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LOW TEMPERATURE RESISTIVITIES OF AMORPHOUS $Fe_xNi_{80-x}B_{20}$ ALLOYS

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The resistance minimum is one of the most unusual features of the amorphous ferromagnets. Recent magnetoresistivity measurements[1,2] seem to rule out any explanation of this phenomenon based on a single impurity Kondo effect. Furthermore the disappearence of the resistance minimum on recrystallization[3] clearly shows its structural origin.

Here we present the first systematic study of the resistivity of $Fe_xNi_{80-x}B_{20}$ alloys (where X varied in steps of 10) in the temperature range 1,5-50K. Together with six $Fe_xNi_{80-x}B_{20}$ alloys we also measured $Fe_{75}B_{25}$, $Fe_{80}B_{18}Si_2$ and $Fe_{20}Ni_{60}B_{19}P_1$. All these alloys are ferromagnets with similar Curie temperatures well above room temperature.

The relative changes in the resistivity $\frac{\Delta\rho}{\rho_{min}}$ of all our alloys are shown in Fig.1. As the low temperature resistivities of all our alloys were the same within the experimental error ($\rho_{4.2}=110\pm6\mu\Omega cm$). $\frac{\Delta\rho}{\rho_{min}}$ also represents well the absolute resistivity variation. Except for $Fe_{30}Ni_{50}B_{20}$ and $Fe_{20}Ni_{60}B_{19}P_1$ the overall resistivity variations and T_{min} values of all our samples are rather similar. As these two alloys are also the most difficult to prepare there is a possibility of a small degree of crystallization and therefore we will not discuss them further. Although the resistivity variations of the other alloys are similar there are also some differences. While the alloys with $X>50$ show a pure log T dependence, in the alloys with less iron there is a change in slope below about 4K. Before discussing our results in detail we briefly summarize the main results of the resistivity calculation for metallic glasses[4] based on the excitations of a two level system[5]. This calculation gives for the resistivity: $\Delta\rho = -A\ln(k_B^2T^2+\Delta^2)$ where A depends on the number of contributing sites and the strength of Coulomb interaction and Δ is the energy difference between the two atomic tunnelling states.

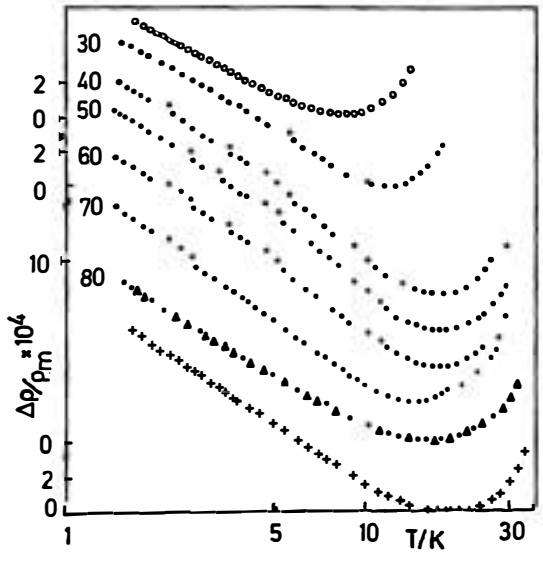

Fig.1. The relative changes in the resistivity $\frac{\Delta\rho}{\rho_{min}}$ vs log T. $\bullet Fe_xNi_{80-x}B_{20}$ alloys (numbers denote x), $\circ Fe_{20}Ni_{60}B_{19}P_1$, $\blacktriangle Fe_{80}B_{18}Si_2$ and + $Fe_{75}B_{25}$.

Thus we tried a fit of our resistivity data (from 1.5 to 15K) to $\Delta\rho = A \ln(1-\frac{T^2}{\Delta^2}) + BT^2$. Here a BT^2 term takes a care of the positive part of the resistivity (Fig.2) From a such fit we obtained Δ values ranging from 1,5-2K(for $X<60$) down to less than 0.3K (for $X>50$). However the accuracy of a such fit was never particularly good.

Because of that we also tried a fit to $\Delta\rho = C(\ln T/\theta)^2 + DT^2$. (The $(\ln T/\theta)^2$ variation agrees to some extent with the recent calculation[6] of the resistivity of amorphous alloys). We found that the resistivities of our alloys could be fitted rather better by that expression than by $-A\ln(1-\frac{T^2}{\Delta^2}) + BT^2$. However from a such fit we obtain θ values which vary from 0.1 to 0.04K.

The small values of Δ (and θ) which we obtain when applying the above expressions to our resistivity data cast some doubts as regards the validity of these calculations[4,6]. We note that a much bigger values of Δ were found in the insulating glasses[5]. Such a big difference in Δ values cannot be explained by a tunnelling of a single atom vs group of atoms type of arguments[4]. Also the way in which log T dependence is obtained in ref.4 does not seem to be quite correct. Apart from introducing a new degree of freedom for the electron the main difficulty with this calculation is that in order to distinguish between the two possible configurations of the tunnelling states, the electron must have a scattering time shorter than the tunnelling time, but the opposite inequality must be obeyed for the flips to give a rise to the resistance minimum.

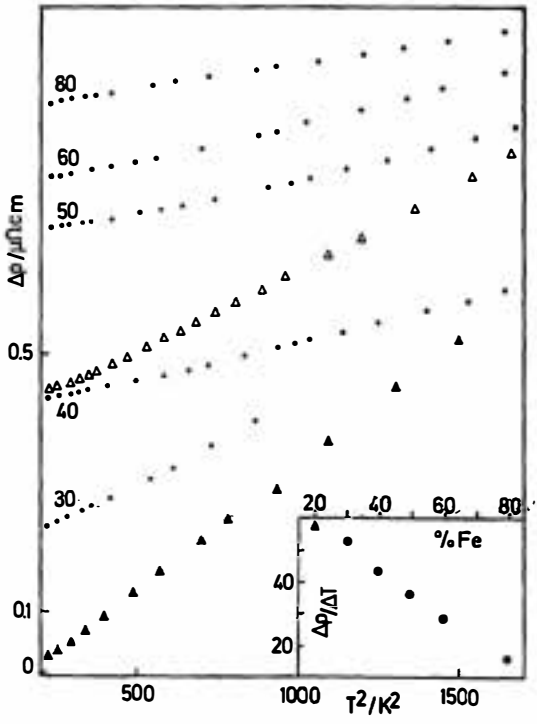

Fig.2. The positive parts of the resistivity of our alloys vs T^2
•$Fe_xNi_{80-x}B_{20}$ alloys (numbers denote x), Δ crystalline $Fe_{50}Ni_{50}$ alloy and ▲ $Fe_{20}Ni_{60}B_{19}P_1$ sample. In the inset room temperature coefficients of the resistivity (in nΩcm/K) vs X.

Returning to our data we note that the slopes of the negative resistivity parts slowly increase with decreasing X(X>30). We also note that the resistivities of $Fe_{80}B_{20}$ and $Fe_{80}B_{18}Si_2$ alloy overlap completely. On the other hand $Fe_{75}B_{25}$ shows stronger resistivity variation than $Fe_{80}B_{20}$. Finally in Fig.2 we show the positive contributions to the resistivity of all our alloys. Again a definite X dependence can be seen. (For the comparison also the resistivity of a crystalline $Fe_{50}Ni_{50}$ alloy is shown). Approximate T^2 resistivity variation is probably due to electron-electron scattering. In the inset to Fig.2 we show room temperature coefficients of the resistivity $(\frac{d\rho}{dT}/_{R.T.})$ for all our alloys. They show a rather strong dependence on X which may be due to band structure effects. All these X dependences indicate that the resistivity of amorphous magnet is strongly influenced by its magnetic state and is not purely structural effect. A more detailed discussion of X dependences is given elsewhere[7].

References

1) Cochrane R.W. and Strom Olsen J.O., J.Phys.F: Metal Phys.7(1977)1799
2) Marohnić Ž., Babić E. and Pavuna D. Phys.Lett.63A(1977)349
3) Babić E. and Marohnić Ž., J.Phys.C6(1978)948
4) Cochrane R.W., Harris R., Strom Olsen J.O. and Zuckermann M.J., Phys.Rev.Lett.35(1975)676
5) Anderson P.W., Halperin B.I. and Varma C.H., Phil.Mag.25(1977)1
6) Kondo J., Physica 848(1976)207
7) Babić E., Marohnić Ž. and Ivkov J.,Sol.St.Commun.(in press)