

MAGNETIC CONTRIBUTION TO THE RESISTIVITY OF AMORPHOUS

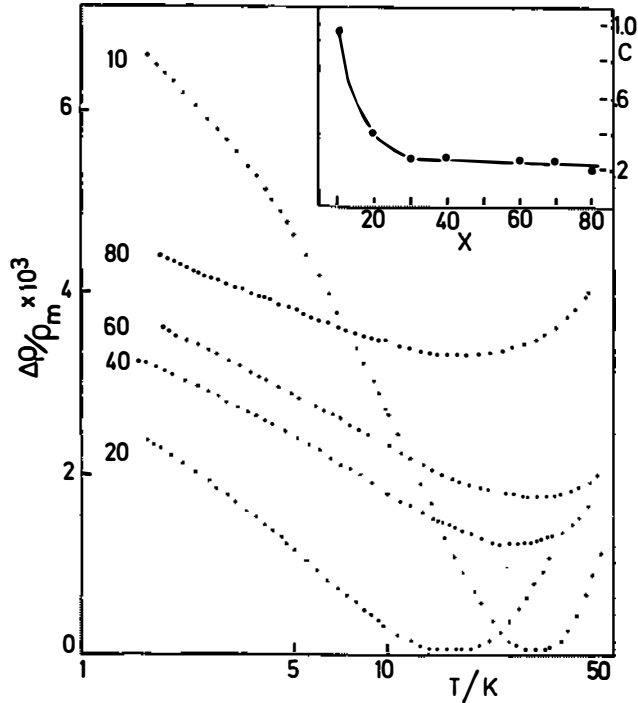
$\text{Fe}_x\text{Ni}_{80-x}\text{P}_{14}\text{B}_6$  ALLOYS

J. Ivkov, Ž. Marohnić, E. Babić, B. Pivac and J. Šubić

Institute of Physics of the University, Zagreb, Yugoslavia

A good deal of interest has lately been devoted to the investigation of the transport properties of amorphous alloys. Most of the work was concerned with the anomalous resistivity variation at the lowest temperatures. Namely in most of these alloys the resistivity decreases with increasing temperature leading to a resistance minimum situated usually around 20K. As such a resistance minimum also appears in amorphous ferromagnets it is interesting to see whether the magnetic state of the samples affects this phenomenon and more generally whether the magnetic contribution to the electrical resistivity of amorphous alloys is significant or not. Our investigation of the low temperature resistivities of  $\text{Fe}_x\text{Ni}_{80-x}\text{B}_{20}$  alloys<sup>2</sup> has shown rather little although systematic variation with X which is probably due to little variation in the magnetic properties of these alloys.

Here we present the results of systematic study of the amorphous  $\text{Fe}_x\text{Ni}_{80-x}\text{P}_{14}\text{B}_6$  alloys. This system was chosen because although similar to the former one its magnetic properties<sup>3</sup> vary much more dramatically with X. Thus for some of these alloys (low x values) Curie temperatures ( $T_c$ ) are in accessible temperature range so that one can easily investigate the changes in the resistivity due to ferromagnetic to paramagnetic transition. High accuracy resistivity measurements were performed on seven  $\text{Fe}_x\text{Ni}_{80-x}\text{P}_{14}\text{B}_6$  alloys with x varying in steps of 10. The details concerning the sample preparation and the actual technique of measurement are given elsewhere<sup>4</sup>. All the samples were measured from 1.5-50K and in some cases the resistivity was also measured down to the lowest as well as to higher temperatures. The results of the resistivity measurements on three alloys at the lowest temperatures ( $T \geq 0.05\text{K}$ ) are already reported<sup>5</sup> and will not be repeated here. Also a detailed analysis of the low temperature resistivities (1.5-50K) of all the samples will be given elsewhere<sup>4</sup> and therefore we discuss only their correlation with the magnetic properties.



**Fig.1. The relative changes in the resistivity  $\Delta\rho/\rho_{\min}$  for four  $\text{Fe}_x\text{Ni}_{80-x}\text{P}_{14}\text{B}_6$  alloys vs  $\log T$ . The numbers denote Fe content (x). In the inset the logarithmic slopes of the resistivity C (in  $\mu\Omega\text{cm}/\text{decade}$ ) vs x.**

The resistivity variations of four alloys which are typical for this system are shown in Fig.1. We plotted the resistivities normalized to their values at the temperature of the resistivity minimum ( $T_{\min}$ ). These values represent also well the absolute resistivities since the residual resistivities of all these alloys were approximately the same ( $\sim 140 \mu\Omega\text{cm}$ ). From Fig.1 can be seen that the increase in the resistivity below  $T_{\min}$  vary strongly with Fe content (x). This variation is more clearly seen in the inset to Fig.1 where the logarithmic slopes (C) of the resistivity below  $T_{\min}$  are plotted vs X for all our alloys. We note that this variation is the strongest for the alloys with X = 10 and 20 which have  $T_c$  well below room temperature. As the other properties of all these alloys are the same or vary very little with x we conclude that a substantial part of the anomalous low temperature resistivity of these alloys is of magnetic origin. Indeed

recent magnetoresistivity measurements<sup>6</sup> have shown that in  $\text{Fe}_{10}\text{Ni}_{70}\text{P}_{14}\text{B}_6$  about half of the increase in the resistivity below  $T_{\text{min}}$  is caused by the magnetic effects. The actual mechanism which causes this increase in resistivity is not clear at moment but it seems that the alloys in this range of concentration are on the border between a ferromagnetic and paramagnetic state. If this is so one would expect even stronger variation in the positive resistivity contribution<sup>4</sup> (above  $T_{\text{min}}$ ) due to crystal fluctuations. In the inset at top of Fig.2 we show the coefficient B of a positive resistivity term (which varies approximately as  $BT^2$ ) vs X. It can be seen that the coefficient B tends to a sharp maximum centered around X = 20 which indicates that below this concentration the alloys are not ferromagnetic.

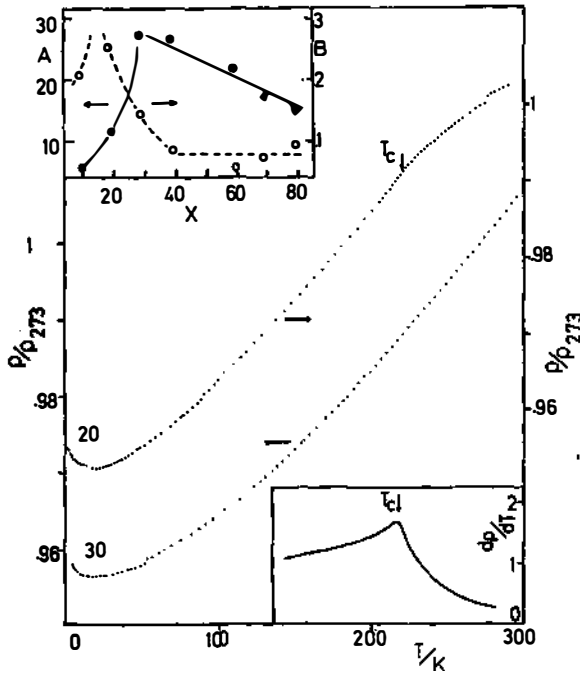


Fig.2. The relative resistivity variations of  $\text{Fe}_{20}\text{Ni}_{60}\text{P}_{14}\text{B}_6$  and  $\text{Fe}_{30}\text{Ni}_{50}\text{P}_{14}\text{B}_6$  alloys from 0 to 300K. Numbers denote Fe content. Inset at top: o the coefficients of a  $T^2$  term in resistivity B (in  $\text{n}\Omega\text{cm}/\text{K}^2$ ), • the room temperature coefficients of the resistivity A (in  $\text{n}\Omega\text{cm}/\text{K}$ ) vs Fe content X. Inset at the bottom shows temperature dependence of  $d\rho/dT$  of  $\text{Fe}_{20}\text{Ni}_{60}\text{P}_{14}\text{B}_6$  alloy.

In order to see the influence of the spin disorder scattering on the resistivity variation of these alloys we have measured the room temperature coefficients of the resistivity  $A$  of all these alloys (also shown in the inset to Fig.2). Strong decrease in  $A$  below  $X = 30$  indicates the dominant role of the spin disorder scattering on the temperature dependence of the resistivity in amorphous ferromagnetic alloys. In order to verify directly that a change in the slope of the resistivity occurs around  $T_c$  we have measured the resistivity of  $Fe_{20}Ni_{60}P_{14}B_6$  alloy up to 300K. From Fig.2 can be seen that in this alloy the resistivity variation changes substantially around  $T_c$  (230K). For the comparison also the resistivity of  $Fe_{30}Ni_{50}P_{14}B_6$  alloy ( $T_c=443K$ ) is shown in the same figure. The resistivity variations in both of these alloys are similar to those observed in the crystalline ferromagnets<sup>7</sup>. In both crystalline and amorphous ferromagnet the temperature coefficient of the resistivity (inset at the bottom of Fig.2) changes sharply at  $T_c$ . This is in variance with some speculations<sup>1</sup> about the unimportance of the magnetic contribution to the resistivity of amorphous alloys.

In conclusion we wish to point out that a conclusive evidence of the magnetic contribution to the resistivity of amorphous alloys is obtained for the first time. A more detailed description of the resistivity behaviour around  $T_c$  is given elsewhere<sup>8</sup>.

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