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Letter

On the magnetic phase diagram of dilute Cr–Au alloys

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The effects of small quantities of different solutes on the magnetic properties of chromium, particularly the effects of such solutes on the magnetic phase diagrams of Cr alloys, are currently still of considerable interest [1, 2]. A large variety of solutes in Cr have been studied in the past [2]. In the case of dilute Cr–Au alloys we are, however, aware of only one previous study of the magnetic phase diagram, namely that of Eroglu *et al.* [3] who determined the magnetic phase diagram of alloys containing 0.27, 0.54 and 0.60 at.% Au through electrical resistivity measurements. These authors observed a linear decrease in the Néel temperature, T_N, at a rate of -32 K/at.% Au added. Unfortunately they did not report on any analysis of the homogeneity or concentrations of their alloys or on any study to determine whether their alloys were single phase solid solutions. In this respect their work is therefore incomplete.

A re-examination of the magnetic phase diagram of dilute Cr–Au alloys is reported here. Electron microprobe and X-ray powder analyses were made of the samples to determine homogeneity, solubility limits and the presence of other phases in the alloys. Magnetic transition temperatures were obtained from velocity of sound (v) measurements. It is known [4] that such measurements are better suited than resistivity measurements to monitor the magnetic transition temperatures in spin density wave (SDW) antiferromagnets such as Cr and its dilute alloys. The reason for this is that magnetic phase transitions which are sometimes undetectable [4, 5] in resistivity measurements of these alloys are usually clearly depicted in v measurements.

Cr–Au alloys containing 0.2, 0.4, 0.6, 1.0 and 1.5 at.% Au were prepared by arc melting appropriate quantities of 99.999% pure Cr and 99.95% Au in a purified argon atmosphere, on a water-cooled copper hearth. The alloys were melted repeatedly, then crushed and remelted five times. The crushing and remelting processes were repeated three times for each alloy to ensure good homogeneity. Longitudinal velocity of sound (10 MHz) measurements were made on the as-cast alloys as well as on alloys that were annealed for 3 days at 1000 °C in an evacuated atmosphere partially filled with pure argon. The experimental techniques have been described previously [4].

Figure 1 shows v–T curves for 0.2, 0.4, 0.6 and 1.0 at.% Au in Cr, representing typical examples of the measurements. The v–T curves of the Cr–Au alloys were very similar to that of polycrystalline pure Cr, for which the corresponding curve is shown in Fig. 2. Two anomalies are observed on the v–T curve of pure Cr (Fig. 2). The small anomaly at low temperatures, not usually observed in resistivity measurements, occurs at $T_{sf}=120\pm3$ K and signifies the transverse to longitudinal SDW transition on cooling, while the deep minimum at higher temperatures is associated with T_N. $T_N=313\pm1$ K for Cr is taken at the temperature of this deep minimum. Anomalies, very similar to those in pure Cr, are also observed on the v–T curves of the Cr–Au alloys in Fig. 1. For Cr+0.2 at.% Au, Cr+0.4 at.% Au and Cr+0.6 at.% Au these anomalies occur at $T_{sf}=123\pm3$ K, 123 ± 3 K and 123 ± 3 K respectively and at $T_N=312\pm1$ K, 312 ± 1 K and 312 ± 1 K respectively. For the other Cr–Au alloys only the anomaly at T_N, similar to that of pure Cr, was observed. Values of $T_N=312\pm1$ K and 308 ± 3 K were obtained for 1.0 at.% and 1.5 at.% Au respectively in Cr. Measurements on as-cast and annealed samples give very similar results, indicating no effect of heat treatment on T_N.

The values obtained for T_{sf} and T_N of the Cr–Au alloys are essentially the same as that of pure Cr, showing within experimental error no effect on T_N when alloying Cr with Au. This is in sharp disagreement with the work of Eroglu *et al.* [3] who observed a linear decrease in T_N at a rate of -32 K/at.% Au added.

In seeking a reason for the discrepancy between the previous and the present measurements, we undertook an investigation of the homogeneity, solubility limits and the presence of other phases in our alloys. X-ray powder photographs of the 1.5 at.% Au sample revealed the presence of both b.c.c. Cr lines and f.c.c. Au lines with no other phases present. Electron microprobe analyses on the samples show that they consist of precipitates, highly rich in Au embedded in a matrix which is highly rich in Cr. These precipitates seem to be concentrated on grain boundaries in the matrix. The

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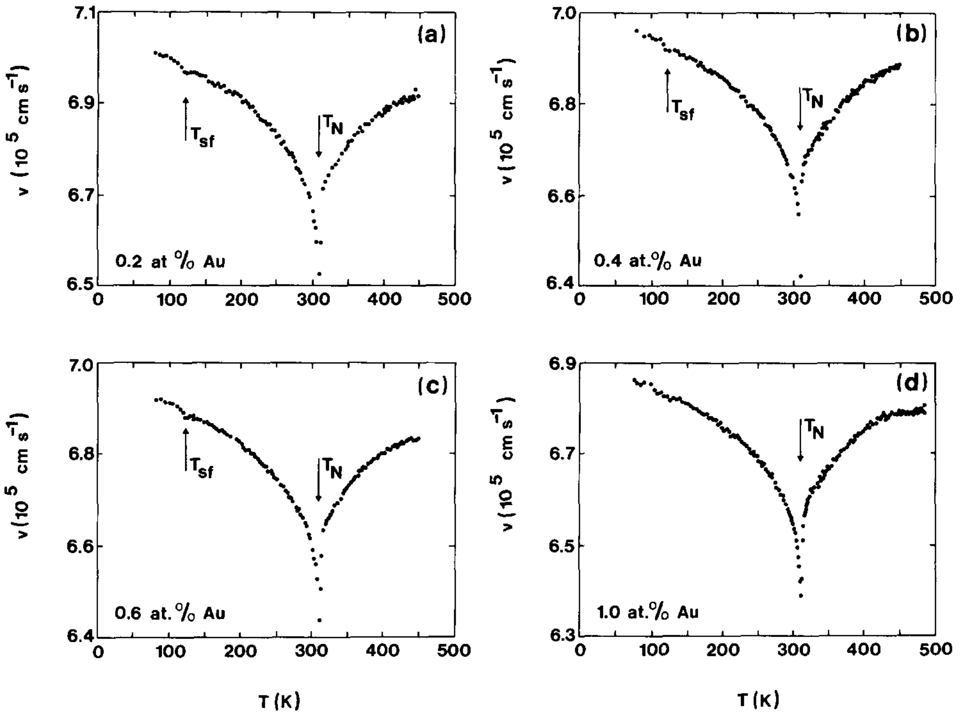

Fig. 1. Temperature dependence of the longitudinal velocity of sound v for (a) Cr+0.2 at.% Au (as-cast); (b) Cr+0.4 at.% Au (as-cast); (c) Cr+0.6 at.% Au (annealed); (d) Cr+1.0 at.% Au (as cast). The transverse to longitudinal spin density wave transition temperature T_{sf} and the Néel temperature T_N are shown by arrows.

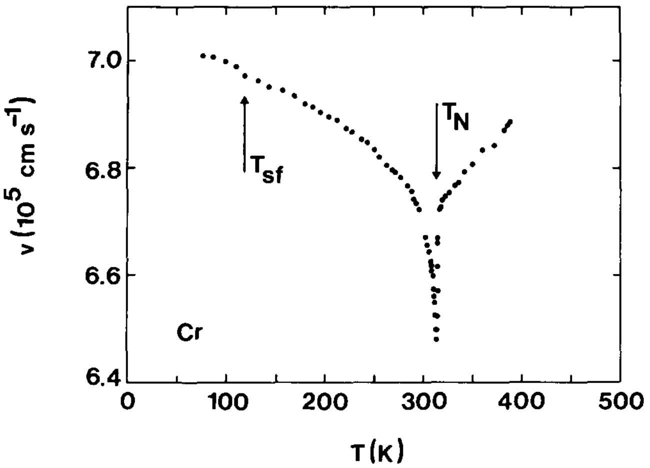

Fig. 2. Temperature dependence of the longitudinal velocity of sound v for polycrystalline pure Cr.

Au concentration in the matrix was found to vary considerably, in a random fashion, and to reach a maximum of about 0.2 at.% Au on going from point to point in each of the samples. This was also found for the Au concentration in different Au-rich precipitates of the same sample. The analyses show similar behaviour in as-cast and annealed samples and the conclusion is that we were not able to obtain homogeneous solid solution of Cr–Au alloys, notwithstanding all our technical efforts to prepare such alloys. This conclusion is in accordance with the findings of Raub [6] who studied the Au–Cr phase diagram and concluded that the solubility of Au in Cr is less than 0.05 at.% Au. It is, however, in disagreement with an earlier phase diagram, compiled by Hansen [7] from much earlier measurements, which suggests a solubility limit as high as 6 at.% Au.

The fact that Au does not form solid solutions in Cr for the concentrations studied, but rather forms precipitates, accounts for the observation that the addition of Au to Cr gives transition temperatures very similar to that of pure Cr. It is then difficult to explain the discrepancy between the present measurements and that of Eroglu *et al.* [3], as the same preparation techniques were used in both cases.

We conclude from X-ray, electron microprobe and velocity of sound measurements that Au does not form homogeneous solid solutions in Cr for the concentrations studied. The magnetic transition temperatures found in Cr–Au alloys containing up to 1.5 at.% Au are essentially similar to those observed in pure Cr, in contrast with the magnetic phase diagram obtained by Eroglu *et al.* [3].

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References

1 J. G. Booth, M. M. R. Costa, J. Rodriquez-Carjaval and J. A. Paixao, *J. Magn. Magn. Mater., 104–107* (1992) 735.

2 E. Fawcett, H. L. Alberts, V. Yu. Galkin, D. R. Noakes and J. V. Yakhmi, *Rev. Mod. Phys.,* in press.

3 A. Eroglu, S. Arajs, C. A. Moyer and K. V. Rao, *Phys. Status Solidi B, 87* (1978) 287.

4 H. L. Alberts and J. A. J. Lourens, *Phys. Rev. B, 29* (1984) 5279.

5 A. Baran, H. L. Alberts, A. M. Strydom and P. de V. du Plessis, *Phys. Rev. B, 45* (1992) 10473.

6 E. Raub, *Z. Metallkde., 51* (1961) 290.

7 M. Hansen, *Constitution of Binary Alloys,* McGraw-Hill, New York, 1958, p. 197.