On magnetization processes in antiferromagnetic chromium

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Longitudinal magnetostriction of chromium is investigated in magnetic fields up to 70 kOe and at temperatures between 90 and 270 K. Possible mechanisms of magnetization of antiferromagnetic chromium are analyzed on the basis of the results.

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We investigated the longitudinal magnetostriction of chromium in polycrystalline samples ($R_{300}/R_{4.2} = 130$) in a magnetic field up to 70 kOe at temperatures 90–270°K. The samples were cut by the electric spark method and were plates measuring $15 \times 7 \times 1$ mm. The measurements were made with a strain gauge in a null circuit in the field of a superconducting solenoid. To stabilize the temperature we used a regulator that made it possible to maintain a set sample temperature accurate to 10^{-3}°K in the entire investigated interval.[1] The field dependence of the magnetostriction at fixed temperature was automatically plotted with an x-y recorder.

Below the Néel point ($T_N = 312$°K) the magnetic structure of Cr is a standing spin wave with wave vector **Q** and a polarization vector η.[2,3] Above the spin-flip temperature ($T_{SF} = 122$°K), a transverse spin-density wave is realized ($\mathbf{Q} \perp \eta$, AF_1 phase), and at $T < T_{SF}$ there is realized a longitudinal spin-density wave ($\mathbf{Q} \parallel \eta$, AF_2 phase). In the AF_1 phase there can exist six types of domains, each of which is characterized by its own spin-density wave ($\mathbf{Q}_i \cdot \eta_j$), $i \neq j$, and in the AF_2 phase there are three types of domains ($\mathbf{Q}_i \cdot \eta_i$).[4] Here i and j can assume the values 1, 3, and 3, which correspond to directions along the [100], [010], and [001] axes of the crystal.

When the single-crystal Cr sample is cooled through the Nêel point in a sufficiently strong magnetic field $H_C \parallel \langle 100 \rangle$, a "one-Q" state is realized, in which all the vectors **Q** are aligned parallel to H_C. Analogous effects connected with cooling in a magnetic field were also observed on well-annealed polycrystalline Cr samples.[4] It assumed that in each crystallite there exists a "one-Q" state with a vector **Q** lying along of the $\langle 100 \rangle$ axes, which is almost parallel to H_C.

When a magnetic field H parallel to the fourfold axis of the crystal is applied, two different magnetization mechanisms are possible in the AF_1 phase. The first provides for an increase in the volume of the domains with polarization vector η perpendicular to **H**, and the second for an increase of the volume of the domains with vector **Q** parallel to **H**.

Below the Néel point, the cubic lattice of the paramagnetic Cr is transformed into an orthorhombic lattice. The axis of the orthorhombic lattice, parallel to the unit vector **n** at $T > T_{SF}$ ($\mathbf{n} \perp \eta$ and $\mathbf{n} \perp \mathbf{Q}$).[5] Consequently, if only the first mechanism were to be realized, then a positive magnetostriction would be observed for all $T > T_{SF}$. In the temperature region $T_{SF} < T < 200$°K, however (see Fig. 1, curve b), there is observed a positive magnetostriction in weak fields, and with increasing magnetic field it becomes negative. This behavior of the magnetostriction cannot be attributed only to the first mechanism. It appears that starting with a certain value of the magnetic field the main contribution is made by the second mechanism. Indeed, when the second mechanism is realized, at a temperature below ~200°K, there should be observed a negative magnetostriction, since the orthorhombic lattice axis, which is parallel to **Q**, is the shortest in this temperature interval.[5] Since the main contribution to the magnetostriction in a strong magnetic field is made by the second mechanism (see Fig. 1, curve b), it follows that in the temperature region $T_{SF} < T < 200$°K negative values are observed on the temperature dependence of the magnetostriction, plotted in a 60-kOe field (Fig. 2). However, when the temperature is raised, a change takes place in the sign of the magnetostriction precisely in that temperature region (~200°K) where a change takes place in the axis of the orthorhombic lattice parallel to **Q**, from short to long.[5] At these temperatures we observe positive magnetostriction at all values of the magnetic field (Fig. 1, curve a). This behavior of the magnetostriction agrees with the fact that in this temperature region both mechanisms should cause a lengthening of the sample. At the point T_{SF}, an abrupt reversal of sign is observed on the temperature dependence of the magnetostriction (Fig. 2). The positive magnetostriction in the AF_2 phase (Fig. 2) indicates that in the AF_2 phase, where $\mathbf{Q} \parallel \eta$, only one magnetization mechanism is possible, namely an increase of the volume of the domains with vectors **Q** and η perpendicular to the magnetic field H. When the Cr is cooled through T_{SF}, the orthorhombic lattice is transformed into a tetragonal one, and in this case the lattice axis parallel to the vectors **Q** and η is the very shortest[5], since a lengthening of the sample in the H direction should be observed when an increase takes place in the volumes of the domains whose vectors **Q** and η are perpendicular to H.

It should be noted that in the investigation of the magnetization of Cr it is important to carry out the measurements in strong magnetic fields, since the rotation of the vector **Q** begins in fields 12–15 kOe. In our

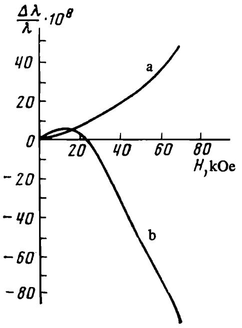

FIG. 1

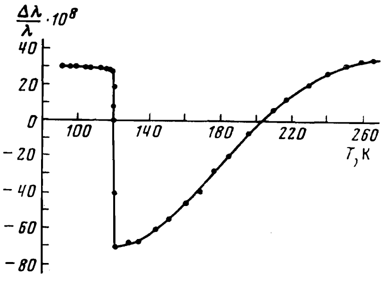

FIG. 2

earlier study[6] we observed no change in the sign of the magnetostriction at T_{SF}, apparently because the measurements were made in fields up to 13 kOe. In addition, we used in our present work new strain-gauge pickups, in which the galvanomagnetic effect was lower by one order of magnitude than in the previously used ones. The sensitivity in the present work was also increased by stabilization of the temperature with accuracy 10^{-3}°K, which is very important in magnetostriction measurements, since the change of the sample dimensions due to magnetostriction, is lower by two orders of magnitude than the change due to thermal expansion.

Our present results agree with the conclusions of investigations of neutron diffraction[7] and chromium magnetization[8] carried out in weak magnetic fields.

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