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# AN INVESTIGATION OF THE MAGNETIC MOMENT ORIENTATIONS IN RECORDING MEDIA USING POLARIZED MÖSSBAUER SPECTROSCOPY

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The polarized source Mössbauer spectroscopy technique used in the present work provides information on the in-plane angle of the magnetic moments in a sample, as well as on the out-of-plane angle which can also be obtained using conventional Mössbauer spectroscopy. The results show significant differences in the degree of alignment in various samples of both maghemite and iron metal recording tape and confirm the value of this method for the investigation of these technologically important materials.

## Introduction

The quality of both maghemite and iron metal tape as recording media is strongly dependent on the texture. Information on the orientation of the magnetic moments therefore has considerable relevance for improving the performance of magnetic recording media.

Conventional Mössbauer spectroscopy usually only gives information on the angle of the magnetic moments to the normal to the plane of the sample. Polarized Mössbauer spectroscopy also provides direct information on the in-plane orientation of the magnetic moments, which is clearly important for magnetic tape where the orientation of the moments is predominantly in-plane. This paper will explain the methodology and provide a comparison of results from various tape and powder samples.

Polarized γ-rays are obtained by magnetizing the $^{57}$Co:Fe source along a particular direction in the plane perpendicular to the direction of the emitted beam. The six emitted γ-rays are polarized parallel and perpendicular to the direction of magnetization in the iron. The relative intensity and polarisation of the lines in the emission spectrum is $3_{\parallel}:4_{\perp}:1_{\parallel}:1_{\parallel}:4_{\perp}:3_{\parallel}$. If the absorber energy levels are also magnetically split, every γ-ray emitted by the source gives six absorption lines and the spectrum consists of 36 lines. The intensity of these lines depends on the angle between the γ-ray beam direction and the magnetic moment directions in the source and absorber, $\theta_s$ and $\theta_a$, respectively, and also on the angle between the in-plane projections of the magnetic moment directions in the source and absorber, $\phi_{sa}$. So, for example, if the moments are all in-plane: for $\phi_{sa} = 0°$

a 20-line spectrum is obtained, while for $\phi_{sa} = 90°$ a spectrum with 16 lines occurs. The experimental details of this technique have been published elsewhere [1]. Figure 1 shows simulated spectra of maghemite ($\gamma$-$Fe_2O_3$) for $\theta_a = 90°$ (moments in plane) taken with a conventional source (Fig. 1*a*) and a polarized source: with $\theta_s = 90°$ and $\phi_{sa} = 90°$ (Fig. 1*b*); and with $\theta_s = 90°$ and $\phi_{sa} = 0°$ (Fig. 1*c*). The two extreme in-plane orientations are clearly distinguishable. Intermediate in-plane orientations correspond to a superposition of the spectra shown in Figs. 1*b* and 1*c*. If the out-of-plane angle becomes less than 90°, this difference between spectra corresponding to different in-plane orientations gradually decreases.

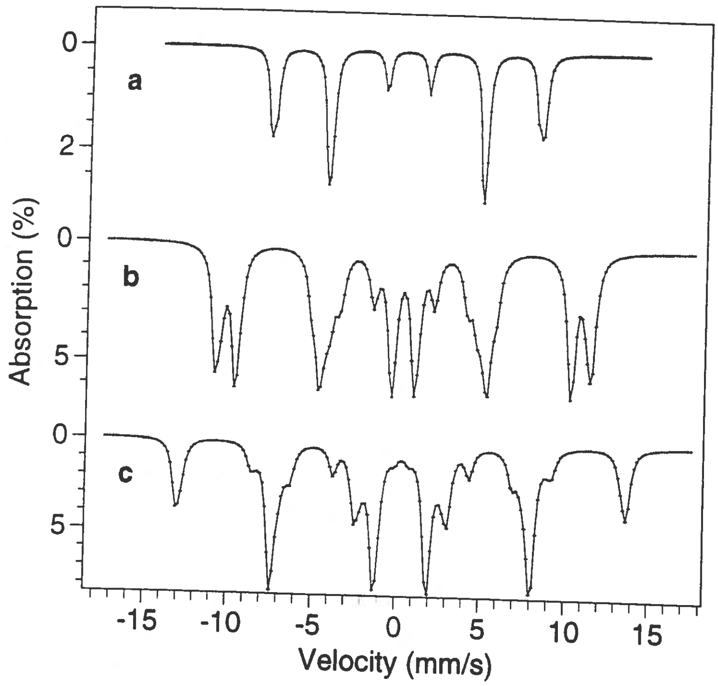


**Fig. 1** Simulated room temperature Mössbauer spectra of $\gamma$-$Fe_2O_3$ with magnetic moments in plane of sample obtained with: *(a)* conventional source, *(b)* polarized source with magnetic moments perpendicular to the source magnetization direction, *(c)* polarized source with magnetic moments parallel to the source magnetization direction.

The samples used in the present investigation consisted of cobalt-modified maghemite, pure maghemite and iron metal ($\alpha$-Fe) recording tapes. The tapes were laid side by side and stacked to produce samples of appropriate area and thickness for Mössbauer spectroscopy. The samples were investigated in zero applied field and with a field of 250 mT applied in the plane of the tape and both parallel and perpendicular to the direction of the applied field at the source.

A limitation of this polarized source technique is that complete alignment of the magnetic moments in the source is impossible to achieve. Previous measurements [2] indicate a misalignment angle of approximately 6° for $\phi_s$ and this value has been assumed in the present work.

## Results

The Mössbauer spectra obtained from the Co:$\gamma$-$Fe_2O_3$ and $\gamma$-$Fe_2O_3$ tape samples in zero applied field are shown in Fig. 2. In each case *a* is a conventional Mössbauer spectrum, while *b* and *c* are polarized source spectra where the direction of the tape length is either perpendicular (*b*) or parallel (*c*) to the source magnetization. Thus each of the sets of three spectra in Fig. 2 can be compared with the corresponding three simulated spectra in Fig. 1.

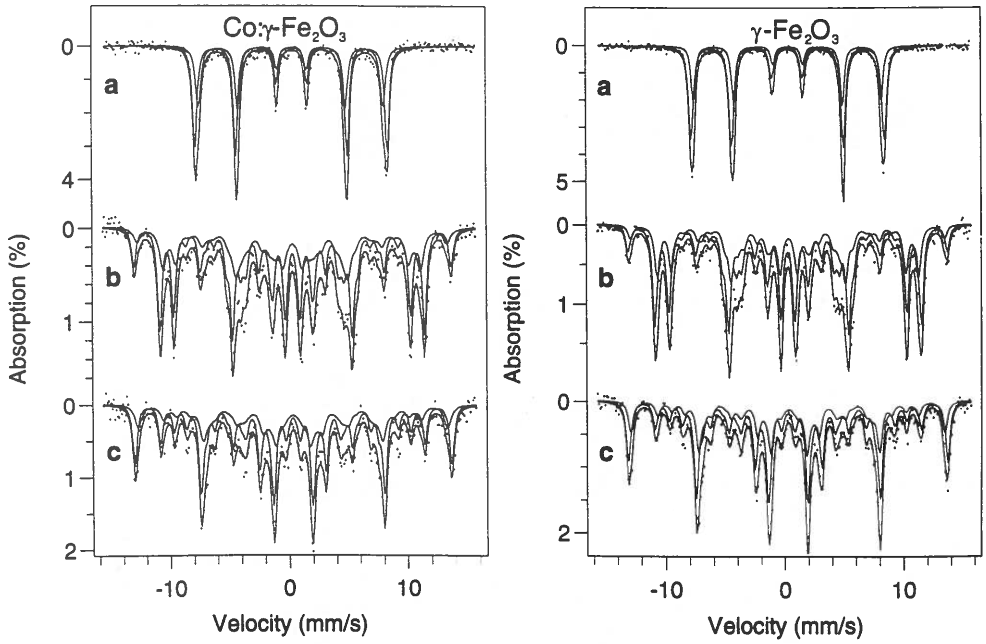


**Fig. 2** Room temperature Mössbauer spectra of the Co:$\gamma$-$Fe_2O_3$ and $\gamma$-$Fe_2O_3$ tapes in zero applied field: *(a)* conventional source, *(b)* polarized source with tape length perpendicular to the source magnetization direction, *(c)* polarized source with tape length parallel to the source magnetization direction.

Each of the sets of three spectra in Fig. 2 have been simultaneously computer fitted with a set of hyperfine parameters and values of $\theta_a$ and $\phi_a$, the out-of-plane and in-plane angles of the moment orientations in the absorber, $\phi_a$ being with respect to the tape length direction. The simultaneous fitting provides a better constraint on the hyperfine parameters and the angles than would be the case if each of these three spectra were fitted independently. Two components, with an area ratio of 5:3, corresponding to the two iron sites in the spinel structure of $\gamma$-$Fe_2O_3$ were used to fit these spectra.

The fitted values of $\theta_a$ and $\phi_a$ for the zero applied field spectra of Co:$\gamma$-$Fe_2O_3$ tape, $\gamma$-$Fe_2O_3$ tape and $\alpha$-Fe tape are all given in Table I. In all cases the alignment in the plane is incomplete (i.e. $\theta_a < 90°$). Small differences in the moment orientations in-plane (i.e. the values of $\phi_a$) can be observed in the spectra by comparing Figs. 1 and 2, in particular the outermost lines in Fig. 2*b* and the next to outermost pair of lines in Fig. 2*c*. The smaller value of $\phi_a$ in the case of the $\gamma$-$Fe_2O_3$ tape can be detected by eye in the spectra and is confirmed by the computer fitted values. This indicates that the technique is sensitive to changes of orientation of only a few degrees. Thus the results show that the magnetic moments in the $\gamma$-$Fe_2O_3$ tape lie closer to the direction of the tape length than is the case with the other tape samples.

**Table I.** Magnetic moment orientation data obtained from the computer fits to the Mössbauer spectra. For details see text. The angles have a fitting error of approximately 1°.

| | Zero Applied Field | | Applied Field | |
|---|---|---|---|---|
| Tape | $\theta_a$ | $\phi_a$ | $\theta_a$ | $\phi_a$ |
| Co:$\gamma$-$Fe_2O_3$ | 67.7° | 31.0° | 78.5° | 16.2° |
| $\gamma$-$Fe_2O_3$ | 70.5° | 25.6° | 78.5° | 6.7° |
| $\alpha$-Fe | 72.2° | 30.2° | 77.4° | 21.6° |

Mössbauer spectra were also obtained with a 250 mT field applied along the tape length, again with both conventional and polarized sources and in the latter case with both possible orientations of the field and tape length with respect to the source magnetization direction. The $\theta_a$ and $\phi_a$ data from these fits are also in Table I. In all cases this gives values of $\theta_a$ nearer to 90° and values of $\phi_a$ nearer to 0° corresponding to a much greater degree of alignment than was the case with no applied field. This effect is significantly more marked in the case of both $\gamma$-$Fe_2O_3$ tapes compared to the $\alpha$-Fe tape.

## Discussion

Magnetic measurements of the same samples have also been made and these have been analysed to provide information on their texture using a technique which has been described elsewhere [3]. These results indicate the highest degree of alignment in the case of the $\gamma$-$Fe_2O_3$ tape and the lowest degree of alignment in the case of the Co:$\gamma$-$Fe_2O_3$ tape. These results are consistent with the much more direct Mössbauer data described above. The Mössbauer data also indicate that the $\alpha$-Fe tape shows the least increase in alignment caused by the application of an applied field, which is consistent with the typically much higher coercivity of $\alpha$-Fe tapes.

## Conclusions

The results described above show the usefulness of the polarized Mössbauer spectroscopy technique in providing detailed information on both in-plane and out-of-plane moment orientations in iron-containing magnetic recording media.

## References


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