EFFECT OF TRANSITION METAL ADDITIONS ON THE RESISTIVITY OF Fe\textsubscript{83}B\textsubscript{17}
AMORPHOUS ALLOYS

B. Sas, T. Kemény and J. Tóth
Central Research Institute for Physics, Budapest 114. P.O.B.49, 1525 Hungary
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Alloying effects of transition metals on Fe\textsubscript{83}B\textsubscript{17} amorphous alloy were investigated. The resistivity versus temperature curves of Fe\textsubscript{83}T\textsubscript{3}B\textsubscript{17} between 4.2-300 K depend on the magnetic behaviour of the transition elements, while below 4.2 K show universal behaviour as it was suggested recently.

1. INTRODUCTION

The temperature dependence of the resistivity of amorphous metals has been extensively investigated [1-3]. In many cases it exhibits a minimum, the origin of which is the subject of some controversy. The tunneling of atoms between inequivalent positions which is characteristic to non-crystalline structures (i.e. two level systems) is a possible cause of low temperature transport anomalies [4-6]. It is also well known that in amorphous ferromagnets there is a finite (non-zero) probability of finding magnetic moments in vanishingly small exchange fields [7]. In this way transport anomalies of magnetic origin (a modified Kondo effect) is expected.

Besides that recent investigation emphasized the dominant influence of localization and electron-electron interaction effects to the transport properties [8]. A systematic investigation of composition dependence might help to identify the respective role of these scattering mechanisms in different temperature ranges. This study of alloying effects is reported in the present work.

The alloy series investigated is Fe\textsubscript{80}T\textsubscript{3}B\textsubscript{17} where T stands for the 3d (V, Cr, Mn, Co, Ni, Cu); 4d (Zr, Nb, Ru, Rh, Pd) and 5d (Ta, W, Os, Ir, Pt) elements of the periodic table. The aim of the present study is the observation of similarities and differences in the temperature dependence of the electrical resistivity of different alloys. The influence of different alloying additives to the average Fe magnetic moment is known [9]. The present study thus might reveal whether the modification of transport properties is mainly determined by magnetic effects or it is dominantly influenced by different factors as possible structural modifications due to alloying elements of different atomic size.

2. EXPERIMENTAL METHODS

Amorphous ribbons were prepared by the single roller quenching techniques. The width of the ribbons was 1-3 mm, the thickness 10-30 \textmu m. In the standard DC four-probe method the measuring leads were attached to the sample by spot welding. The temperature dependence of the electrical resistivity was measured by a potentiometric method, with a relative resolution of 1 ppm. The absolute resistance is determined with an accuracy of 5\% using mass density results of the Fe\textsubscript{84-x}Cr\textsubscript{x}B\textsubscript{16} alloys in the 0<x<15 concentration range.

3. RESULTS AND DISCUSSION

In Fig.1, the relative resistance change versus temperature is plotted for the above mentioned alloys. It is evident that the same amount of different transitional metals has a different effect on the temperature dependence of resistivity. For all elements of groups VB, VIB and VIIB, which are located to the left of iron in the periodic table, T\textsubscript{min} is shifted towards higher temperatures (Fig.2) whereas elements in groups VIII and IB, to the right of Fe do not change significantly the value of T\textsubscript{min}. The same influence was observed by Rao et al. [10] for some mixed transition metal based alloys (A\textsubscript{1-x}B\textsubscript{x}G where A and B are transition metals and G is metalloid). It was observed that in Fe-based alloys when diluted with
transition elements to the left of Fe, $T_{\text{min}}$ was shifted to higher temperatures. The temperature coefficient of resistivity and also the absolute thermoelectric power (both of about room temperature) showed systematic variations with atomic number [2].

The influence of alloying additives to the magnetic properties were investigated for the $(Fe_{1-x}T)_{78}Bi_{27}$ alloys where $T$ stands for elements of the 3d transition metal series. The correlation of Mössbauer spectroscopy results with bulk magnetization studies revealed a significant decrease of average Fe magnetic moment and a substantial broadening of the hyperfine field distribution [9] just for those elements where a significant increase of $T_{\text{min}}$ is observed in the present study. A similar trend of magnetic behaviour is also confirmed for the Fe$_{80}$T$_3$B$_{17}$ alloys [11-12].

The onset of resistivity minimum and its shift cannot be explained by a size effect. For example, atoms of Cr and Co are of similar size, but due to the replacement of Fe by Cr, $T_{\text{min}}$ is pushed up, whereas the replacement of Fe by Co does not yield any measurable change of $T_{\text{min}}$. On the other hand atoms of Cr and W are of different size but the shift of $T_{\text{min}}$ was quite similar. For the Fe$_{80}$T$_3$B$_{17}$ system examined by us, there is a general rule: viz. effects caused by geometrically different and magnetically similar additives are similar; that is, the decisive contribution to the resistivity in this temperature range is a scattering of magnetic origin. Fig.2, shows with a better resolution the influence of transition elements located to the left of iron. The appearance of two minima and a maximum between them is evident in the figure. It was shown that neither a relaxation heat treatment (200 °C/2 h) nor the application of magnetic field up to 8T has any effect to the shift of minima or to the appearance of the maxima. The composition dependence has been studied in details for TM=Cr, W, V, Nb and Mn. As an example, the resistivity of Fe-V-B alloys is shown in Fig.3. Taking into account also the results of independent investigations [13] the overall trend (displayed in Fig.4) is the following: the minimum temperature at first fastly increases which is followed by a much slower decrease above approximately 5 at%. Fig.4 indicates that this behaviour is characteristic to this whole class of TM impurities. In the composition region where resistivity minima are shifted to higher temperatures, resistivity maxima also appear and with the further increase of TM concentration this feature shows a similar composition dependence as the resistivity minima.

Fig.2. The temperature dependence of the resistivity of Fe$_{83-x}$VB$_{17}$ alloys. 

Fig.3. The temperature dependence of the resistivity of Fe$_{83-x}$VB$_{17}$ alloys.

Fig.4. The concentration dependence of the resistivity minimum temperature for Fe$_{83-x}$T$_3$B$_{17}$ alloys, (T=Cr, W, V, Nb, Mn) dashed line: Want et al. [17].
In Fig.3, the relative variation of the resistivity $\Delta \rho /\rho_0 = (R_{\text{RT}}-R_{4.2}) /R_{4.2}$ is reported. Using this quantity the effect of the sample geometry is eliminated. $\Delta \rho /\rho_0 = 0$ at $T = 4.2$ K is the consequence of this normalization, further on we discuss the temperature dependence which is on the other hand unaffected.

The temperature dependence of the resistivity of the different alloys are widely different above the normalization point. In contrast to this, they show a remarkable uniformity below this temperature. This fact, together with the observation that the absolute resistance of the Fe$_{84-x}$Cr$_x$B$_{16}$ alloys in the $0 \leq x \leq 15$ concentration range is practically constant (120±5 $\Omega$cm), is in complete agreement with the findings of Cochrane and Strom-Olsen [8] and must be explained by the dominant role of incipient localization and electron-electron interaction [14,15].

Our temperature range is not wide enough to decide between a $\Delta T$ and an $\ln T$ temperature dependence, but the uniform behaviour at the lowest temperature which is definitely independent of the kind and concentration of transition metals is in good agreement with the results of Cochrane and Strom-Olsen [8]. Their work demonstrated that the most widely different high resistivity materials show the same functional form of the temperature dependence of the resistivity at the lowest temperature region ($\Delta T$ in their case). In this way the temperature dependence of different alloys should be similar if $\rho_{\text{abs}}$ does not change significantly which is true for our sample.

The high temperature behaviour is on the other hand significantly modified by different impurities. While non-magnetic scattering may also play a role [16] it is evident that the changes caused by an impurity in transport and magnetic properties are closely correlated. TM impurities causing significant magnetic perturbations increase the number of the spin-effectively decoupled from the bulk moment, i.e. capable of spin-flip scattering [7]. This effect is responsible for the initial fast increase of $T_{\text{min}}$ with TM composition. When the concentration is increased further, interactions should gradually set in among these decoupled moments which freeze spin-flip scattering, causing now the decrease of $T_{\text{min}}$ with TM concentration.

4. CONCLUSION

The temperature dependence of the electrical resistivity was measured on an extended series of Fe-TM-B amorphous alloys. The different temperature dependence observed above the liquid He temperature range is found to be correlated with the magnetic properties of the alloys. In contrast to this a remarkable similarity is observed below this temperature range. It is therefore concluded that incipient localization and electron-electron interaction determine the low temperature universal behaviour but scattering of magnetic origin is dominant above this temperature range.

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REFERENCES