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RESISTANCE MAXIMUM IN GOLD-COPPER ALLOYS WITH IRON IMPURITIES

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Abstract.- We have measured the electrical resistivity maximum in $\text{Au}_{1-x}\text{Cu}_x$ (x = 5, 10, 15 and 20 at.% with 0.1 at. % Fe impurities. This maximum lies between 2-4 K for the host alloys studied and indicates the coexistence of Kondo and spin glass effects in these systems.

1. INTRODUCTION.- The study of resistance maximum in a dilute magnetic alloy is a very important one, because it leads to our understanding of the nature of interactions between impurity local moments. Ternary alloys of Cu-Au(Fe) have been found to be interesting because these systems when cooled down to low temperatures (\textdegree{}K), the single impurity Kondo effect is greatly influenced by the impurity-impurity (RKKY) interactions giving rise to experimentally observed resistance maximum at a temperature $T_{\text{max}}$.

2. RESULTS.- In this paper we report the study of this resistance maximum on $\text{Au}_{1-x}\text{Cu}_x$ (x = 5, 10, 15 and 20 at.%) alloys with 0.1 at. % Fe impurities. While the earlier measurements /1/ were carried out on Cu rich hosts (x > 16 at. %), our studies are confined to the Au rich alloys. These alloys were studied in the form of foils, cold rolled to about 10 micron thickness, in a temperature range of 2-100 K. Temperatures were measured with a carbon resistor (calibrated from Cryo-Cal) with an accuracy of $\pm$ 30 mK at the lowest temperatures studied. A dc constant current source (Keithley model 225), stable to about 1 part in $10^5$ was used. Using the standard four probe technique, voltages were measured with a dc potentiometer. Figure 1 shows the result of our electrical resistivity measurements. The lattice resistivity in these plots have not been subtracted. Figure 2 shows the values of $T_{\text{max}}$ obtained for the alloys studied, along with those of Star /1/. $T_{\text{max}}$ decreases with increasing Cu concentration and within this narrow concentration range studied by us, our points roughly lie on a straight line with slope $\frac{dT_{\text{max}}}{dx} = -0.07$ K/at.%Cu. However, we know that such a simple variation of $T_{\text{max}}$ with x is not of general validi-

3. DISCUSSION.- The understanding of this variation of $T_{\text{max}}$ is rather difficult to explain quantitatively. It has been found from the studies by Loram et al. /3/ that adding Cu atoms to Au(Fe) alloys lead to an increase in $T_K$ (Kondo temperature) all the way from 0.24 K for Au(Fe) to 24 K for Cu(Fe). An increase of $T_K$ would imply an increase of the impurity-conduction electron spin coupling parameter J in RKKY based theories /4-6/ and this would consequently predict an increase of $T_{\text{max}}$ with Cu concentration in Cu-Au(Fe) alloys. However, such theories are not found to be adequate to explain
the resistance maximum behaviour even in simple systems like Au(Fe).

![Graph](image)

Fig. 2: Temperature of resistivity maximum against Cu concentration for Al$_{1-x}$Cu$_x$(Fe) alloys. □: ref. /1/ ; △: present work; ○: $T_{\text{Max}}$ against average volume normalized to pure Au from high pressure data on Au (0.13 at.%Fe) /7/. 

A detailed calculation by Larsen /2/, taking both Kondo and RKKY interactions into account, have been able to show that there is no simple relationship between $T_{\text{Max}}$ and $J$, but depends in a complex manner on both $T_K$ and the mean RKKY interaction energy $\Delta_{\text{RKKY}}$.

Apart from this magnetic impurity problem, possible local atomic clustering of Fe atoms with Cu in these ternary systems, makes the analysis even more difficult. Magnetization measurements /8/ on Cu(Fe) alloys with 100 ppm Fe impurities indicate the presence of giant moments, in addition to single and Fe-Fe pair moments and these clusters seem to persist /9/ even to the lowest temperatures of 0.012K so far studied.

We find that these metallurgical inhomogeneities enhances the residual resistivity in Al$_{1-x}$Cu$_x$ alloys very much, due to increase in defect scattering, and we find it to be about 4 $\mu\Omega$.cm as we go from Au to the Cu$_3$Au$_{95}$ alloy. Attempts are being made at present to understand these ternary alloys on the basis of Larsen's theory /2/ in a more accurate manner, taking these view points into account.

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