using the equation $B_{\rm hf} \approx C(g_J-1)J+A$.

Within the framework of the standard RKKY theory, $B_{\rm hf}$ should be given by $B_{\rm hf} \approx C(g_J-1)\langle J_z\rangle + A$,[5,19] where A is the magnetic hf field coming from the Fe magnetic moment and the second term is the transferred magnetic hf field resulting from the RE moments with total momentum J. In this first term, C is an impurity dependent constant across the RE series.[19] If crystal-field effects are neglected, one has $J_z = J$.[5] The quantity (g_J-1), which is the projection of the spin S on the total angular momentum J of the RE ions, decreases almost linearly with the atomic number of RE. We have made a least-squares fit through the data points for *S*-Fe and *I*-Fe sites, assuming that $B_{\rm hf}$ is given by the RKKY theory, using A and C as a free-fitting parameter and the results correspond to the solid lines in Fig. 7. One can see from this figure that the measured $B_{\rm hf}$ values for substitutional Fe in different RE metals scales with the de Gennes factor, while the corresponding one for interstitial Fe do not show any systematic behavior: the hf field at interstitial Fe in RE matrices seems to have an average $B_{\rm hf}$ value of 1.9 T. Dunlap *et al.*[20] have pointed out that deviations from the linear relation between $B_{\rm hf}$ and $(g_J-1)J$, for a substitutional nonmagnetic impurity, can occur due to the effects of the nonzero angular momentum on the exchange interaction between the localized $4f$ moments and the conduction electrons, i.e., contributions due to orbital and spin-dipolar interactions. On the other hand, Leal and Troper[21] have discussed the different contributions to $B_{\rm hf}$ using a model based on an extended RKKY theory. In our case, the deviations from the standard RKKY theory could be even larger due to the fact

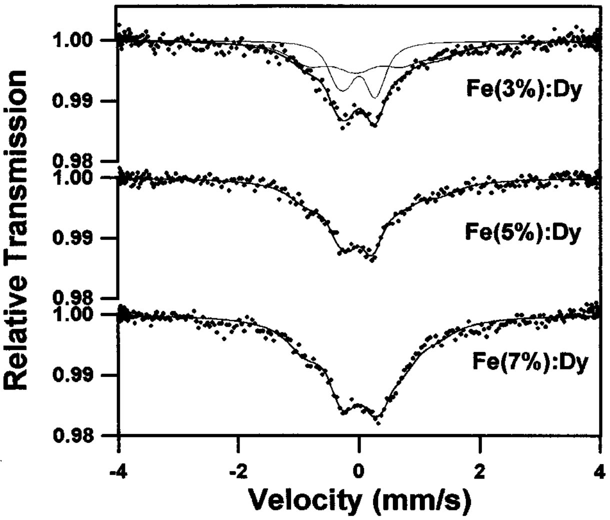

FIG. 8. ^{57}Fe Mössbauer spectra at 7 K for Fe(x):*Dy* as-prepared films with different values of Fe composition ($x=3$, 5, and 7 %). The full lines are least-squares fits as described in the text.

that we have a magnetic impurity located at an interstitial site, where the pressure effect is expected to be more relevant.

In general, the values of A obtained for both substitutional and interstitial sites are quite small. This indicates that Fe may lose its own magnetic moment when it is built-in into a RE host. *In situ* Mössbauer measurements with an external magnetic field at the Fe in Yb matrix, which can elucidate the small values of B_{hf} observed at the two sites, for Fe in RE matrices have been performed. The results of such an experiment will be published elsewhere (Ref. 22).

V. ADDITIONAL EXPERIMENTS WITH HIGHER Fe CONCENTRATION

There is, in principle, an alternative explanation for the two components appearing in the ^{57}Fe:*RE* spectra than the one given in Sec. IV A. This is based on the probability for different Fe nearest-neighbor configurations. In order to test this model, we have prepared two additional samples of the Dy matrix with different iron compositions, namely, ^{57}Fe(x):*Dy* ($x=3$ and 7 at. %). The spectra for these films at 7 K, including the spectrum for the ^{57}Fe(5%):*Dy* film already discussed, are shown in Fig. 8.

TABLE II. The experimental relative area (%) of each component, obtained by fitting the Mössbauer spectra of Fe(x):*Dy* films, and the normalized values of nearest-neighbor configurations, calculated using the binomial probability distribution (we have assumed 12 nearest neighbors). [$P(n=0)$ is the probability for isolated Fe atoms and $P(n=1)$ is the probability for having one Fe nearest neighbor.]

	Experimental values		Calculated values	
x in Fe(x):*Dy*	Component A (%)	Component B (%)	$P(n=0)$ (%)	$P(n=1)$ (%)
$x=3\%$	59	41	73	27
$x=5\%$	62	38	61	39
$x=7\%$	71	29	53	47

By comparing the results, obtained from the fits of the Mössbauer spectra for these three samples with different Fe compositions, and the calculated normalized values for the occurence of different Fe nearest-neighbor configurations, using a binomial probability distribution (see Table II) we have to conclude the following: comparing the tendencies (increasing or decreasing intensity with increasing x) we could attribute component A (greater field) to iron atoms with one Fe in the nearest-neighbor coordination and component B (smaller field) to isolated Fe atoms (with only RE atoms as nearest neighbors). However, in this case we have to assume a nonstatistical distribution of the Fe atoms, i.e., quite general a higher probability for having another Fe atom as a nearest-neighbor atom than expected from a statistical distribution. The calculated probabilities for Fe with more than one Fe as nearest neighbor ($n=2,3\ldots$) are so small that these configurations can be neglected. Furthermore, these

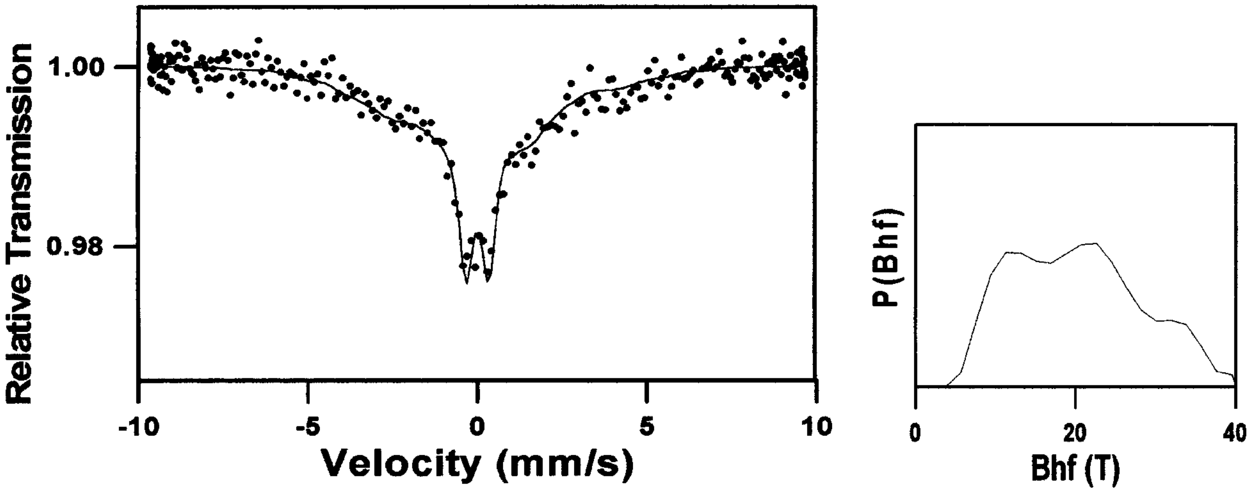

FIG. 9. ^{57}Fe Mössbauer spectrum for the Fe(10%):*Dy* film taken at 7 K. The full line is a least-squares fit with three components: the two low-field components as shown in Fig. 2 and a high-field component. The right side of the figure shows the hf field distribution for the broad magnetic component only.

configurations would probably appear in spectra with large B_{hf} fields and, therefore, they will disappear in the background, at low temperature. These configurations will contribute to the area of the Mössbauer spectra collected with the low velocity range only at high temperatures, as we have seen for the temperature dependence of the Mössbauer spectra of $^{57}\mathrm{Fe}{:}Er$ and $^{57}\mathrm{Fe}{:}Tm$ films. In order to support this argument, with respect to configurations with more than one Fe nearest-neighbor atom, we prepared an $^{57}\mathrm{Fe}(x){:}Dy$ film with $x = 10\%$.

The ^{57}Fe Mössbauer spectrum at 7 K for $\mathrm{Fe}(10\%){:}Dy$ is shown in Fig. 9. It shows a very broad magnetic hf field distribution (see right side of Fig. 9) with an average hf field of 23 T, this indeed indicates that at such high composition we have a high probability of forming Fe clusters.

The discussion made above leads us to conclude that, from the results obtained in this work, the assignment of component A to Fe on a substitutional site seems to be clear, while the assignment of component B is difficult. However, we believe that our first model (substitutional and interstitial sites) is the correct one since it is supported by the values of the IS and B_{hf}, as discussed above, and, in addition, by the predictions made by Miedema.[17] Besides that, the identification of substitutional and interstitial Fe sites is also supported by the following experimental findings: in a previous work, we studied $^{57}\mathrm{Fe}{:}Pb$ (Ref. 7) and $^{57}\mathrm{Fe}{:}Yb$ (Ref. 23) systems by VQ. These studies have shown that there is a large similarity with the results obtained by in-beam Mössbauer spectroscopy of Fe atoms in Pb (Ref. 16) and Yb (Ref. 24) crystalline matrices.

VI. CONCLUSION

We have prepared films of ^{57}Fe diluted in RE matrices at low and high substrate temperatures. The films obtained at low substrate temperature show that the Fe atoms occupy interstitial as well as substitutional sites, while the films prepared at high substrate temperature exhibit only one component for the Fe atoms, which corresponds to an interstitial site. The behavior of B_{hf} for Fe at the substitutional site in different RE metals scales with the de Gennes factor, while B_{hf} for interstitial Fe does not show such a systematic behavior. The values A of the magnetic hf field coming from the Fe magnetic moment are quite small for both the substitutional site and the interstitial site. This indicates that Fe may lose its own magnetic moment, if built into a RE host. *In situ* Mössbauer experiments with Fe in a *non*magnetic $(J=0)$ Yb matrix under applied external magnetic field will be performed.[22] In this way the values of A can be determined in a more direct way $(B_{\mathrm{hf}}=A$ for $J=0)$.

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