INVESTIGATION OF SPIN REORIENTATION IN SINGLE-CRYSTAL $TmFeO_3$ BY THE NMR METHOD

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Spin reorientation in rare-earth orthoferrites was investigated by various methods, viz., magnetic torsion, neutron diffraction, Mossbauer or optical spectroscopy, and microwave absorption [1 - 5].

It was established in these investigations that the transition from one spin configuration to another is effected in a finite temperature interval (10 - 20°K). In addition, it is concluded that the transition is via a smooth rotation of the resultant moment from the c axis to the a axis of the crystal, and is a second-order phase transition.

We have investigated the reorientation process in $TmFeO_3$ by nuclear magnetic resonance of Fe^{57}, an NMR signal which was first observed in [6].

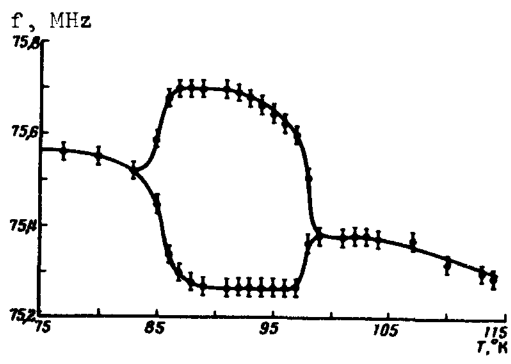
We used a single-crystal sample grown by crucibleless zone melting with optical heating, using the procedure of [7]. The Fe^{57} content was natural. The measurements were made with a spin-echo spectrometer with frequency scanning and automatic recording of the spectra at pulse duration τ_1 = 3.5 μsec and τ_2 = 7.0 μsec. The pulse repetition frequency was 2.8 Hz and the interval between pulses 300 μsec.

The low values of the NMR gain ($\eta \approx 20$) far from the reorientation region (T = 77°K) and the large relaxation times indicate that echo signals from the nuclei in the interior of the domains were observed.

We investigated the behavior of the resonant frequencies in the temperature interval 75 - 114°K. These measurement data are shown in the figure.

A single absorption line, with a resonant frequency that varies in accordance with the temperature dependence of the sublattice magnetization is observed in the temperature intervals 75 - 83°K and 98 - 114°K. The width of this line, under the registration conditions indicated above, is 120 kHz.

In the temperature range 83 - 98°K, however, an anomalous splitting of the single line into two lines of equal intensity takes place. The maximum splitting at 91°K is 450°K; this corresponds to a difference of 3.3 kOe between the local fields at the nuclei.



Temperature dependence of the resonant frequencies of Fe^{57} in $TmFeO_3$ in the spin-reorientation region. The systematic error in the measurement of the resonant frequencies (±70 kHz) is not shown in the figure.

The peculiar behavior of the resonant frequencies in the region of spin reorientation of $TmFeO_3$ can be explained as follows. Since the surrounding of the Fe^{3+} ions is not cubic, there exists apparently an anisotropy of the resonant frequencies, due to the anisotropy of the dipole field and of the hyperfine interaction. At temperatures T < 83°K and T > 98°K, the magnetic moments of the Fe^{3+} ions are oriented approximately along the c and a axes of the crystal, respectively. The contributions from the anisotropic terms to the local fields at the Fe^{3+} ion in the sublattices are equal in this case, and a single line is observed as a result.

In the course of the reorientation, the easy axis is symmetrically split into two directions at angles $\pm\theta$ to the c axis. In this case the equivalence of the Fe^{3+} ions is violated, i.e., the anisotropic contributions to the local field have different signs, and this lead to splitting of the resonant line into two lines of equal intensity.

The order of magnitude of the splitting does not contradict this assumption.

The results confirm the continuity of the change of the angle θ and are evidence favoring the second-order phase transition.

The reorientation temperature range determined by us (83 - 98°K) agrees satisfactorily with the data of [1] (81.5 - 94°K), obtained by the magnetic-torsion method. The small discrepancy in the size of the interval can be attributed to the fact that our measurements are free of the influence of an external magnetic field.

The absence of anomalies in the temperature dependence of the effective magnetic fields at the Fe^{57} nuclei in the orthoferrite $SmFeO_3$ in the reorientation region, noted in [4], may be connected with the lower resolution of the Mossbauer spectroscopy.

A calculation of the anisotropy of the dipole field and of the hyperfine interaction make it possible to determine from the presented data the temperature dependence of the angle θ. These data will be published later.

[1] E.M. Gyorgy, J.P. Remeika, and F.B. Hagedorn, J. Appl. Phys. 39, 1369 (1968).

[2] K.P. Belov, R.A. Volkov, B.P. Goranskii, A.M. Kadomtseva, and V.V. Uskov, Fiz. Tverd. Tela 11, 1148 (1969)[Sov. Phys.-Solid State 11, 935 (1969)].

[3] J.A. Leake, G. Shirane and J.P. Remeika, Solid State Comm. 6, 15 (1968).

[4] A.M. Balbashov, V.M. Golubev, E.F. Makarov, V.A. Povitskii, and A.Ya. Chervonenkis, Fiz. Tverd. Tela 13, 685 (1971) [Sov. Phys.-Solid State 13, 567 (1971)].

[5] R.B. Hagedorn, E.M. Gyorgy, R.C. LeCraw, J.C. Hensel, and J.P. Remeika, Phys. Rev. Lett. 21, 364 (1968).

[6] N.M. Kovtun, E.E. Solov'ev, A.A. Shemyakov, and V.A. Khokhlov, ZhETF Pis. Red, 14, 105 (1971) [JETP Lett. 14, 68 (1971)].

[7] A.V. Antonov, A.M. Balbashov, and A.Ya. Chervonenkis, Fiz. Tverd. Tela 12, 1724 (1970) [Sov. Phys.-Solid State 12, 1363 (1970)].

SINGLE-FREQUENCY BRILLOUIN LASER USING METHANE

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In all the presently known Brillouin lasers (see [1]) the active media employed are different liquids. In many cases, however, it is preferable to use compressed gases, owing to the higher self-focusing threshold and the better optical quality [2]. On the other hand, a study of the operation of such lasers is usually greatly hindered by processes of successive scattering in the resonator, which lead to the appearance of several lines in the emission