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NUCLEAR MAGNETIC RESONANCE

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Abstract

Full Text

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PHYSICS

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NUCLEAR MAGNETIC RESONANCE

IN THIN MAGNETIC FILMS OF Co^{59}

NMR was observed in thin films of ferromagnetic Co^{59} with a thickness of $8 \cdot 10^3$ Å for flat specimens and a thickness of $5 \cdot 10^4$ Å for cylindrical specimens at a frequency of 213.2 MHz at 300°K. The decrease in the signal amplitude in an applied constant field parallel to the boundaries shows that the principal losses of the specimen are determined by the presence of boundaries. By orienting in a definite way the easy-magnetization axis, the high-frequency (rf) and constant fields, it is possible to separate the resonance of domains from the resonance of boundaries.

Introduction. NMR has been investigated for a large number of ferromagnetic materials since its discovery in Co^{59} (^{1}). NMR has been studied on multidomain and single-domain specimens (^{2}) with masses of the order of several grams. To carry out NMR experiments on thin films, which have masses of $0.1 \div 0.01$ g, spectrometers of higher sensitivity are required. An increase in the sensitivity of the spectrometer can be achieved by using superregenerative detectors. For observation of the nuclear magnetic resonance of Co^{59} in internal fields, the detector must be continuously tunable in the range $200 \div 250$ MHz and have frequency modulation with a low level of parasitic amplitude modulation (a.m.). The resulting a.m. signal, containing information on the NMR absorption lines, is amplified by a narrow-band amplifier, synchronously detected, and fed to a strip-chart recorder.

Fig. 1. Shape of the absorption signal $\Delta f = 0.8$ MHz

Experiment and interpretation. Cobalt metallic films were formed by vacuum evaporation onto flat and cylindrical glass substrates. The cylindrical substrates had dimensions $D = 2$ cm, $l = 3$ cm; the film thickness was $d = 5 \cdot 10^4$ Å, and the easy axis was along the circumference. The rf field h_1 in the circuit coincides with the direction of the easy-magnetization axis (e.m.a.). The flat substrates had dimensions 1×2 cm, and the film thickness was $d \approx 8 \cdot 10^3$ Å.

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Fig. 2 and Fig. 3

Figure 2: Fig. 2 and Fig. 3

To increase the mass of the specimen, the films were combined into a packet, i.e., an "analog" of layered films was obtained. The deposition time of the films was $40 \div 60$ min. The coercive force of all the films was in the range $28 \div 30$ Oe. In zero constant field H_0 there is a resonance at a frequency of 213.2 MHz.

The typical shape of the resonance line is shown in Fig. 1. The half-width of the line is 0.8 MHz. The signal-to-noise ratio for a packet with a total metal thickness up to $5 \cdot 10^4$ Å is about 10.

Application of an external magnetic field decreases the signal amplitude, as shown in Fig. 2. The different behavior of the curves presented is connected with the specific change of the boundary resonance and the domain resonance under the action of the external field. Curve 1 shows the dependence of the amplitude

of the absorption signal as the constant magnetic field along the easy magnetization axis increases (Fig. 3 shows the arrangement of the fields and the easy magnetization axes). In this case, the growth of 180° domains will occur by displacement of the boundaries until the domains oriented unfavorably with respect to the field are completely absorbed. Thus the boundaries are eliminated, and the film becomes magnetized in the direction of the easy magnetization axis, which corresponds to the disappearance of the NMR signal due to nuclei located in the boundaries. Curve 2 for the cylindrical film shows the dependence

Fig. 2. Dependence of the amplitude of the absorption signal on the magnitude of the constant field H_0. 1 –plane films $H_1 \parallel H_0 \parallel$ e.m.a.; 2 –cylindrical film $h_1 \perp H$, $H \parallel$ e.m.a.

Fig. 3. Arrangement of the fields and the easy magnetization axes. *a* and *b* –plane film; *c* and *d* –cylindrical film.

of the absorption signal on the field H_0 acting perpendicular to the easy magnetization axis (the rf field acts along the easy magnetization axis). When the field H_0 is increased to approximately 60 Oe, the signal amplitude decreases in accordance with the decrease in the number of boundaries. At the same time, domain resonance contributes to the NMR signal. With further increase of the field H_0, the absorption is determined mainly by the resonance of domains whose magnetization becomes perpendicular to the direction of the rf field, and the signal amplitude changes only slightly. In Ref. (2), single-domain and multidomain particles corresponded to different resonance frequencies because spherical single-domain particles have a demagnetizing field $\frac{4}{3}\pi M$, which increases the effective field at the nuclei. In the plane of the films the demagnetizing field is equal to 0, and the resonance frequencies of boundaries and domains coincide.

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