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NUCLEAR MAGNETIC RESONANCE OF Fe^{57} IN $FeBO_3$ SINGLE CRYSTALS

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The recently synthesized compound $FeBO_3$ [1, 2] is a ferromagnet transparent in the visible region, with a Neel temperature $T_N = 348°K$. Its structure is rhombohedral and the magnetic anisotropy is of the "easy plane" type.

We present here a report of the first observation of nuclear magnetic resonance (NMR) in the hyperfine fields of single-crystal $FeBO_3$ on Fe^{57} nuclei. The crystals were not artificially enriched with Fe^{57} during their synthesis.

The sample comprised a large number of arbitrarily oriented single-crystal plates grown by the method of spontaneous crystallization from the solution in the melt [3]. The NMR signals were registered by the method of spin echo and free precession in the temperature range 4.2 - 300°K. The measured values of the NMR gain η and of the relaxation times T_1, T_2, and T_2^* are listed in the table.

T, °K	Resonant frequency ν_0, MHz	Field at nuclei H_n, kOe	NMR gain, η	Relax. times			Resonant line width	
				T_1, msec	T_2, msec	T_2^* μsec	$\Delta\nu = \frac{1}{2\pi T_2^*}$, kHz	ΔH, Oe
77,0	75.48	549	$0,12 \cdot 10^6$	3,3	1,2	67	2,4	17.5
63,0	75,93	551	$0,22 \cdot 10^6$	–	–	–	–	–
4,2	76,45	555	$0,25 \cdot 10^5$	10	2,9	68	2,3	17,0

An essential feature of the NMR in the $FeBO_3$ is the anomalously large gain of the NMR, reaching $\eta = 0.22 \times 10^6$ at $T = 63°K$. The average gain was measured by the method of spin precession and spin echo under the assumption that the signals reach a maximum at the resonant frequency if $\gamma_n H_x \eta \tau = \pi/2$ and $\gamma_n H_x \eta \tau = 2\pi/3$, respectively. Here γ_n is the gyromagnetic ratio, H_x the rotating component of the exciting pulse, and τ the duration of this pulse. Such large values of η can be explained in the following manner. The gain connected with the rotation of the magnetization in the domain in a zero external field is $\eta_{rot} \sim H_n/H_a$, where H_n is the hyperfine field and H_a the anisotropy field. In the

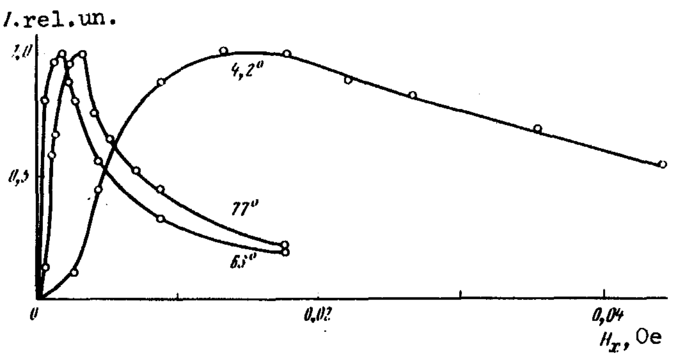

Fig. 1

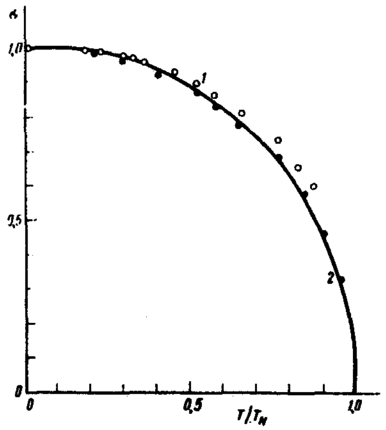

Fig. 2

Fig. 1. Relative amplitude of free-precession amplitude at the resonant frequency vs. the rotating component of the exciting pulse. τ = 4.6 μsec.

Fig. 2. Temperature dependence of the relative sublattice magnetization $\sigma = M(T)/M(0)$: 1 - neutron-diffraction measurements [7], 2 - results of NMR measurements. Solid curve - Brillouin function for S = 5/2.

(111) plane of the investigated crystal the anisotropy field is so small that only its upper limit was determined, $H_a < 1$ Oe at 200°K [3, 4]. We can therefore expect η_{rot} to have a large value. An even larger value is usually possessed by the coefficient η_{dis}, connected with the displacement of the domain boundaries, although for the weak ferromagnet α-Fe_2O_3 it can be of the same order as η_{rot} [5].

The characteristic form of the dependence of the free-precession signal intensity on H_x (Fig. 1) allows us to conclude that boundary-displacement processes predominate, and consequently the signals come from nuclei in domain boundaries. Were the signals to come from nuclei in domains, for which $\eta_{rot} \simeq$ const, then the averaging connected with the arbitrary orientation of the crystals relative to the direction H_x would lead to an oscillatory damped character of this dependence. The monotonic decrease of the intensity after reaching the maximum is characteristic of the additional averaging to the inhomogeneity of η in the domain boundary [6]. Apparently an even greater value of η can be registered in an oriented sample. The reason for the decrease of η at T = 4.2°K is not clear.

The relaxation times were measured at the optimal amplitude of the exciting pulses. A fact worthy of attention is that at T = 4.2°K and T = 77°K the absorption line width ΔH, estimated from the value of T_2^*, does not exceed 20 Oe.

The temperature dependence of the relative sublattice magnetization $\sigma = M(T)/M(0)$, which is identified with $H_n(T)/H_n(4.2°K)$, is shown in Fig. 2. The Neel temperature (348.1 ± 0.2°K) was measured by the nuclear gamma resonance (NGR) method. The same figure shows neutron-diffraction data on $FeBO_3$, taken from [7]. The value of the hyperfine field, measured by the NGR method, $H_n(4.2°K)$ - 561 kOe, differs by 1.1% from the value measured by us. This discrepancy cannot be attributed to the error in the measurement of the NMR frequency ($\Delta\nu/\nu \simeq 0.1\%$) and is due to another cause. Unfortunately, the authors of [8] do not indicate the measurement error of H_n in their experiments. At

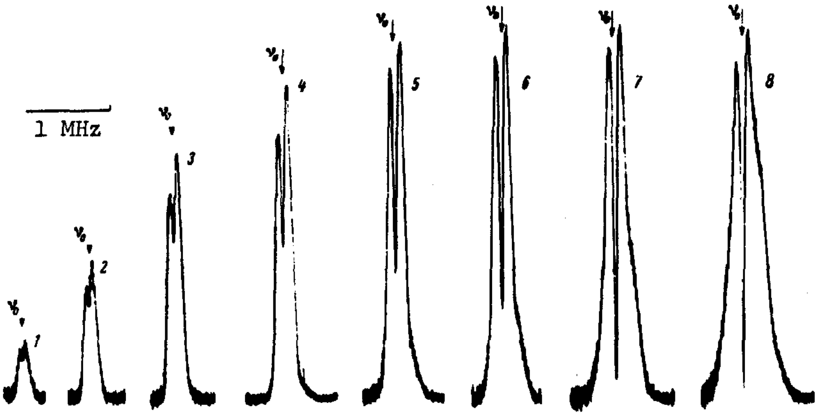

Fig. 3. Integral intensity of echo signal as a function of the carrier frequency of the exciting signals, $\tau_1 = \tau_2 = 4.6$ μsec, T = 77°K. The values of H_x (Oe) are: 1 - 0.0018, 2 - 0.0027, 3 - 0.0044, 4 - 0.0062, 5 - 0.0089, 6 - 0.013, 7 - 0.018, 8 - 0.026.

T = 300°K the deviation from the theoretical curve is 7%.

Since the Fe^{3+} ions occupy crystallographically equivalent positions, a single NMR line was observed, as expected. The complicated form of the spectrum (Fig. 3) in the case of a large high-frequency field ηH_x acting on the nucleus, under the condition $\Delta H \ll \eta H_x$, is connected with the features of the pulse procedure and is analyzed in detail in [6].

The question of the relation between η_{rot} and η_{dis} for the compound $FeBO_3$ can be finally resolved by NMR investigations in an external magnetic field.

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