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INVESTIGATION OF MAGNETIC SUSCEPTIBILITY OF HEMATITE IN THE REGION OF HIGH TEMPERATURE MAGNETIC PHASE TRANSITION

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This paper presents measurement results of magnetic susceptibility of high purity (>99,998%) alpha Fe_2O_3 in the temperature range from 300 to 100 K. The existence of a magnetic phase transition lying at 939 K is determined on the basis of these measurements.

INTRODUCTION

The hamatite, alpha Fe_2O_3, has been a subject of numerous investigations due to its highly interesting magnetic properties (e.g./1/). The linear antiferromagnetic of about 1000 K becomes a weak ferromagnet (antiferromagnet with canted sublattices) at the temperature of 260 K. In a strong magnetic phase, weak ferromagnetism is maintained to the highest temperatures. The theory explaining such behavior of hematite is developed /2/.

However, there are some disagreements among the authors as regards the magnetic phase transition of hematite in paramegnetic state. According to one group of authors, with the increase of temperature a weak ferromagnetism disappears first (Curie temperature, T_C) and the hematite becomes a linear antiferromagnet, and then, at a somewhat higher temperature there is a transition into a paramagnetic phase (Neel temperature, T_N) (e.g. /3/). But according to another group of authors, weak ferromagnetism disappears simultaneously with antiferromagnetism, i.e. there is only one magnetic phase transition (e.g. /4/.

The investigation of high temperature magnetic phase transition of hematite is performed by means of various mathods: neutronographic /5/, dilatometric /6/, method of differential thermal analysis /4/, method of Mössbauer spectroscopy /3/ as well as by the methods of classical magnetic measurements /5/. These, as well as other measurements performed later on by means of the same methods /8-12/ show that temperature, i.e. temperatures of phase transition, lie, i.e. lies in the range of 920-998 K.

The temperature of magnetic phase transition is determined to a certain extent by real features of samples investigated; it depends on whether a monocrystalline or polycrystalline sample is investigated. It also depends on the chemical composition (deviation from the stoechiometric ration and the presence of impurities), structure defects, and previous thermal, i.e. magnetic treatment /13-15/ as well as on the temperature magnetic hysteresic (TMH) which is very significant for hematites /16/. Still, if investigations are performed on pure enough samples, deviations in measurement results should not be significant; but in case they are, they should be explained especially if different results are a consequence of application of different methods.

This paper presents the results of our investigation of high temperature magnetic transition of hematites.

EXPERIMENT

The investigation is performed by measurement of magnetic susceptibility by Gouy method. Measurements are done on a powder sample of high purity (≥ 99,998%, Koch Light) alpha Fe_2O_3. The device described in /17/ is used.

Experiment comprised measurements of the dependence of magnetic susceptibility χ on temperature T for three different maximum intensities of magnetic field in the gap of electromagnet: H=4,1; 5,1 and 6,1 kg. Such experiments are performed in the nonhomogeneous magnetic field, so that the appropriate measurements yield values of the effective susceptibility /17/.

EXPERIMENTAL RESULTS

Figs. 1 and 2 present measurement results of χ (T) for hematite. Fig. 1 shows results of the first measurement at H=6,1 kg. It is evident that the curve of the first heating lies significantly below the one for the first cooling. Such behavior of hematite is typical for TMH of the first kind /16/. This effect is eliminated by cyclic thermal treatment: the heating curve "climbs" untill it overlaps the cooling curve and measurement results become reproducive.

Fig. 2 presents measurement results of χ (T) after cyclic thermal treatment; every curve representing a reproducive dependence χ(T) in a given field. It can be noticed that all three curves flow into one (with a possible error being significantly below susceptibility measurement error and the error of temperature definition).

The form of curves obtained suggests that magnetic phase transition corresponding to Curie temperature, e.e. disappearance of weak ferromagnetism, is determined by these measurements. Repeated measurements performed at temperature of up to 1000 K do not indicate the existence of the second phase transition.

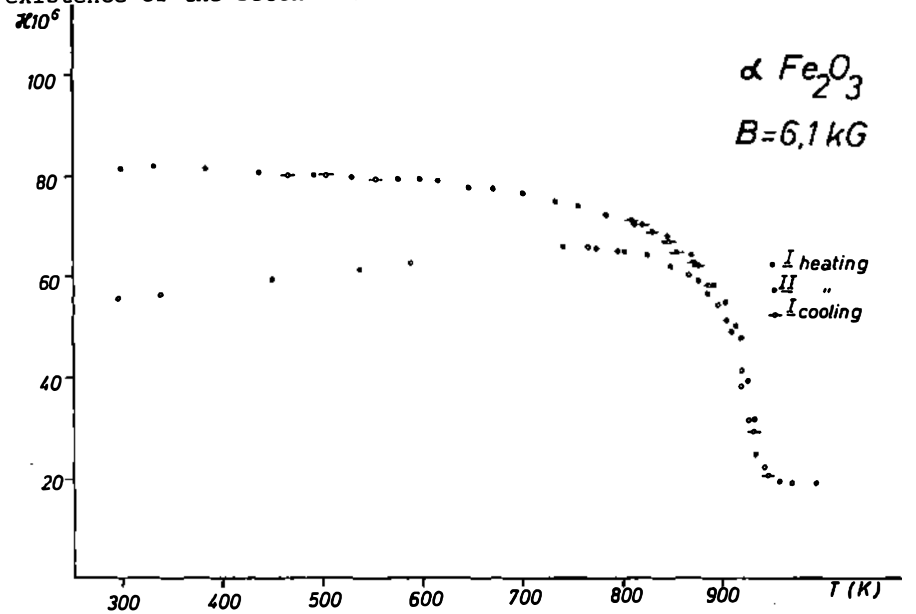

Fig. 1.

This result is checked by DSC calorimetry (Dupont commercial device) and an interesting effect is obtained. During heating, the first experiment yields two peaks in the temperature range below 970 K, the first of them being stronger and the second one weaker. The peaks are spaced at about 20 K. Repeated experiments yield only the first peak, the second one not appearing at all. In that way the second high temperature transition in hematites becomes a very interesting problem demanding further investigations.

Note that there is an opinion in literature /1/ that magnetostatic experiments, like ours, do not permit observation of the antiferromagnetic - paramagnetic phase transition due to a small anisotrophy of hematite in basal plane. It is difficult to tell if that is a reason for the negative result of the experiment. It should be emphasised that in our experiments the susceptibility determination error is about 5.10^{-8}CGS what means that the effect, if it exists, should cause cause changes of χ (T) lying below this limit.

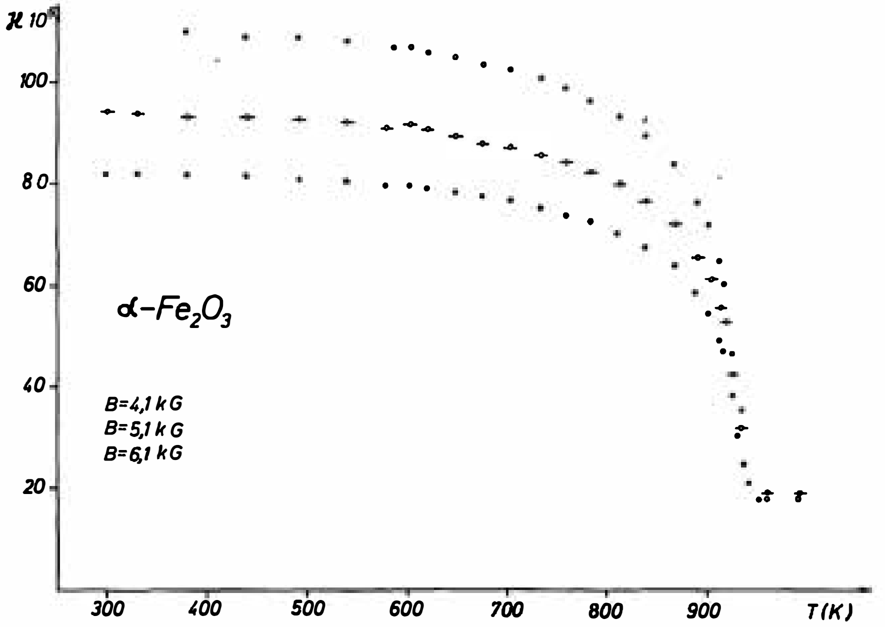

Fig. 2.

ANALYSIS OF RESULTS

Another problem arising in these experiments deals with the Curie temperature definition. The form of curve χ (T) allows for some uncertainties. Without going into details, we may mention that here there are difficulties of the same nature as those in the investigation of magnetic phase transition in a pure antiferromagnet /17/. The solution of such problems in the case of NiO and Cr_2O_3 /17/ suggests that a similar procedure should be applied in our case. The principle of the procedure suggested is explained in Fig. 3. Transition temperature is determined by the position of the cross point for the tangent on inflection point of the curve with the horizontal tangent of the curve drawn for the part of the curve corresponding to the paramagnetic phase restablished. In our case this procedure yields

$$T_C = (939 \pm 2)\ K.$$

It is interesting that this value corresponds (with the accuracy of 0,5 K) to C(T) curve minimum, C being the parameter of hematite unit cell /12/. Dependence C(T) is determined by the method of high temperature x - ray diffractometry, while the measurements are performed on samples made out of a substance which is investigated in our experiments.

CONCLUSION

By measurement of the effective magnetic susceptibility in the function of temperature, the investigation of high temperature magnetic transition of hematite is performed. It is determined that the reproducive magnetic measurements enable determination of the Curie temperature. The procedure for T_C determination on the basis of experimental data is suggested. This experiment has not confirmed the existence of a distinct, antiferromagnetic transition.

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