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LATENT HEAT STUDIES OF MAGNETIC TRANSITIONS IN DILUTE CrFe AND CrSi ALLOYS

H.U. Åström, G. Benediktsson and K.V. Rao

*Department of Solid State Physics, Royal Institute of Technology,
S - 100 44 Stockholm, Sweden*Résumé.- La constitution du diagramme des phases magnétiques CrFe et CrSi dilué et l'ordre des transitions ont été étudiés par des mesures calorimétriquesAbstract.- The constitution of the magnetic phase diagrams for dilute CrFe and CrSi and the order of the transitions have been investigated by calorimetric measurements.

The magnetic properties of chromium are very sensitive to alloying and have been the object of extensive studies in the past years. There are, however, two alloying elements causing a behaviour differing markedly from that of other chromium alloys. For dilute CrFe there have been observed sharp first order changes in the magnetic susceptibility and in the electrical resistivity at the Néel temperature (T_N) for concentrations between 2 and 4 at% Fe. For CrSi similar step-like effects in susceptibility and resistivity have been reported for alloys in the concentration range between 1 and 3 at% Si. Discontinuous changes in the thermal expansion at T_N have also been observed for both alloys in these concentration ranges.

Several investigations in order to determine the magnetic phase diagrams of CrFe and CrSi have been reported. The results have, however, in some cases lead to mutually inconsistent interpretations and there is still some uncertainty about the details of these phase diagrams. The present investigation was undertaken in order to study the magnetic transitions in CrFe and CrSi by measurements of the energy changes connected with the transitions. From these results information on the constitution of the magnetic phase diagrams and on the order of the transitions has been obtained.

Three CrFe samples with compositions 1.20, 2.22 and 3.35 at% Fe and four CrSi sample of 0.98, 1.39, 1.67 and 1.85 at% Si have been investigated. The samples were spark cut to a suitable size and carefully annealed before the calorimetric measurements for which a differential technique similar to that previously applied to the study of magnetic

transitions in Cr and some Cr-alloys [1] was used. A typical result is seen in figure 1 showing the rate of change of energy, dQ/dt , versus temperature curve (the temperature changing linearly with time) for the Cr-2.22 at% Fe sample.

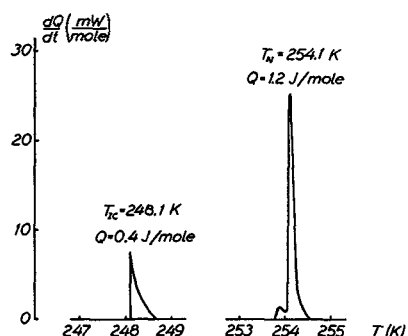


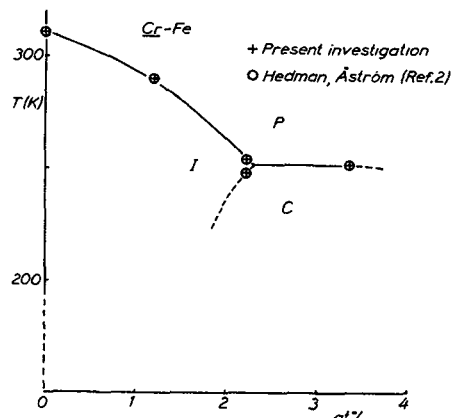
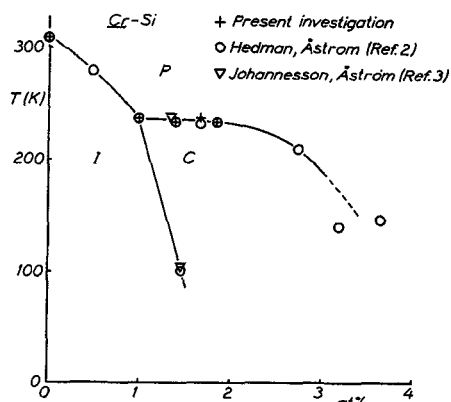
Fig. 1 : The rate of change of energy (dQ/dt) versus temperature (time) for the magnetic transitions in Cr-2.22 at% Fe.

Two well separated peaks with maxima at 254.1 and 248.1 K were obtained in this case indicating two different transitions. The peaks are well localized in temperature, the half-value width being some tenths of a degree, and are due to the first order nature of the transitions. Integration with respect to time gives the latent heat of the transitions, 1.2 and 0.4 J/mole respectively. In table 1 temperatures and latent heats (Q) of the transitions for the alloys investigated are collected. For two samples, Cr-1.39 at% Si and Cr-3.35 at% Fe, the dQ/dt curve was split in 3-4 smaller peaks within a temperature interval of a few degrees. This is probably due to concentration inhomogeneities in the samples. For these cases, T_N is chosen as the temperature of the maximum of the largest peak, while the Q -values are the total energy of the individual peaks of the transition.

Table 1

Cr	Transition temperatures (T_N) and latent heats (Q)	
	T_N (K)	Q(J/mole)
Cr	311	1.1 ± 0.1 (from Ref. 1)
Cr-0.98Si	237	0.4 "
Cr-1.39Si	234	2.5 "
Cr-1.67Si	237	4.2 "
Cr-1.85Si	234	5.4 "
Cr-1.20Fe	291	-
Cr-2.22Fe	254	1.2 "
Cr-2.22Fe	248	0.4 "
Cr-3.35Fe	252	12.6 "

In figures 2 and 3 the magnetic phase diagrams of CrFe and CrSi have been drawn using the T_N -values from table 1 and transition temperatures obtained from magnetic susceptibility /2/ and thermal conductivity/3/ measurements on CrFe and CrSi made in this laboratory. The results are in principal agreement with recent determinations of the magnetic phase diagrams for CrFe /4/ and CrSi /5/. According to neutron diffraction investigations /6,8/ in both systems for concentrations below the triple point of the phase diagrams there is a transition between the paramagnetic state (P) and the antiferromagnetic incommensurate spin-density-wave state (I) at T_N while for concentrations above that of the triple point the transition is between P and the commensurate antiferromagnetic state (C). For the P-C transition in both systems a latent heat was measured. The transition is therefore of first order type. This is also true for the P-I transition for concentrations close to the triple point, while for lower concentrations in the CrFe system the absence of a latent heat in this sample indicates that the transition probably is of second order. The transition between the I and C state measured for the Cr-2.22 at% Fe sample is also of first order. For CrSi we have not succeeded in obtaining any accurate determination of a latent heat corresponding to the I-C transition. For Cr-1.39 at% Si a small peak at about 100 K could possibly be resolved. The I-C transition in CrSi might therefore have a first order character, although very weak.

Fig. 2 : Magnetic phase diagram for CrFe Fig. 3 : Magnetic phase diagram for CrSi

The magnetic phase diagram of CrFe has recently been calculated with a two band model taking the effects of impurity scattering and magnetoelastic energy into account /9/. The diagram agrees in principle with that of figure 2. For CrSi no similar calculation has been made. There has not been any attempt either to calculate the latent heats of the transitions in CrFe and CrSi from first principles. An estimate of the latent heat can, however, be obtained with the Clausius-Clapeyron equation. From experimental determinations of the change of T_N with pressure /10,11/ and of the thermal expansion /5,6/ latent heats of 10 J/mole for CrFe and 7 J/mole for CrSi for the highest concentrations used in this investigation are obtained in reasonable agreement with the calorimetrically measured values.

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