

SPONTANEOUS MAGNETOSTRICTION OF CrTe

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An x-ray diffraction study of the ferromagnetic compound CrTe with the NiAs-type structure was carried out at temperatures in the region of the magnetic transition point. The results obtained indicated that the magnetic ordering, which appeared when the temperature was lowered, was accompanied by an anomalous increase of the lattice parameter a . The ordering did not have a perceptible effect on the temperature dependence of the lattice parameter c . Near the magnetic transition temperature, the thermal expansion coefficient $a^{-1}\partial a/\partial T$ was $-65 \times 10^{-6} \text{ deg}^{-1}$ at temperatures $T < T_c$, whereas $a^{-1}\partial a/\partial T \approx c^{-1}\partial c/\partial T = +28 \times 10^{-6} \text{ deg}^{-1}$ at temperatures $T > T_c$. The absence of an appreciable spontaneous magnetostriction along the c axis was attributed to the existence of two competing and different exchange interactions. The observed anomaly in $a(T)$ was ascribed to a strong dependence of the dominant positive exchange interaction in the basal plane on the interatomic spacing.

THE compound CrTe belongs to the group of substances with the NiAs-type crystal structure. It is interesting to note that the majority of known magnetic compounds with the NiAs-type structure are antiferromagnets. A study of solid ternary solutions based on Cr and Mn and on group V and VI metalloids has shown^[1] that variation of the concentrations of the components alters, in some cases, the nature of spin ordering in magnetic materials of this type. The transition from the ferromagnetic to antiferromagnetic state is found to be associated with a reduction of the unit cell dimensions. It is likely that these features of magnetic properties are the results of competing and different exchange interactions.^[2,3]

The problem of the nature of the exchange interactions in compounds with the NiAs-type structure is still far from being solved. The magnetic and exchange interactions in these compounds are manifested most clearly in their magnetoelastic properties. Therefore, investigations of these properties using such compounds, particularly their single crystals, are of special interest.

In view of this, we carried out a study of the spontaneous magnetostriction of the compound CrTe, which is one of the few known ferromagnets with the NiAs-type structure.

Since the preparation of single crystals of CrTe is difficult, our study was carried out by x-ray diffraction analysis of a polycrystalline sample.

EXPERIMENTAL METHOD AND RESULTS

Our sample was in the form of a powder, taken from the same batch as the sample studied on an earlier occasion.^[4] According to the results given in^[5], the Curie point of CrTe is 54°C .

The temperature dependences of the crystal lattice parameters of CrTe were determined using a URS-50IM diffractometer, modified for investigations over a range of temperatures. An electronic circuit was used to stabilize the temperature so that it did not vary by more than 0.02 deg . The diffraction patterns were obtained using filtered copper radiation.

It was found that each diffraction peak could be re-

solved into two separate peaks whose intensities were in the approximate ratio of 1:10. The additional peaks could be explained by the presence of a second phase (with the same type of lattice but with somewhat smaller parameters a and c), which was evidently antiferromagnetic.^[6] However, this did not interfere with a reliable determination of the temperature dependences of the lattice parameters of the main phase. In order to increase the accuracy of our calculations, we used the method of recording a diffraction peak in steps of $1'-2'$. The average error in the determination of the angle ϑ , calculated using the results of repeated stepwise recording of the same diffraction peak, amounted to $0.5'$ for the (002) and (110) reflections and $1'$ for the (004) reflection (these reflections were used to calculate the lattice parameters).

The average values of the lattice parameters at room temperature were found to be: $a = 3.988_3 \pm 0.003 \text{ \AA}$, $c = 6.214_0 \pm 0.004 \text{ \AA}$. An analysis of the diffraction peaks showed that their profile did not vary with temperature. Therefore, the temperature dependences of the parameters a and c were calculated using the practically undistorted leading edge of a diffraction peak.

According to measurements of the magnetic moments of the sample as a function of the temperature and ap-

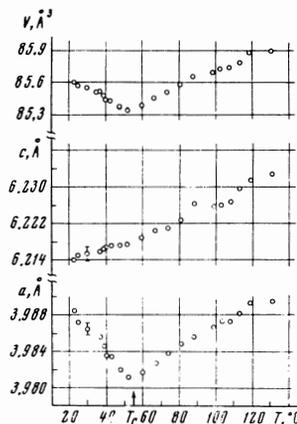


FIG. 1. Temperature dependences of the lattice parameters and of the unit cell volume of the compound CrTe in the magnetic transition region.

plied field, the Curie point was $\approx 55^\circ\text{C}$, which was in good agreement with the results given in^[5]. The magnetization measurements were carried out using a vibrating-sample magnetometer.^[7]

The values of the parameters a and c at various temperatures are shown in Fig. 1. It is evident from this figure that the thermal expansion of the crystal lattice of CrTe has an anomaly in the region of the magnetic transition temperature. Above T_C , the temperature coefficients of the parameters a and c are practically equal: $28 \times 10^{-6} \text{ deg}^{-1}$. The magnetic ordering, which appears when the temperature is reduced below T_C , has no perceptible influence on the nature of the temperature dependence of the parameter c . However, the temperature dependence of the parameter a changes greatly: at temperatures $T < T_C$, the temperature coefficient $a^{-1}\partial a/\partial T$ becomes negative. Assuming that the dependence $a(T)$ below T_C is linear, we find that this coefficient is $-65 \times 10^{-6} \text{ deg}^{-1}$ (in the temperature range from 22 to 55°C).

DISCUSSION OF RESULTS

It is evident that the temperature dependences of the parameters a and c , shown in Fig. 1, are due to a spontaneous magnetostriction which accompanies the appearance of magnetic order. The magnetostriction of CrTe is not only strongly anisotropic but also anomalously high (in the basal plane). Already at room temperature ($T/T_C = 0.9$) it reaches 3000×10^{-6} . Such a high striction is direct evidence of a strong dependence of the exchange interactions in the basal plane on the interatomic spacings. This result is in qualitative agreement with the results of a study of the influence of hydrostatic compression on the magnetic transition temperature of CrTe.^[8,9]

It is worth noting that the thermal expansion coefficient along the direction of the parameter c of CrTe is practically independent of temperature (as in the isomorphous ferromagnetic compound MnSb^[10]).

The absence of an appreciable spontaneous magnetostriction along a given direction may be explained by the existence of two different interactions, each of which gives rise to a magnetostriction proportional to the derivative of the exchange integral with respect to the interatomic spacing. These interactions are evidently the competing positive ferromagnetic and the negative antiferromagnetic interactions of somewhat different origin.^[2,3]

If, for a given distance between the magnetic atoms, the striction strains due to each of the two competing interactions are approximately equal in magnitude but

opposite in sign, the spontaneous magnetostriction along such a direction is practically absent even in the case of a strong dependence of each of the exchange integrals on the interatomic spacing. In this case, the nature of the magnetic ordering and the magnetic transition temperature are, as usual, determined uniquely by the magnitude and sign of the total exchange integral, but the nature of the dependence of this integral on the interatomic spacing no longer governs in a simple manner the magnitude and sign of the spontaneous striction.

This explains not only the dependence $c(T)$ of CrTe but also the observed anomaly of the parameter a of this compound. The high value of the spontaneous striction in the basal plane is, evidently, the result of the dominant positive exchange interaction. This conclusion is in agreement with the results of neutron-diffraction studies of the compound CrTe.^[11]

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