

THERMOELECTRIC POWER AND RESISTIVITY OF AMORPHOUS FERROMAGNETS
 NEAR CURIE TEMPERATURE

B.Pivac, Z.Vučić, Ž.Marohnić and E.Babić
 Institute of Physics of the University, POBox 304, Zagreb,
 Yugoslavia

In the last few years rather extensive studies of transport properties of amorphous alloys have been carried out. Particularly interesting are the amorphous ferromagnetic alloys due to their big potentialities in industry. Therefore it is rather surprising that a little work has been done on the magnetic influence to the transport properties of amorphous ferromagnets. In particular to our knowledge the thermoelectric power of these materials was not studied in any detail. Here we wish to present the results of the preliminary investigations of the thermoelectric power and resistivity variation in two amorphous ferromagnetic alloys near Curie temperature (T_c).

The thermoelectric power was measured in a special apparatus¹⁾ in the temperature interval 80 - 470K. The relative accuracy of these measurements was few percents and the absolute thermopower (S) was obtained by subtracting the thermoelectric power of silver normal (S_n) against which the thermopower was actually measured. The resistivities were measured from 80-480K by using a standard potentiometric technique.

The actual measurements were performed on $Fe_{20}Ni_{60}P_{14}B_6$ ($T_c = 235K$) and $Fe_{30}Ni_{50}P_{14}B_6$ ($T_c = 443K$) amorphous alloys. The variation in the thermopower of both alloys in the broader range of temperatures around T_c is shown in Fig. 1. The standard expression²⁾ for the absolute thermoelectric power is:

$$S = \frac{\pi^2 k^2 T}{3e} \left[\frac{\partial \ln \sigma(E)}{\partial E} \right]_{E_F} \quad (1)$$

where $\sigma(E)$ is the electrical conductivity of electron of energy E , e is the electronic charge, k is the Boltzmann constant and E_F is the Fermi energy. From the above expression follows that the thermoelectric power would be large in the case of strong energy dependence of the scattering of the conduction electrons. As this should be the case in the transition metals and ferromagnetic alloys ³⁾ one would expect rather large S also in our alloys. From Fig. 1. can be seen that this is not a case and the thermopowers of our alloys are smaller than $1 \mu\text{V}/\text{K}$ i.e. for a factor of ten and more lower than those in crystalline Fe-Ni alloys. Thus the energy dependence of the conductivity in amorphous alloys appears to be much smaller than that in comparable crystalline materials.

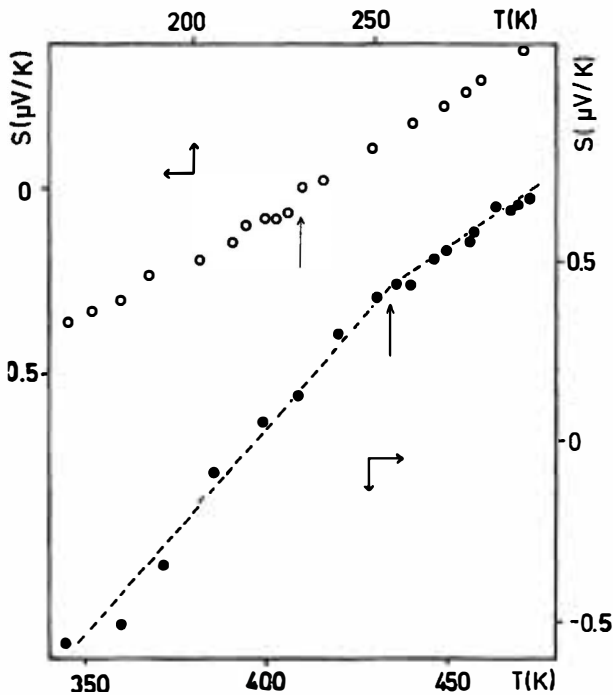


Fig. 1. Absolute thermopowers of ● $\text{Fe}_{30}\text{Ni}_{50}\text{P}_{14}\text{B}_6$ and ○ $\text{Fe}_{20}\text{Ni}_{60}\text{P}_{14}\text{B}_6$ alloys vs T. Long arrows denote Curie temperatures.

The temperature dependence of the thermoelectric power of ferromagnetic metals was calculated by Kasya ⁴⁾ in the molecular field approximation on the basis of s-d exchange model. He obtained:

$$S = - \frac{k}{|e|} \left\{ \frac{\pi^2}{3} \frac{kT}{E_F} + 2 \frac{H_c}{E_F} \frac{1 - \exp(-x)}{1 + \exp(-x)} \right\} \quad (2)$$

where T is the temperature, H_c is the change in the conduction electron energy due to s-d interaction which can be approximated as $\bar{S}_z J(0)$ (with \bar{S}_z mean value of spin of the magnetic ion and J(0) the s-d exchange integral) and x can be represented by single molecular field H_0 as H_0/kT . It can be seen that the above expression predicts the thermopower as a sum of two terms one linear in temperature and another varying exponentially below and becoming zero at T_c . The expression (2) in qualitative agreement with the thermopower results for most of ferromagnetic metals and alloys and it also seem to describe fairly well the thermopower of our $Fe_{30}Ni_{50}P_{14}B_6$ alloy. In the case of $Fe_{20}Ni_{60}P_{14}B_6$ alloy no change in slope of S around T_c is observed. This seems to indicate that the nature of the transition is somewhat different in that alloy.

Indeed it was shown by the low temperature resistivity measurements ⁵⁾ that this alloy is on the borderline of ferromagnetism. Thus one would expect that the difference observed in the thermopower variations of these two alloys would be seen even better in the resistivity behaviours around T_c . In Fig. 2. we show the resistivity and temperature coefficient of the resistivity behaviours of our alloys in the vicinity of T_c are rather different. While in $Fe_{30}Ni_{50}P_{14}B_6$ alloy the resistivity variation is similar to that of a pure crystalline Ni ⁶⁾ the resistivity behaviour of $Fe_{20}Ni_{60}P_{14}B_6$ alloy is more complex. The resistivity of $Fe_{30}Ni_{50}P_{14}B_6$ shows a clear change in slope at T_c (443K). This change is better seen in the inset at top of Fig. 2. where the variation of $d\rho/dT$ vs T is shown for that alloy. A large change in $d\rho/dT$ shows a predominant influence of the spin-disorder scattering on the temperature dependence of the resistivity.

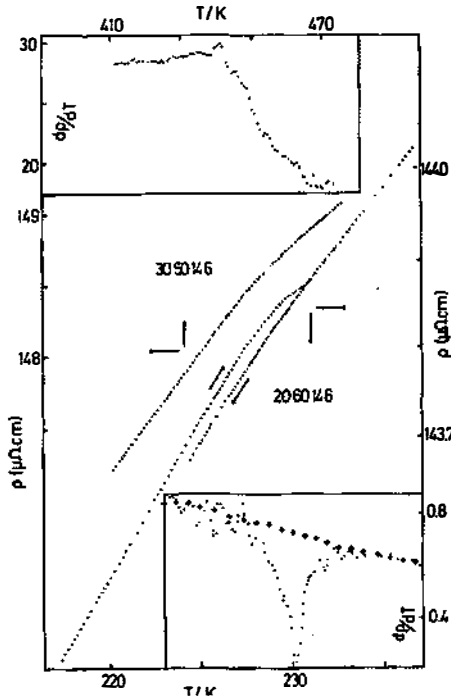


Fig. 2. The resistivities of $Fe_{20}Ni_{60}P_{14}B_6$ and $Fe_{30}Ni_{50}P_{14}B_6$ alloys around T_c (denoted with long arrows) vs temperature. Insets at the top and at the bottom show the temperature derivatives of the resistivity of $Fe_{30}Ni_{50}P_{14}B_6$ and $Fe_{20}Ni_{60}P_{14}B_6$ respectively.

We note however that the decrease in $d\rho/dT$ above T_c is much more gradual than in pure Ni which indicates that the transition to the paramagnetic state is less sharp in amorphous ferromagnets. Unfortunately our data is still not detailed enough to enable us to calculate the critical exponents and therefore to get a better insight in the nature of the transition.

The behaviour of the resistivity of $Fe_{20}Ni_{60}P_{14}B_6$ alloy around T_c is dissimilar to that of the other ferromagnets. Apart from the unusual change in the resistivity at T_c the resistivity also behaves differently depending on whether the measurements are taken by increasing or decreasing temperature.

This difference can be seen the best in d/dT , shown in the inset at the bottom of Fig. 2., which varies smoothly passing T_c by decreasing the temperature and has a deep minimum by increasing the temperature.

At present we cannot give any precise explanation of this phenomenon. It seems clear however that such a behaviour is not typical for the true ferromagnet and may be associated with some kind of transitional behaviour between the spin glass and ferromagnetic ordering. Further measurements of the other properties of this system may clarify this phenomenon.

We wish to thank Drs. J. Durand and F. E. Luborsky for some useful discussions.

References

- 1) J. R. Cooper, Z. Vučić and E. Babić, J. Phys. 6 (1976)
- 2) N. F. Mott and H. Jones, The Properties of Metals and Alloys, Oxford University Press, Oxford, (1936) p 310
- 3) T. Maeda and T. Somura, J. Phys. Soc. Japan, 44 (1978) 148
- 4) T. Kasuya, Progr. theor. phys. 22 (1959) 227
- 5) J. Ivkov et al, This Conference
- 6) F. C. Zumsteg and R. D. Parks, Phys. Rev. Lett. 24 (1970) 520