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HAL Id: jpa-00220218
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Submitted on 1 Jan 1980

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THE RESISTIVITY OF THE AMORPHOUS Fe$_{1-x}$B$_x$ FILMS

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This work presents a systematic investigation of electrical resistivity in thin films of Fe$_{1-x}$B$_x$ in wide range of concentration $x$ up to $x=0.70$. Samples were prepared by RF sputtering technique described in paper [1]. Amorphous state exists for $0.12 \leq x \leq 0.70$ which was tested by electron diffraction microscopy [1]. The film composition was determined by microprobe and Auger analysis with accuracy of 5 atomic percent of B.

The resistivity was measured by four-probe method for temperatures between 4.2 and 300 K.

1. Composition effect

Specific resistivity $\rho$ of Fe$_{1-x}$B$_x$ films increase with increasing concentration of B /see Fig.1/ up to about five times of its initial value and the films become amorphous at $x=0.12$. The resistivity increases slightly for $0.12 < x < 0.40$ /1.5 times/ and there is a rapid increase above $x=0.40$.

Temperature Coefficient of Resistivity (TCR) decreases suddenly at the transition into the amorphous state. The TCR is linear against $x$ and changes its sign at about $x=0.25$. Similar dependence of $\rho(x)$ and TCR $\chi$ was observed for amorphous alloys of Ni$_{1-x}$P$_x$ [3] and Pd-Ni$_{1-x}$P$_x$ [4] in the range of concentration 0.15 $x$ 0.30 /although the magnitudes

2. The dependence of the resistivity on temperature

Fig.3 shows typical dependence of $\rho(T)$ for samples with different concentration of B. The data were found to fit

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Fig.1. The room temperature resistivity of Fe$_{1-x}$B$_x$ films as a function of B content. (o) our results, (x) data after J.A. Aboaf and E. Klokholm [2]. The dotted line indicates the transition from crystalline (c) to amorphous state (A).

Fig.2. TCR at room temperature of Fe$_{1-x}$B$_x$ films as a function of B content.

Fig.3 shows typical dependence of $\rho(T)$ for samples with different concentration of B. The data were found to fit
the following equations for $x < 0.25$

$$\frac{\rho(T)}{\rho(300)} = a + b \ln T + cT^2 \quad T < T_o$$

$$\frac{\rho(T)}{\rho(300)} = a' + dT \quad T > T_o$$

for $x > 0.25$

$$\frac{\rho(T)}{\rho(300)} = a + b \ln T \quad T < T_b$$

$$\frac{\rho(T)}{\rho(300)} = a' + dT \quad T > T_b$$

where $\rho(300)$, $a$, $a'$, $b$, $c$ and $d$ are listed in Table I.

Fig. 3. The normalized resistivity of crystalline /c/ and amorphous /A/ Fe$_{1-x}$B$_x$ films as a function of $T$.

Low temperature dependence of resistivity is shown in Figs 4a and 4b. For a crystalline sample with small concentration of B /Fe$_{0.94}$B$_{0.06}$/ one can see weak increase of $\rho$ with decreasing temperature. This tendency is even stronger for amorphous films where $\rho \sim \ln T$. A monotonic increase of $T_b$ and $b$ with concentration /see Table I and Fig. 4/ of B takes place.

Fig. 4. The normalized resistivity change of crystalline /c/ and amorphous /A/ Fe$_{1-x}$B$_x$ films vs log $T$; a/ for $x < 0.25$ and b/ for $x > 0.25$. $T_b$ indicates the temperature where a deviation from the $\rho \sim \ln T$ becomes noticeable.

The coefficient $c$ and temperature $T_b$ decrease with $x$ /Fig. 5 and Table I/. For $x > 0.25$ /Fig. 3/ the resistivity decreases linearly vs temperature for $T > T_b$. The deviation for $T > 200$ K can be explained as the result of stress
between substrate and the film. Table I, A comparison of resistivity measurements between Fe$_{1-x}$B$_x$ films and ribbons...

Table I. Results of resistivity measurements of Fe$_{1-x}$B$_x$ films

<table>
<thead>
<tr>
<th>x</th>
<th>$\rho$ (300) $\mu\Omega$ cm</th>
<th>$a'$</th>
<th>$a$</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>21.3</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>0.06</td>
<td>85.5</td>
<td>0.885</td>
<td>0.9205</td>
</tr>
<tr>
<td>0.12</td>
<td>113</td>
<td>0.961</td>
<td>0.9001</td>
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<tr>
<td>0.18</td>
<td>131.6</td>
<td>0.985</td>
<td>0.9924</td>
</tr>
<tr>
<td>0.32</td>
<td>141</td>
<td>1.011</td>
<td>1.0133</td>
</tr>
<tr>
<td>0.37</td>
<td>151.2</td>
<td>1.0115</td>
<td>1.0169</td>
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</table>

<table>
<thead>
<tr>
<th>x</th>
<th>$b$ $10^{-4}$</th>
<th>$c$ $10^{-7}$</th>
<th>$d$ $10^{-4}$</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>50.8</td>
<td>0</td>
</tr>
<tr>
<td>0.06</td>
<td>-0.83</td>
<td>11.78</td>
<td>3.89</td>
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<tr>
<td>0.12</td>
<td>-3.47</td>
<td>3.24</td>
<td>1.29</td>
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<tr>
<td>0.18</td>
<td>-6.38</td>
<td>1.43</td>
<td>0.50</td>
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<td>0.32</td>
<td>-9.62</td>
<td>0</td>
<td>-0.435</td>
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<tr>
<td>0.37</td>
<td>-12.46</td>
<td>0</td>
<td>-0.506</td>
</tr>
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</table>

3. Conclusions

We draw following conclusions from electrical resistivity measurements of amorphous Fe$_{1-x}$B$_x$ films:
- there is a transition concentration range $0.12 \leq x \leq 0.25$ where contribution $\rho \sim cT^2$ from spin wave scattering characteristic for a crystalline state, is diminishing.
- low temperature resistivity anomalies $\rho \sim b \ln T$ strongly depend on concentration of B. Both $T_b$ and b increase with $x$ /Table I/; it can be explained after Grest and Nagel [8] as result of superexchange interactions between next-nearest-neighbor magnetic atoms which are separated by Boron atoms.
- negative TCR and temperature dependence of $\rho$ for $T > T_b$ for films with $x > 0.25$ is likely to be due to temperature dependence of form factor $S(K)$ [9].
- differences in between our results and given by Cochrane et al [5] and Tóth [6], especially with respect to $T_{\text{min}}$ and $\rho (4.2)/\rho (300)$ /see Table II/, seem to indicate that sputtered...
films are more amorphous than ribbons.

Work was supported by Deutscher Forschungsgemeinschaft.

References

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