Experimental and calculated frequencies of the surface phonons in MgF_2

Orientation	Surface-phonon frequency	
	exper., cm^{-1}	calc., cm^{-1}
c || z	295	300
	541	543
c || x	–	–
	541	543
c || y	283	291
	543	545

In TiO_2, the regions of negative values of $\varepsilon_\perp'$ and $\varepsilon_\parallel'$ overlap in all three frequency regions, and accordingly three type-1 phonons were observed for this crystal at all orientations.

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MAGNETIC AND MAGNETOSTRICTION PROPERTIES OF THE COMPOUND Tm_6Fe_{23}

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Magnetic materials which are compounds of rare-earth metals with 3d transition metals are now attracting the attention of many researchers. Compounds of the type RCo_5 having unprecedented values of magnetic energy, have been discovered [1, 2], and giant magnetostriction was observed at room temperature in compounds of the RFe_2 type [3, 4].

Belonging to the same class of magnetic materials are also compounds of the type R_6Fe_{23}, but the published data on the magnetic properties of these compounds [5 - 7] are incomplete. We report here the results of a study of the magnetic and magnetostriction properties of the compound Tm_6Fe_{23}, on which there are no data in the literature.

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The compound Tm_6Fe_{23} was observed in the study of the thulium-iron phase diagrams [8]. Specimens of the compound were melted in an arc furnace on a copper water-cooled hearth in a helium atmosphere. It was homogenized by annealing in vacuum at 850°C for 300 hours. X-ray and metallographic analyses have shown that the specimens are single-phase and have a cubic lattice.

The magnetization was measured in the interval 4.2 - 80°K in the field of a superconducting solenoid up to 53 kOe, using a vibration magnetometer, and in the interval 80 - 700°K in an electromagnetic field up to 15 kOe.

The coercive force was measured in an ordinary solenoid at a maximum magnetizing field 1700 Oe. The magnetostriction was measured with strain pickups. The Curie point Θ = 449°K and the spontaneous magnetization σ_s near Θ were obtained by a thermodynamic method with the aid of plots of $H/\sigma = f(\sigma^2)$.

Figure 1 shows the temperature dependences of the specific spontaneous magnetization σ_s, the susceptibility χ_n in a strong field (~11 kOe), and the coercive force H_c.[2)] The magnetization σ_s decreases strongly at low temperatures. This effect can be attributed to the ferrimagnetic structure of this compound.

It follows from the neutron-diffraction data that the magnetic structure of Ho_6Fe_{23} can be represented as consisting of two sublattices of Ho and Fe atoms [7], with oppositely directed magnetic moments. The presence of an analogous structure can be assumed also for the compound Tm_6Fe_{23}.

We measured the magnetization at 4.2°K in fields up to 53 kOe, and found that the absolute saturation magnetization, obtained by extrapolation to H = 0

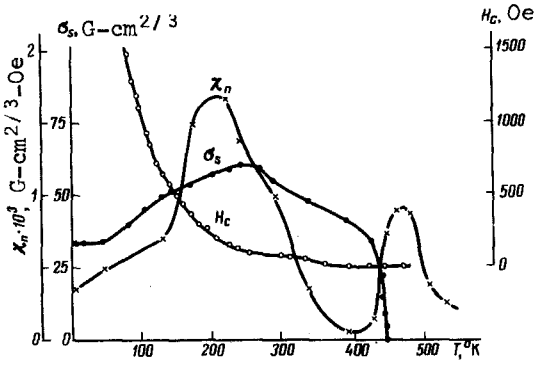

Fig. 1

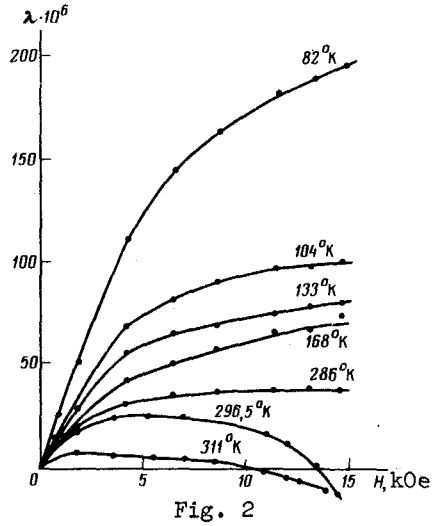

Fig. 2

Fig. 1. Temperature dependences of the specific spontaneous saturation magnetization σ_s, of the coercive force H_c, and of the susceptibility in a strong field χ_n, of the compound Tm_6Fe_{23}.

Fig. 2. Magnetostriction of the compound Tm_6Fe_{23} as a function of the magnetic field at different temperatures.

[2)] The residual magnetization and the coercive force decrease strongly when the specimen is heated to the vicinity of the Curie point and become equal to zero at $T \geq 470$°K.

from the field region 30 - 53 kOe amounts to 33.0 G-cm^3/g. This yields a value of 13.65μ_B for the magnetic moment μ_0 per molecule of the compound. On the other hand, our measurements of the absolute saturation magnetization of the compound Lu_6Fe_{23}, obtained by the same method as the Tm_6Fe_{23}, yielded a magnetic moment per molecule $\mu_0 = 23\mu_{Fe} = 44.6\mu_B$ and a magnetic moment per iron ion $\mu_{Fe} = 1.94\mu_B$. Assuming that the magnetic moment of the iron ion does not change significantly in the series of compounds R_6Fe_{23}, which is usually true for the series of like compounds of rare-earth metals with iron [9], we obtain for the magnetic moment per thulium ion the value $\mu_R = (1/6)(23\mu_{Fe} - \mu) = 5.15\mu_B$, i.e., a value much lower than for the free trivalent ion ($7\mu_B$). The lower value of μ_R can be attributed to the strong effects of the crystal field, owing to the fact that the thulium ion has an orbital momentum. We note that the magnetization curve exhibits no saturation even in fields 30 - 50 kOe at 4.2°K, the value corresponding to this field interval is 0.275×10^{-3} G-cm^3/g-Oe, and a hysteresis loop is observed only up to 20 kOe.

The decrease of σ_s at low temperatures (Fig. 1) can be attributed to the rapid ordering of the thulium sublattice at lower temperature and to the fact that the magnetic moment of the thulium sublattice has an orientation opposite to that of the iron sublattice.

Such a conclusion agrees with other data. The coercive force (Fig. 1) and the magnetostriction (Fig. 2) increase strongly when the temperature drops below room temperature, owing to the ordering of the magnetic moments of the thulium ions. The single-ion anisotropy and magnetostriction constants of thulium should make the maximum contribution to the anisotropy and magnetostriction, and consequently also to the coercive force.

The maximum on the susceptibility curve in a strong field at $\Theta_H = 200$°K can be attributed, in analogy with rare-earth iron garnets [10], to the fact that the most abrupt disturbance of the long-range magnetic order in the thulium sublattice occurs at this point (the low temperature point Θ_H), so that a maximum susceptibility of the paraprocess should be observed, just as at the Curie point. It follows from an analysis of the data that intense magnetic ordering in the thulium sublattice occurs at temperatures below 200°K. We can conclude from this that the exchange interaction between the thulium and iron sublattices is much less than the exchange interaction inside the iron sublattice. The exchange interaction in the iron sublattice in Lu_6Fe_{23} (the magnetic moment of Lu is equal to zero) determines the rather high value of the Curie temperature, $\Theta = 494$°K.

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