ANOMALIES IN THE TEMPERATURE DEPENDENCE OF THE THERMAL EXPANSION COEFFICIENT OF A GADOLINIUM SINGLE CRYSTAL

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The thermal expansion coefficients of a gadolinium single crystal were measured along the a and c axes in the temperature range 78—330°K. A very complex nonmonotonic temperature dependence of the thermal expansion coefficient α was observed along both axes. Along the c axis, the coefficient α was negative over a wide range of temperatures, from 150°K to the Curie point (290°K). A maximum in the thermal expansion coefficient along the c axis was observed at temperatures of 210—220°K and a maximum in α along the a and c axes was found at the Curie point.

THE thermal expansion of polycrystalline gadolinium has been investigated in a number of studies.[1-3] It has been established that above the Curie point the thermal expansion coefficient is positive, at the Curie point and below it (220°K) the coefficient is negative, and at still lower temperatures it again becomes positive. X-ray measurements [4,5] have shown that the lattice parameters of gadolinium a and c behave anomalously as the temperature is varied.

Recently, Bozorth and Wakiama [6] discovered that the thermal expansion anomaly of single-crystal gadolinium in the region of the Curie point is anisotropic.

In the present communication, we report the results of our measurements of the thermal expansion of a gadolinium single crystal. The single crystal was grown in the laboratory of E. M. Savitskiĭ. The thermal expansion coefficient and magnetostriction were measured under the same conditions using the strain gauge method. The change in the resistance of the strain gauge attached to the crystal was measured with a Wheatstone bridge. One of the arms of the bridge was another strain gauge of exactly the same resistance as the measuring gauge. This second gauge was attached to a fused quartz plate and kept at the same temperature as the gauge attached to the crystal. The thermal expansion coefficients $\alpha = (dl/dT)/l$ along the a and c axes were determined graphically by differentiating the curves of the temperature dependence of the resistance of the gauge attached to the crystal. The magnetization was measured with a Domenicali pen-

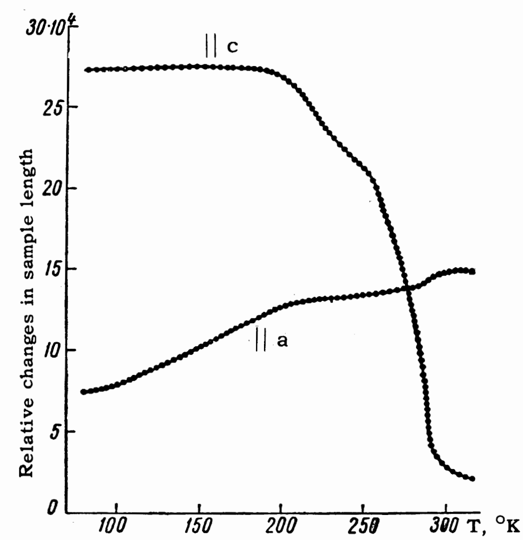

FIG. 1. Relative change in the length of a gadolinium single crystal along the a and c axes.

dulum null magnetometer. The results obtained are given in Figs. 1 and 2. It is evident from Fig. 2 that, along the a axis in the temperature range from nitrogen to room temperature, the coefficient α is positive and its value is small, but its temperature dependence is very complex. The thermal expansion coefficient along the c axis also behaves in a complex way. Below 150°K, the latter coefficient is small and positive, then it changes sign and has two negative maxima. One of these maxima corresponds to the Curie point (290°K); at this temperature, the anomalous value becomes -70×10^{-6} deg^{-1}. At 210—220°K, there is a second negative maximum in the coefficient α. It is worth mentioning that other physical

Direction of measurement	$10^3 \Delta\left(\frac{\partial I}{\partial H}\right)_{T,P}$, G/Oe	$\Delta\left(\frac{\partial I}{\partial T}\right)_{P,H}$, G/deg	$10^{10}\Delta\frac{1}{l}\left(\frac{\partial l}{\partial H}\right)_{P,T}$, Oe^{-1}	$10^6\,\Delta\alpha$, deg^{-1}, calc. from Eq. (1)	$10^6\,\Delta\alpha$, deg^{-1}, estim. from exper. data
c axis	+9.0	—17.3	+340,0	—65,0	—70.0
a axis	+7,0	—18,5	—14,0	+3,7	+5,0

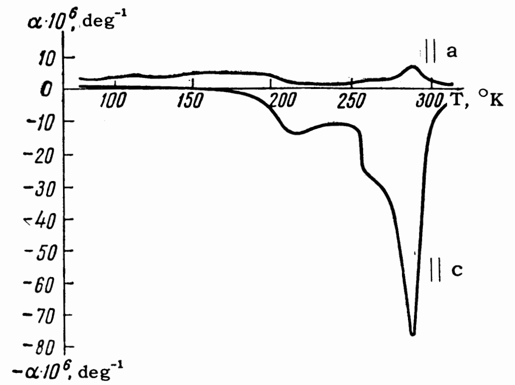

FIG. 2. Thermal expansion coefficients of a gadolinium single crystal along the a and c axes.

properties of gadolinium also have anomalies in the same range of temperatures [7]. The reasons for the appearance of this maximum are still not clear. However, the nature of the thermal expansion coefficient anomalies, observed in a gadolinium crystal in the region of the Curie point along the axes a and c, is due to the influence of the spontaneous deformation of the lattice, caused by the magnetic transformation. The thermal expansion anomaly at the Curie point itself may be expressed [8] in terms of the jumps of: the magnetostriction in the absolute saturation region $\Delta l^{-1}(\partial l/\partial H)_{T,P}$, the susceptibility in the absolute saturation region $\Delta(\partial I/\partial H)_{P,T}$, and the temperature coefficient of the saturation magnetization $\Delta(\partial I/\partial T)_{H,P}$:

$$\Delta\alpha = \Delta\frac{1}{l}\left(\frac{\partial l}{\partial H}\right)_{T,P}\Delta\left(\frac{\partial I}{\partial T}\right)_{H,P} \Big/ \Delta\left(\frac{\partial I}{\partial H}\right)_{T,P}.$$

The quantities which occur in this formula were measured using the same single crystal of gadolinium and are listed in the table.

It can be seen that the values of $\Delta\alpha$, calculated using Eq. (1), agree in sign and the order of magnitude with the experimental values of $\Delta\alpha$.

In conclusion, the author expresses his deep gratitude to K. P. Belov for his close interest in directing this work and for discussing the results obtained.

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