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SKIN DEPTH EFFECT IN THE RF COLLAPSE STUDIES

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In the Mössbauer studies of the rf effects induced in ferromagnetic materials performed so far the skin depth problem was not discussed in detail. Especially when studying the rf collapse effect (see e.g./1, 2, 3/) the discrepancy between the calculated skin depth and the observed changes in the Mössbauer spectra is evident. The skin depth is calculated in a conventional way according to the formula:

$$d = \frac{\lambda_0}{2\pi\sqrt{\mu\nu}}$$  \hspace{1cm} (1)

where $$\rho$$ is the specific resistivity, $$\mu$$ is the magnetic permeability and $$\nu$$ is the frequency. In the paper in which the skin depth effect was mentioned in connection with the rf induced effects /1/ $$d$$ was calculated using the static value of $$\mu$$.

The skin depth for iron foil at 50 MHz using typical values of $$\rho$$ and static value of $$\mu$$ ($$\mu=1200 \div 6000$$, /4/) varies from 0.2 to 0.5 $$\mu$$m. The thickness of the samples normally used in Mössbauer experiments is 10 to 20 $$\mu$$m, so the skin depth calculated in this way is two orders of magnitude smaller than the thickness of the typical sample. Since the external rf field decreases within the metallic foil as:

$$H_{rf} = H_0 \exp \left( -\frac{x}{d} \right)$$  \hspace{1cm} (2)

where $$H_0$$ is the rf field intensity at the sample surface, then the major part of the sample volume should not be affected by the rf field. However, the rf collapsed spectra show 1/1, 2, 3/ that the whole volume of the sample is affected by the rf field even when the sample is about 50 times thicker than the skin depth calculated according to the formula (1) with the use of the static value of $$\mu$$.

To solve this discrepancy we suggest that the strong frequency dependence of the magnetic permeability should be considered. It is well known /5/ that the effective magnetic permeability depends on the frequency of an applied magnetic field and decreases markedly for high frequencies when compared with the static value typical for a given ferromagnet. When one assumes that in the extreme cases of the rf collapsed spectrum the permeability $$\mu$$ decreases to the value of the order of 1 for the frequency of about 50 MHz, then the skin depth calculated with $$\mu(\nu)\cong 1$$ is of the order of 10 $$\mu$$m.

The present paper reports the results of an experiment where this assumption was verified. The rf collapse effect was studied for iron samples of the composition: 37.00Ni-61.98Fe-0.02Mn, and the thicknesses (d): 12, 17, 30, 41, 46, 61 and 80 $$\mu$$m. The samples were prepared and the experiment was performed in the same way as in /2/. The intensity of the 50 MHz rf field applied varied from 3 to 11 Oe. The skin depth $$d_0$$, calculated with $$\mu(\nu)\cong 1$$, $$\nu=50$$ MHz and $$\rho=90 \mu$$ohm cm is equal to 18 $$\mu$$m. So, the sample thicknesses studied cover the range from less than one skin depth $$d_0$$ (for 12 $$\mu$$m) to 4.5 $$d_0$$ (for 80 $$\mu$$m).

Typical results obtained for the rf collapse effect as a function of the sample thickness are reported in Figs.1 and 2, Figs. 1A, 1B, 1C and 1D present the Mössbauer spectra obtained for the rf field intensity of 5.7 Oe for the sample thicknesses of 12, 17, 30 and 41 $$\mu$$m, respectively. Fig. 2 shows similar results obtained at 7.5 Oe for the samples of 12, 17, 30, 41, 46, 61 and 80 $$\mu$$m; spectra 1B and 2B were obtained for 41 $$\mu$$m sample in the absence of the rf field.

The results obtained suggest that the rf collapse effect depends strongly on the sample thickness when the frequency and the intensity of the rf field are fixed. As can be seen from Fig. 1 the 5.7 Oe rf field is large enough to collapse the spectrum to a single broad line for the 12 $$\mu$$m sample (Fig. 1A). The other spectra are less narrowed, and the spectrum of the 41 $$\mu$$m sample is only slightly affected by the rf field (Fig. 1D). In this case the rf field is considerably reduced due to the skin effect and is too small to force the magnetization reversal fast enough to collapse the hf spectrum. In Fig. 2 the skin depth effect is much more distinguishable. For thin samples (12 - 30 $$\mu$$m) the spectra are completely collapsed to a single narrow line which is accompanied by rf sidebands. Thickness of these samples are still smaller than 2$$\mu$$m.

With the increase of the sample thickness the spectra still consisting of a single line are considerably broader, Figs. 2D - 2F. Skin depth effect...
which reduces \( H_0 \) starts to be important for the sample thickness comparable to \( 2d_A \). For the thickest sample studied (Fig. 2G) the spectrum obtained consists of partly resolved hf lines. In this case the thickness of the sample is about \( 4.5d_A \), so the skin depth effect very strongly reduces \( H_0 \) field which is then too small to force fast enough relaxation of the hf field to average it to zero.

\[
\overline{H}_{rf}(H_0^i, d_i) = \overline{H}_{rf}(H_0^i, d_2)
\]
\[
\overline{H}_{rf}(H_0^i, d_i) = \overline{H}_{rf}(H_0^i, d_j)
\]

The number of equations is equal to the number of pairs of the spectra with similar full widths at half depth. The parameter \( \delta \) was calculated numerically to fulfill the set of equations (4). The skin depth found in this way varied from about 10 \( \mu \text{m} \) to about 40 \( \mu \text{m} \). Since this method of evaluation of the skin depth is not very accurate the agreement of the experimentally estimated \( \delta \) and the calculated value with the assumption that \( \mu(\nu) \rightarrow 1 \) is quite good.

The experiment described shows that the skin depth effect can not be treated in a conventional way when interpreting the rf induced effects, and that the strong frequency dependence of the magnetic permeability should be taken into account.

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References