MAGNETIC PROPERTIES OF A SINGLE CRYSTAL OF SCANDIUM

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The magnetic properties of a scandium single crystal obtained by recrystallization annealing have been investigated. The magnetic susceptibility χ was measured in a broad temperature range from 77 to 1100°K. The susceptibility is greater in a direction parallel to the c axis than perpendicular to it. For both directions the paramagnetic Curie point is negative.

1. The temperature dependence of the magnetic susceptibility of polycrystalline scandium has been investigated previously.[1] It was found that the reciprocal of the susceptibility varies linearly with temperature with a negative value of Θ_p from nitrogen temperatures to 1100°K.

An investigation of the magnetic properties of a single crystal of scandium would be of great interest, the more so since no such investigation has ever been made. It should be noted that there are extremely few experimental data on the magnetic properties of single crystals of weakly magnetic transition metals,[2] although these investigations can give extremely valuable information on the magnetic anisotropy of weakly magnetic substances and elucidate the character of the interaction in these metals.

It is difficult to obtain single crystals of scandium. For the most part this is caused by the high chemical activity of scandium, the insufficient purity of the polycrystalline metal, and the existence of polymorphism at high temperatures. A single crystal of scandium was obtained by the recrystallization annealing method in high vacuum.[3] The advantage of this method over others is that in the growth process there is by far less contamination by impurities. The most harmful impurities are those which separate out on the grain boundaries and hinder the growth of individual crystals. For scandium these impurities are usually atoms of oxygen and calcium. The starting material, obtained by the reduction of scandium fluoride by distillation over calcium, contained impurities in the following limits: oxygen $\leq 0.11\%$, carbon $\leq 0.015\%$, molybenum $\leq 0.006\%$, nitrogen $\leq 0.04\%$, calcium $\leq 0.02\%$, and hydrogen 0.0089%.

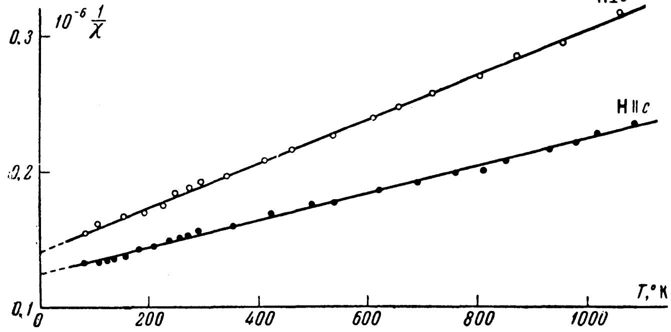
After remelting in an arc furnace, the scandium ingot was polished and annealed in a vacuum of 10^{-5} — 10^{-6} mm Hg at 1350°C for 8 hr. After annealing, a single crystal measuring $6 \times 9 \times 14$ mm was found in the body of the starting material.

2. It is known that metallic scandium has a magnesium type A3 hexagonal close packed structure with parameters $a = 3.306 \pm 0.005$ Å, $c = 5.271 \pm 0.005$ Å and $c/a = 1.594$.

The sample was nearly cubic in shape and was placed in the holder in such a way that the magnetic field was directed either parallel or perpendicular to the c axis. The crystal was oriented by the Laue method.

The measurements were carried out in vacuum by the usual Faraday-Sucksmith ponderomotive technique over the wide temperature interval 77 to 1100°K. The temperature of the sample was determined with copper-constantan and Pt-Pt, Rh thermocouples which had been calibrated with pure metals.

Figure 1 shows the dependence of the reciprocal of the specific susceptibility $1/\chi$ on temperature for both relative orientations of the magnetic field. It can be seen that the susceptibility along the axis is greater than perpendicular to it. This is evidence that the magnetic moments are preferentially oriented along the c axis. By applying the Curie-Weiss law to the observed dependence of $1/\chi$ on T



Dependence of $1/\chi$ on T for a single crystal of scandium.

it is possible to determine the paramagnetic Curie point Θ_p. For magnetic field parallel to the c axis, we find $\Theta_p = -1300°K$, and perpendicular to it, $\Theta_p = -900°C$.

Thus Θ_p is larger in the first case than in the second. If one compares the values of Θ_p determined from a monocrystal with the results obtained on a polycrystalline specimen,[1] the following relation can be written

$$(\Theta_p)_{\text{polycr}} = \frac{1}{3}\Theta_{p\parallel} + \frac{2}{3}\Theta_{p\perp}. \qquad (1)$$

It should be mentioned here that a similar rule for Θ_p was found in the rare earth metal neodymium by Behrendt, Legvold, and Spedding.[2] They also established that Nd is antiferromagnetic at low temperatures.

3. Thus, although according to the results $1/\chi$ depends linearly on T, it is hardly possible to calculate the mean magnetic moment of the ions from the slope of the curve $1/\chi = f(T)$, as is done in the case of paramagnetic solutions. According to contemporary theory of the magnetism of transition metals, in this case a significant contribution to the demagnetization is furnished by the electronic d-bands participating in conduction (non-localized).

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[2] Behrendt, Legvold, and Spedding, Phys. Rev. **106**, 723 (1957).

[3] Savitskiĭ, Terekhova, Naumkin, and Burov, Tsvetnye metally (Nonferrous Metals), No. 5, 1963.

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289