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THE NMR ANALYSIS OF LOCAL MAGNETIC PROPERTIES OF Co IN (Y₁₋ₓNdₓ)₂Co₁₄B

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Abstract. The ⁵⁹Co NMR spin-echo spectra of (Y₁₋ₓNdₓ)₂Co₁₄B and relaxation curves were measured. From the shifts of line positions caused by easy magnetisation direction change the orbital contributions to Co site magnetic moments were evaluated. The corresponding anisotropy energy of Co sites is comparable with the bulk value.

The polycrystalline samples of (Y₁₋ₓNdₓ)₂Co₁₄B were investigated by use of NMR spin-echo technique at 4.2 K within the frequency range from 90 up to 230 MHz, where the ⁸⁶Co lines for Y₂Co₁₄B and Nd₂Co₁₄B were detected [1]. The resonance lines in the range below were attributed to boron and yttrium nuclei [2]. The sequence 1.5/30/2.6 μs of exciting pulses have been applied. The relaxation effects were also measured for peak frequencies of the samples \( x = 0.0 \) to \( x = 0.2 \) and \( x = 1.0 \). The spectra are shown in figure 1. The positions of resonance lines and the shape of the spectra change drastically for \( x \) increase from 0.0 to 0.2, whereas for higher concentrations, especially for \( x ≥ 0.7 \) minor shifts of resonance lines may be deduced. That feature of the spectra was correlated with easy direction of magnetisation i.e. easy plane (e.p.) or easy axis (e.a.). From magnetic measurements the transition from e.p. to e.a. for \( x \sim 0.1 \) was found [3]. The NMR signal of the samples with e.p. perpendicular to c-axis (e.g. \( x = 0.0 \)) comes out mainly from nuclei of cobalt ions having their magnetic moments in this plane. For the samples with \( x ≥ 0.2 \) the e.a. is tilted from the c-axis (at about 11° for \( x = 1.0 \) [4]). For such a case in the most populated domain walls (DW) in the material, magnetic moments transit through (001) direction. So the dominant DW signals observed for Co correspond to c-axis direction. The above assumptions have been additionally confirmed by NMR spectra of magnetically aligned powder sample (\( x = 1.0 \)) for parallel and perpendicular orientation of radiofrequency field \( B_\text{rf} \) to the aligned direction.

In order to ascribe the resonant lines and corresponding effective fields \( B_\text{e} \) to Co sites of the compound, the intensities of resonant lines have been compared with site abundances. The lines between 100 and 210 MHz were taken into account as coming from investigated phase. The most intense lines and weaker lines with comparable relaxation times were taken into account and the quadrupolar splits [5] were considered. The proposed correlations are given in table I for \( x = 0.00, 0.20 \) and 1.00. For other concentrations it was too uncertain to give any proposal.

To explain changes of \( B_\text{e} \) with \( x \), the following contributions were considered:

\[
B_\text{e} = B_\text{loc} + B_\text{hf}
\]

where

\[
B_\text{loc} = B_D + B_L + B_{\text{dip}}
\]

and \( B_D \) - demagnetizing field, \( B_L \) - Lorentz field, \( B_{\text{dip}} \) - dipolar field.

\[
B_\text{hf} = B_S + B_{\text{orb}} + B_N
\]

where \( B_S \) - term originating from core and conduction electron polarization by Co spin moment itself, \( B_{\text{orb}} \) -
Table I. - Positions of $^{59}$Co NMR lines of cobalt sites in direction; Because both $E_i$ and $\Delta B_{orb}$ are related to $\Delta \mu_L$ (the change of $\mu_L$ caused by reorientation of magnetisation), $E_i^a$ may be expressed as:

$$E_i^a = \frac{|\lambda| \Delta B_{orb}^i \langle \mu_B^i \rangle}{4 \langle r^{-3} \rangle \mu_B}$$

(5)

where $\langle \mu_B^i \rangle$ is the mean value of the spin magnetic moment and the rest symbols have their usual meaning. The $\Delta \mu_L^i$ is also related to $\Delta B_{orb}^i$ by formula:

$$\Delta \mu_L^i = \frac{\Delta B_{orb}^i}{2 \langle r^{-3} \rangle \mu_B}$$

(6)

Accounting on $\Delta B_{dip}$ the corresponding $\Delta B_{orb}^i$, $E_i^a$ and $\Delta \mu_L$ values were calculated from the experimental values of $\Delta B_{orb}^i$ (Tab. I). The values of $\lambda = -300$ cm$^{-1}$, $\langle r^{-3} \rangle = 0.35 \times 10^6$ cm$^{-3}$ as for metallic cobalt were used. The maximum change of $\Delta \mu_L = 0.062 \mu_B$ was obtained for 4e site. Using the spin contributions to hyperfine fields calculated from [8], the maximum value of $\mu_L = 0.064 \mu_B$ was obtained for 8 j2 site. The weighted sum of such calculated local Co anisotropy energies $E_a = -5 \times 10^6$ J/m$^3$ appeared to be comparable with the value of $E_a = -10.2 \times 10^6$ J/m$^3$ obtained for $Y_2Co_{14}B$ from bulk magnetometric measurements [3, 9].

From the above analysis of NMR results it may be drawn, that Co sites in this compound possess differentiated orbital magnetic moments giving meaningful contribution to anisotropy.

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