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MAGNETIC SUSCEPTIBILITY OF Cr_2O_3 AND NiO IN THE REGION OF THE NEEL TEMPERATURE

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The problem of phase transition temperature definition is investigated by measurement of the magnetic susceptibility of high purity (99,998%) powder samples of Cr_2O_3 and NiO in the temperature interval of 150°C in the range of antiferromagnetic paramagnetic transition. A broad peak of magnetic susceptibility near the Neel temperature (T_N) allows for some uncertainty so that the unique procedure for determination of T_N should be defined. Such procedure is defined in this paper. When it is applied to Cr_2O_3 and NiO we obtain $T_N=(307\pm0,2)$ K and T_N = (522,5 ± 0,2) K, respectively.

INTRODUCTION

Numerous examples show that the magnetic susceptibility in the range of antiferromagnetic - paramagnetic phase transition has a broad peak which further increases in breadth if measurements are not performed on a monocrystal but on a polycrystalline sample (e.g./1,2,3/) Due to the anisotropic nature of monocrystals, at least two separate experiments can be done enabling the unique determination of a transition temperature (Neel temperature, T_N).

Behaviour of magnets in the range of phase transition and thus, the phase transition temperature depends on a number of factors, i.e. presence of impurities, domain structure, the size of crystal grains, previous magnetic and thermal treatment, and so forth. A certain disagreement of data on the phase shift temperature to be found in literature, can only partly be accounted for these features of real samples of magnets. This disagreement of data for T_N is, at least for the pure enough samples, due to some uncertainty in the procedure for transition temperature definition on the basis of a broad maximum.

The problem of defining T_N occurs during the investigation of transition metals magnetic oxides. This paper presents the procedure for its solution.

EXPERIMENT

Magnetic susceptibility of high purity (99,998%, Koch-Light) powdery samples of Cr_2O_3 and NiO was measured. It was measured by Gouy method. An electromagnet with a cylindrical pole caps of 15 cm in diameter was used. Measurement were performed at various maximum field intensities in the gap of a magnet ranging from 4 to 8 kG. These measurements were performed with the average error of about 0,7%. Let us note that force methods for the measurement of susceptibility require application of nonhomogenous fields so that in the case when susceptibility depends on the field intensity, these measurements enable determination of the effective susceptibility that depends on the function by which the field change along the sample is presented.

In the above mentioned experiments the sample temperature was regulated by specially constructed thermostats. For measurements in the temperature range up to 160°C we used a glass thermostat coated by asbestos and Al-foil in which the temperature regulation was obtained by glycerine flow. A quartz thermostat coated by asbestos and Al-foil in which the temperature was regulated by a series of heaters made out of alumel was used for measurements performed in the temperature range up to 350°C. Temperature was measured by chromel - alumel thermocouple which was placed in a referent sample placed in the thermostat. The sample temperature was constant along the length and during the measurement with the experimental error less than 0,1%.

EXPERIMENTAL RESULTS

Figs. 1. shows dependence of the magnetic susceptibility χ on temperature T obtained for various field intensities of Cr_2O_3. Figs. 2. presents the same data for NiO.

Figs. 1. shows that the values of magnetic susceptibility for Cr_2O_3 do not, while the values of χ for NiO alter with a change of H. However, at the same time it is determined that curves $\chi(T)$ for different H are not displaced in the temperature scale. The latter fact justifies this type of measurements for the determination of magnetic susceptibility.

RESULTS ANALYSIS

The experimentaly determined dependences $\chi(T)$ point out the essence of the problem of T_N definition. The curve maxima lie significantly above the values of T_N given in literature as determined by

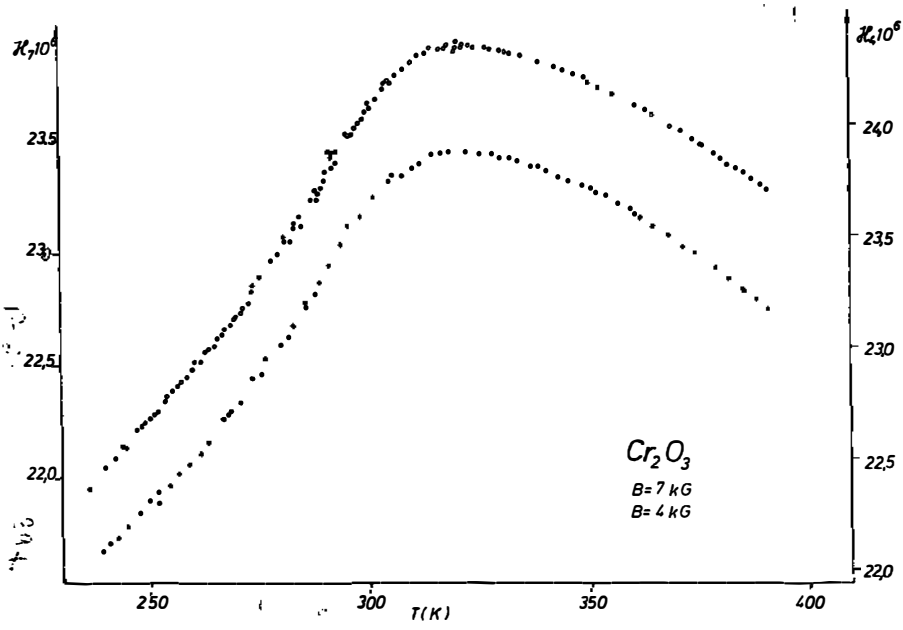

Fig. 1.

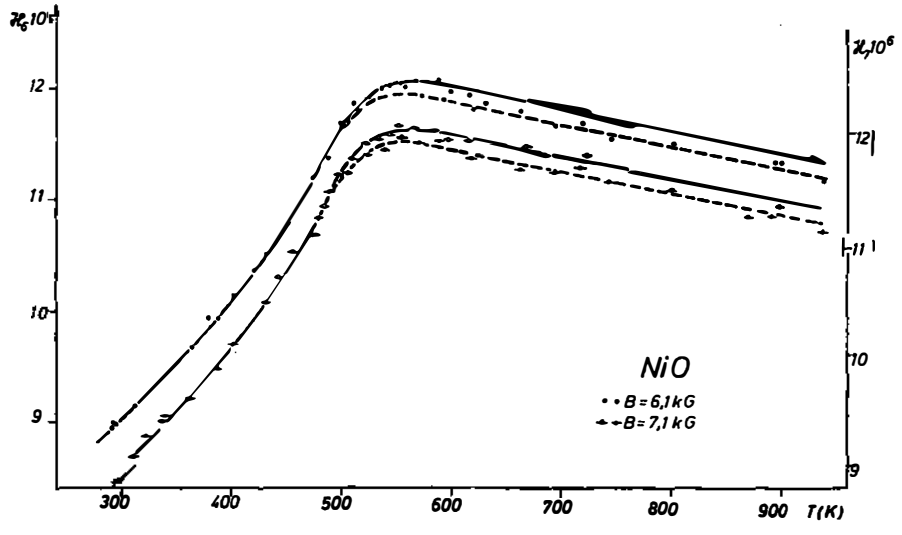

Fig. 2. Dotted line: data for first two cycles of measurements; full line: data for last two cycles of measurements

calorimetric, neutronographic and other methods. In the case of diffuse phase transitions existing in polycrystalline materials, transition temperature can be defined according to the position of the inflection point (3). Comparison with data given in literature indicates that these values lie too low.

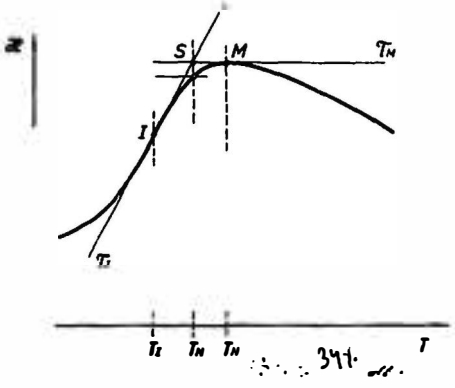

Fig. 3.

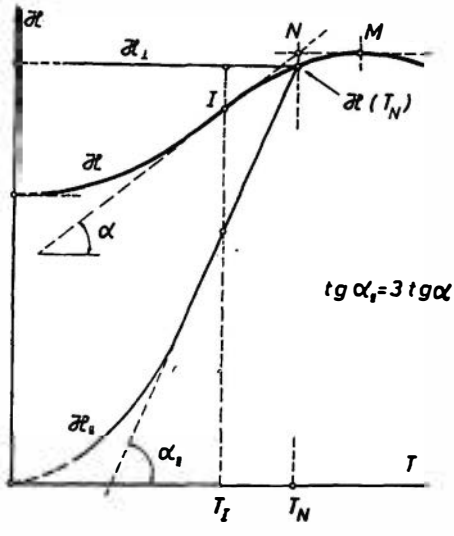

Fig. 4.

Fig. 3. illustrates the procedure we used in determination of T_N. This temperature is defined by the position of the cross point of two tangent of (T): the horizontal tangent that passes through the maximum of the curve and the tangent that passes through the inflection point of the curve. This procedure yields:

for Cr_2O_3 $T_N = (307 \pm 0{,}2)$ K

for NiO $T_N = (522 \pm 0{,}2)$ K

If these values are compared with those given in literature we obtain:

Cr_2O_3 . Data for T_N lie in the temperature range from 492 to 647 K /5,15/ while the greatest number of recently obtained data group in the interval from 523 K /16,23/.

Without going into a deeper analysis of the above mentioned data obtained by other authors, due to a lack of space, let us note that there is an excellent agreement of the results of out measurements with the above listed ones.

The applicability of this procedure on other physical systems is a question which may be posed. However, its application on neutronographic data for $CsMnFeF_6$ taken from literature (/24/, Fig. 1), proves the correctness of the procedure described.

Position of the cross point of the vertical line N-T_N and the curve $\chi(T)$ should yield a value for $\chi(T_N)$. This can be concluded on the basis of qualitative comparisons with figures of $\chi(T)$ given for monocrystals /1,2/ as well as with the position of $\chi(T_N)$ values used in the theory of phase transition /25/. This fact points out the possibility for qualitative testing of the correctness of the procedure applied. Molecular field theory (MFT) for magnetic susceptibility yields /3/:

$$\chi(T) = \frac{2}{3}\chi_{\perp} + \frac{1}{3}\chi_{\parallel}(T) \qquad (1)$$

where $\chi_{\perp}$ = const is normal and $\chi_{\parallel}$ is a parallel antiferromagnetic susceptibility.

According to MFT for $T = T_N$:

$$\chi(T_N) = \chi_{\perp} = \chi_{\parallel}(T_N)$$

At the same time, $\chi_{\parallel}$ alters with a change of temperature so (Fig.4) that near T_N it can be approximated by a straight line. According to (1) $d\chi_{\parallel}/dT = 3\,d\chi/dT$ what enables the approximate graphic construction and determination of χ for $T = T_I$. If on the basis of this construction χ_I and χ_{II} for T_I are determined, and then $\chi(T_I)$ calculated according to /1/ for both Cr_2O_3 and NiO, we obtain values that are equal to the experimentally determined value for $\chi(T_I)$ within the limits of experimental error.

This can be taken as a supplementary argument to justify the application of the procedure suggested.

CONCLUSION

The procedure suggested for determination of T_N of polycrystalline samples enables magnetic phase transition investigation, which had formerly been performed on monocrystals only, to be performed on large number of different substances because a difficulty connected with monocrystal obtainment is in such a way eliminated. Further

applications of this procedure on phase transition investigations shall soon be investigated and reported on.

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